Analysis of Resource Use Efficiency in Smallholder Mixed Crop-Livestock Agricultural Systems: Empirical Evidence from the Central Highlands of Ethiopia

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Abstract

The study uses data generated through a survey from rural households in Ethiopian central highland districts to assess farm-level resource use efficiency in the production of major crops including *teff*, wheat and chickpea in the mixed crop-livestock agricultural systems of Ethiopia, under conditions of diminishing land resource and environmental constraints. Data Envelopment Analysis (DEA) results show that smallholder farmers are resource use inefficient in the production of major crops with mean technical, allocative and economic efficiency levels of 0.74, 0.68 and 0.50, respectively. A Tobit model regression results on the determinants of inefficiency reveal that livestock ownership and participation in off-farm activities are associated with reduced level of resource use inefficiency. Furthermore, large family size and membership to associations contribute to higher level of resource use inefficiency. The findings suggest that resource use efficiency would be significantly improved through a better integrated livestock and crop production systems; expansion and promotion of off-farm activities; and reform of farmer's associations.

Keywords*:* Data Envelopment Analysis; Tobit; Resource use efficiency; mixed crop-livestock agriculture; Ethiopia

1. Introduction

Although Ethiopia managed to achieve rapid and consecutive economic growth from 1998 to 2007, the country ranked 157 out of 169 countries in the 2010 United Nations Human Development Index and 80 out of 84 in the Global Hunger Index (World Food Programme (WFP), 2011)). Moreover, while 38% of rural households in Ethiopia live below poverty line (World Bank, 2009); chronic food insecurity has been a defining characteristic of the poverty that has affected millions of Ethiopians of which the vast majority of these poor households live in rural areas that are heavily dependent on rainfed agriculture (Subbarao & Smith, 2003). This suggests that broad based and sustainable agricultural development in Ethiopia is critical in mitigating problems of poverty and chronic food insecurity.

In general, the agricultural sector plays a critical and multidimensional role in Ethiopian economy. According to Diao et al. (2010), 85% of the population in the rural areas derives its livelihood from agriculture; the sector accounts for more than 40% of national GDP; and it is the source of 90% of the country's export earnings. This means that the rate at which agricultural sector attains its growth and sustainability highly determines the country's macroeconomic performances such as overall economic growth, employment, food security, poverty reduction and per capita income growth.

Despite its importance, however, Ethiopian agricultural sector is dominated by subsistence and smallholder-oriented system (Bishaw, 2009). Particularly, Ethiopian highland agriculture is characterized by high dependency on rainfall, traditional technology, high population pressure, and severe land degradation combined by low level of productivity (Medhin & Köhlin, 2008). Notwithstanding the government's policy to expand crop production for exports, domestic consumption and universal food security (Ministry of Finance and Economic Development (MoFED), 2006), low productivity levels in *teff* (Haile et al., 2004) and chickpea (Shiferaw & Teklewold, 2007) have been reported. Whereas Ethiopia's huge potential in wheat production remains unexploited, the country is a net importer of the commodity (Rashid, 2010). Besides, until 2005, the government of Ethiopia mainly used emergency appeals for food aid on a near annual basis to tackle poverty and hunger (Gilligan et al., 2008). With time, however, the Ethiopian government established the New Coalition for Food Security strategy, including the Productive Safety Net Programs (PSNP) through which it sought to tackle food insecurity (World Bank, 2011).

However, in order to achieve poverty alleviation objectives among smallholder farmers, productivity and efficiency of resource use must be improved to increase income, attain better standard of living and reduce environmental degradation (Ajibefun, 2000). Moreover, Ajibefun & Daramola (2003) also argue that there is a need to increase growth in all sectors of the economy for such growth is the most efficient means of alleviating poverty and generating long-term sustainable development, where resources must be used much more efficiently to improve productivity and income. Thus, resource use efficiency in smallholder agriculture could be the basis for achieving universal food security and poverty reduction objectives of the country particularly among the rural households in Ethiopia.

Thus, the current study estimates resource use efficiency of smallholder major crop producers in three central highland districts of Ethiopia under mixed crop-livestock (traditional) agricultural systems. The study covers a relatively larger population and considers important major crops including chickpea, *teff* and wheat so as to increase farm household's income, reduce poverty and address nutritional and food insecurity problems in the study areas. Moreover, the study areas are some of the areas where cereal crops and legumes are largely produced whereby resource use efficiency and productivity improvement can have a substantial impact to improve the lives of many farm households.

The study established that smallholder mixed crop-livestock farmers are resource use inefficient in the production of chickpea, *teff* and wheat with mean technical, allocative and economic efficiency levels of 0.74, 0.68 and 0.50, respectively. Findings on the level of resource use efficiency suggest that had farmers utilized inputs efficiently, they could have increased current output of the three crops by 26% using existing resources and level of technology and reduced cost of production by 50% to achieve the potential minimum cost of production relative to efficient farmers given current output. A Tobit regression model results also reveal that livestock ownership and households' participation in off-farm activities simultaneously result in significant increases in technical and economic efficiencies in the production of major crops.

The rest part of the paper is organized as follows. In the next section we discuss the empirical modeling strategies of the paper including Data Envelopment Analysis (DEA) technique and Tobit regression model. Discussion of results is presented under section 3. In the last section we forward conclusions and key policy implications for improving resource use efficiency which is considered critical in reducing rural household poverty and achieve food security in the study areas.

2. Methodology

2.1 Data Envelopment Analysis (DEA)

The history of efficiency measurement goes back to the influential work of Farrell (1957) who defined a simple measure of firm efficiency. In the approach, Farrell (1957) proposed that efficiency of any given firm is composed of its technical and allocative components. According to Farrell, technical efficiency (TE) is associated with the ability of a firm to produce on the iso-quant frontier while allocative efficiency (AE) refers to the ability of a firm to produce at a given level of output using the cost-minimizing input ratios. On the other hand, economic efficiency (EE) is the combination of technical efficiency and allocative efficiency. Thus, it is defined as the capacity of a firm to produce a predetermined quantity of output at a minimum cost for a given level of technology. For estimation of these efficiencies a number of methods have been developed. These methods are broadly classified as parametric and non-parametric Methods.

DEA was first introduced by Charnes et al. (1978) and it has served as the corner stone for all subsequent developments in the nonparametric approach (Hadi-Vencheh and Matin, 2011). As discussed by several researchers (Coelli et al., 2005; Headey et al., 2010), DEA has several advantages: it does not require a prior specific functional form for the production frontier, it can handle multiple outputs and inputs and it is also possible to identify the best practice for every farm. Furthermore, it also does not require the distributional assumption of the inefficiency term (Coelli et al., 2005). Regarding its potential disadvantages, the technique is sensitive to extreme observations and a hypothesis testing using DEA is not possible. Moreover, DEA attributes all deviations from the frontier to inefficiency. However, despite its weaknesses, in this study DEA is found appropriate and adopted to estimate efficiency of multiple crop producer farmers.

Suppose there are n homogenous Decision-Making Units (DMUs), in order to produce r number of outputs ($r=1,2,3,\ldots k$) s number of inputs are utilized ($s=1,2,3,\ldots m,$) by each DMU i ($i=1,2,3,\ldots n$). Assume also that the input and output vectors of i^{th} DMU are represented by x_i and y_i, respectively and data for all DMUs be denoted by the input matrix $(X)_{m\times n}$ and output matrix $(Y)_{k\times n}$. Accounting for financial limitations or imperfect competitive market effects, the DEA model for variable returns to scale (VRS) which was developed by Banker, Charnes and Cooper (BCC) (Banker et al., 1984) is used. The model allows for a given change in inputs use to result in a non-proportionate change in output.

Thus, following Banker et al. (1984), the output maximization process to measure technical efficiency for each DMU can be expressed as:

$$\begin{aligned} &\text{Maxi}_{\phi\lambda}\ \phi \\ &\text{Subject to :} \\ &x_i - X\lambda \geq 0 \\ &-\phi y_i + Y\lambda \geq 0 \\ &N1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \quad (1)$$

where, in the restriction $N1'\lambda=1$, $N1'$ is convexity constraint which is an $N\times1$ vector of ones and λ is an $N\times1$ vector of weights (constants) which defines the linear combination of the peers of the i^{th} DMU. $1\leq\phi\leq\infty$ and ϕ-1 is the proportional increase in outputs that could be achieved by the i^{th} DMU with the input quantities held constant and $1/\phi$ defines a technical efficiency score which varies between zero and one. If ϕ=1 then the farm is said to be technically efficient and if ϕ< 1 the farm lies below the frontier and is technically inefficient.

Similarly, to estimate economic efficiency (EE), a cost minimizing DEA is specified as:

$$\begin{aligned} &\text{Min}_{\lambda, X_i^*}\ W_i' X_i^* \\ &\text{Subject to :} \\ &-y_i + Y\lambda \geq 0 \\ &X_i^* - X\lambda \geq 0 \\ &N1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \quad (2)$$

where, W_i' is a transpose vector of input prices for the i^{th} DMU and X_i^* is the cost-minimizing vector of input quantities for the i^{th} farm given the input prices W_i and total output level y_i. Economic efficiency is measured as the ratio of potential minimum cost of production ($W_i'X_i^*$) to the actual cost of production ($W_i'X_i$) as $EE= W_i'X_i^*/W_i'X_i$. Allocative efficiency can be estimated as the ratio of economic to technical efficiencies as $AE=EE/TE$. In order to generate the technical, economic and allocative efficiency scores DEAP Version 2.1 computer program described in Coelli (1996) was used.

2.2 Tobit regression model analysis

The Tobit regression model is an econometric model that is employed when the dependent variable is limited or censored at both sides. The concept was first proposed by Tobin (1958) in the research of the demand for consumer durables and then it was first used by Goldberger (1964). If the data to be analyzed contain values of the dependent variable that is truncated or censored, the ordinary least squares (OLS) is no longer applicable to the concept of estimated regression coefficients. If OLS is directly used it will lead to biased and inconsistent parameter estimation whereby the Tobit model, that follows the concept of maximum likelihood, becomes a better choice to estimate regression coefficients (Chu et al., 2010). Thus, Tobit regression model is appropriate for this study based on the following justification regarding the nature of the dependent variable.

It is assumed that farmers in the current study areas operate under the same policy and institutional environments and face exogenous variables denoted as Z_i and that these conditions determine farmers' decision to choose set of input vector x and produce output vector y. In the production process a given farmer is considered to be full efficient if it operates along the boundary of the frontier (Y^*) which also defines the level of technology in the system. The boundary of the frontier represents a locus of output points constructed by best practice farms without a room for further improvement in their production process. In this case the output of efficient firms (Y_i) to the potential output along the frontier is equal ($Y^*=Y_i$). Relative efficiency measures, computed as the ratio of actual (realized) to the potential (frontier) output level (Y_i /Y^*) (Karagiannis and Tzouvelekas, 2009), of efficient farms will be unity ($Y_i /Y^*=1$). On the other hand, firms which are relatively inefficient operate at points in the interior of frontier and score less than unity ($Y_i/Y^*<1$) but greater than zero. In this case unless the farmer loses his/her crop due to complete crop failure as a result of pest and diseases infestation or drought, efficiency score will not be zero which is not applicable in the current study case. Therefore, while the scores are bounded between zero and one (two-limit) with the upper limit set at one, the distribution is censored at both tails.

Thus, following Amemiya (1985), the two-limit Tobit regression model of the following form was estimated:

$$\begin{aligned} U_i^* &= \beta_0 + \sum_{j=1}^{k} \beta_j Z_{ij} + \mu_i, \\ U_i &= 1, \quad if \quad U_i^* \geq 1 \\ U_i &= U^*, \quad if \quad 0 < U_i^* < 1 \\ U_i &= 0, \quad if \quad U_i^* \leq 0 \end{aligned} \tag{3}$$

where: i refers to the i^{th} farm in the sample, U_i is inefficiency scores representing technical and economic inefficiency of the i^{th} farm. U_i^* is the latent inefficiency, β_j are parameters of interest to be estimated and μ_i is random error term that is independently and normally distributed with mean zero and common variance of δ^2 (μ_i~NI $(0, \delta^2)$). Z_{ij} are socio economic, institutional and demographic variables.

2.3 The study area and data

2.3.1 Study area

The study was conducted in three districts, namely Minjar-Shenkora, Gimbichu and Lume-Ejere, which are found in the central highlands of Ethiopia. In 2007, the districts had a total population of 345,177 persons (CSA, 2007). The total area of the districts is about 379,754 hectares of which 36.5% is arable (DARDO, 2011). The study areas represent some of the major cereals and legumes growing areas in the country. The agricultural production system is mixed crop-livestock (traditional) agricultural system whereby a smallholder farmer practices crops and livestock productions under the same management. The major crops grown in the central highlands include *teff*, wheat, barley, maize, sorghum, chickpeas, lentils, banana and coffee. These crops are produced both for source of cash and for household consumption. Cattle, goats, sheep, equines and poultry are also important tame animals kept by the smallholder farmers integrated with crops production. Thus, crops and livestock contribute their share to the farmers' farm income. *Teff,* chickpea and wheat are major crops in terms of quantity and area grown in the study areas and they are the focus of this study (DARDO, 2011).

2.3.2 Sampling techniques and data collection

The data used for this study originate from a baseline survey conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Ethiopian Institute of Agricultural Research (EIAR) in 2008. A multi-stage sampling procedure was used to select districts, *kebeles*[a] and farm households. In the first stage, three districts namely Minjar-Shenkora, Gimbichu and Lume-Ejere were purposively selected from the major legume producing areas based on the intensity of chickpea production, agro-ecology and accessibility. Then, eight *kebeles* from each of Gimbichu and Lume-Ejere and ten *kebeles* from Minjar-Shenkora were randomly selected. Finally, 700 farm households were randomly selected (of which 149, 300 and 251 farm households were from Gimbichu, Lume-Ejere and Minjar-Shenkora districts, respectively). However, for the sake of efficiency analysis and homogeneity among farm households, 466 households who engage in chickpea, *teff* and wheat productions were considered for the study.

Data were collected by trained enumerators from sample households using structured interview schedule. The survey collected valuable information on several factors including household composition and characteristics, land and non-land farm assets, household membership in different rural institutions, crop acreage, costs of production, yield data, and indicators of access to infrastructure and household market participation.

3. Results and discussion

3.1 The DEA results on farm household resource use efficiency levels

In the DEA efficiency estimation procedure three groups of variables (output, input and input costs) are used. While the outputs considered for the analysis include chickpea, *teff* and wheat outputs, input variables are land, labor, *teff* seed, chickpea seed, wheat seed and chemical fertilizers. Furthermore, input costs, computed by multiplying the amount of input used by the average market price of the input, for respective farmers are used. Table 1 presents the summary of input, input cost and output variables used in the efficiency estimation procedure.

Table 1: Descriptive Statistics of variables used for DEA method (N=466)

DEA Variable	Description of Variables	Unit of Measurement	Mean[a]
	Output variables		
Y_1	Output of chickpea	kilogram	1,545.78 (1,262.03)
Y_2	Output of *teff*	kilogram	1,212.04 (967.48)
Y_3	Output of wheat	kilogram	1,227.47 (1,071.21)
	Input variables		
X_1	Plot Size	hectare	2.18 (1.03)
X_2	Labor (Family and Hired)	man-day	961.42 (454.85)
X_3	Chickpea seed	kilogram	102.68 (95.97)
X_4	*Teff* seed	kilogram	84.55 (81.03)
X_5	Wheat seed	kilogram	81.07 (73.18)
X_6	Chemical fertilizer used	kilogram	439.70 (314.74)
	Input Costs		
C_1	Cost of Land used	ETB	5,738.36 (2,876.30)
C_2	Cost of Labor used	ETB	19 609.02 (10,135.74)
C_3	Cost of chickpea seed	ETB	483.50 (485.16)
C_4	Cost of *teff* seed	ETB	180.46 (172.82)
C_5	Wheat seed	ETB	337.45 (306.84)
C_6	Cost of fertilizer	ETB	1,606.50 (1,217.83)

[a] Values in the parentheses are standard deviations.

Source**:** Authors' computation, 2011

Considering the output variables the descriptive statistics shows that a typical smallholder farmer produces 1545.78kilogram (kg) of chickpea, 1212.04kg of *teff* and 1227.47kg of wheat. During the production process about 2.18 hectares of land is allocated for the production of these crops and its average cost is computed as ETB[b] 5,738.36. In addition, the mean level of family and hired labor in man-day is about 961.72 with the associated cost of ETB 19 609.02. Furthermore, on average, farmers use 102.68, 84.55 and 81.07kg of chickpea, *teff* and wheat seed, respectively. The mean costs of seed are ETB 483.50, 180.46 and 337.45 for chickpea, *teff* and wheat, respectively. Moreover, a typical smallholder farmer applies about 439.70kg of chemical fertilizers, while the associated cost is computed to be

ETB 1606.50. The average cost of production for the three crops is estimated to be ETB 27 955.29 (USD 2,070.76 as of mid 2009 exchange rate).

The estimated and distribution of technical, allocative and economic efficiency levels using the DEA model are presented using Table 2. The results show that the mean levels of technical, allocative and economic efficiency scores are 0.74, 0.68 and 0.50, respectively. The mean score of technical efficiency implies that a smallholder farmer could increase current output of chickpea, *teff* and wheat by 26% using existing resources and level of technology. The result for mean allocative efficiency also suggests that cost of production could be reduced by 32% had farmers used the right inputs and outputs mix relative to input costs and output prices. On the other hand, the mean level of economic efficiency indicates that farmers could reduce current average cost of production by 50% to achieve the potential minimum cost of production relative to the efficient farmers given the current output level. These efficiency results suggest that there is considerable potential for increasing output and reducing cost of production.

Table 2: Distribution of technical (TE), allocative (AE) and economic efficiency (EE) (N=466)

Efficiency Categories	TE		AE		EE	
	Freq.	Percentage	Freq.	Percentage	Freq.	Percentage
E<0.1	0	0	0	0	0	0
0.1≤ E≤ 0.2	0	0	1	0.22	15	3.22
0.2< E ≤ 0.3	6	1.29	8	1.72	50	10.73
0.3< E ≤ 0.4	21	4.51	24	5.15	109	23.39
0.4< E ≤ 0.5	58	12.44	55	11.80	106	22.75
0.5< E ≤ 0.6	66	14.16	86	18.45	68	14.59
0.6< E ≤ 0.7	56	12.02	90	19.31	44	9.44
0.7< E ≤ 0.8	56	12.02	69	14.81	23	4.94
0.8< E ≤0.9	43	9.23	61	13.09	14	3.00
0.9< E≤1.0	160	34.33	72	15.45	37	7.94
Full efficient Farmers	131	28.11	31	6.65	30	6.44
Inefficient Farmers	335	71.89	435	93.35	436	93.56
Mean Scores	0.74		0.68		0.50	

Note: E stands for Efficiency,

Source: Authors' computation, 2011

Furthermore, it is revealed that 28.11%, 6.65% and 6.44% of farmers are fully technically, allocatively and economically efficient. Finally, using test results from one-sample *t*-tests it is concluded that, on average, smallholder farmers are not technically, allocativelly and economically efficient ($P<0.001$), which means average level of efficiency scores are significantly different from unity.

3.2 The Tobit model results on the determinants of resource use inefficiency

In order to identify key determinants of resource use inefficiency, technical and economic inefficiency scores are separately regressed on selected demographic, socio economic and institutional variables. Table 3 presents descriptive statistics of the variables used in the analysis of resource use inefficiency.

Table 3: Descriptive statistics of variables for Tobit model (N=466)

Variables	Description		Mean	Std. D
	Continuous Variables			
age	Age of the household head (year)		47.87	11.88
familysize	Family size (number of persons)		6.79	2.13
livestockTLU	Household ownership of livestock size in tropical livestock unit		7.81	4.32
wlkdsmnm	Walking distance to the nearest main market (Kilometer)		9.89	5.95
	Dummy Variables	***Response***	***Freq.***	***Percent***
gender	Sex of the household head	Female (0)	31	6.65
		Male (1)	435	93.35
membership	Membership of household in associations	Yes (0)	414	88.8
		No (1)	52	11.2
creditacc	Access to Credit at market interest rate	Yes (0)	321	68.9
		No (1)	145	31.1
particoffarm	Household Participation in nonfarm activities	Yes (0)	158	33.90
		No (1)	308	66.10

Source: Authors' computation, 2011

Results reveal that age of household head (*age*) is on average 47.87 years while the mean level of family size (*familysize*) of farmers is 6.79 persons. The study also shows that farmers own an average of 7.81 tropical livestock unit (TLU) size (*livestockTLU*). In addition, regarding their access to market and road (*wlkdsmnm*), households locate about 9.89 kilometers away from the nearest main market. Furthermore, while about 6.65 percent of households are female headed (*gender*), about one third of households participate in various off-farm activities (*particoffarm*). Finally, some of the institutional variables such as membership and access to credit show that while 88.8 percent of households are members of farmer related associations and cooperatives (*membership*), about two third of the households have accessed credit (*creditacc*) at the market interest rate.

The analysis of the determinants of resource use efficiency is important as a basis for informing agricultural policy on what needs to be done to improve smallholder agricultural productivity (Tchale, 2009) hence reduce resource wastage and improve farmers' livelihoods. Table 4 presents the determinants of technical and economic inefficiency in the production of crops under mixed crop livestock agricultural systems.

Table 4: Results of Tobit regression analysis for sources of resource use inefficiency (N=466)
(Dependent variables: Technical Inefficiency and Economic Inefficiency)

	Technical Inefficiency			Economic Inefficiency		
Independent variables	β	Std. E.	*t*	β	Std. E.	*t*
gender	0.072	0.056	1.28	0.070*	0.040	1.75
age	0.002*	0.001	1.83	0.001	0.001	1.28
livestockTLU	-0.006*	0.003	-1.70	-0.014***	0.002	-5.52
familysize	0.001	0.007	0.04	0.011**	0.005	2.29
particoffarm	0.065**	0.030	2.20	0.050**	0.021	2.34
wlkdsmnm	0.002	0.002	1.05	0.002	0.002	1.47
membership	-0.078*	0.044	-1.76	-0.042**	0.032	-1.34

creditacc	-0.019	0.030	-0.63	-0.007	0.021	-0.35
Constant	0.029	0.091	0.31	0.355***	0.066	5.42
Log Likelihood	-179.55			14.82		

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

Source: Authors' computation, 2011

Livestock ownership (measured by Tropical Livestock Unit, TLU[c]) results in significant reductions of technical *(P <* 0.1) and economic ($P < 0.01$) inefficiencies among farm households. This positive effect of livestock ownership on crop production efficiency, under the smallholder mixed crop-livestock agricultural systems, could be through improving farmers' liquidity position, thereby ensuring that farmers are able to respond rapidly to demands for cash to buy inputs and other factors (Tchale, 2009). However, while successful crop-livestock integration can also be seen through nutrient use efficiency and nutrient cycling benefits but the whole issue of mutually beneficial integration must be addressed at the community and regional level involving grazing management, species composition and matching stocking rate to carrying capacity (FAO, 2010). The result confirms with the findings by Bogale and Bogale (2005), Tchale (2009) and Hussien (2011) where livestock ownership increases efficiency in crop production.

On the other hand, households' non participation in off-farm activities positively and significantly increases their technical and economic inefficiencies ($P < 0.05$) suggesting that households' decision to participate in off-farm activities is associated with increase in technical and economic efficiencies. Similarly, a positive association between technical efficiency and the farms with the off-farm income is reported by Bojnec and Fertő (2011) from Slovenia. The spill-over effect of off-farm income on farm technical efficiency might be due to relaxation of surplus of farm labor and its remaining more efficient use on the farm due to possible investment in more advanced technology, which in turn provides a higher farm efficiency (Bojnec and Fertő, 2011). Moreover, Tchale (2009) and Hussien (2011) also established that efficiency increases with an increase in non-farm income.

The study also reveals a negative and significant association between farmers' belongingness to association (*membership*) and their technical ($P < 0.1$) and economic ($P < 0.1$) inefficiency levels, implying that farmers who are members to associations and cooperatives are less likely to benefit from membership to associations. Being a member in farmers' association is expected to benefit farmers to share information on farming technologies which tends to influence the production practices of members through peer learning. However, this finding could be attributed to the fact that farmers' cooperatives and associations have less capacity in personnel and technology to shorten the marketing chain by directly connecting small producers to markets; less capable to coordinate crop production and marketing activities and facilitating farmer access to production inputs at fair prices. Nevertheless, this result is consistent with the findings by Binam et al. (2003) who also reported a negative and significant relationship between membership in a farmers' association and technical efficiency for coffee farmers in Cote d'Ivoire, Tchale (2009) from Malawian farmers and Nyagaka et al. (2010) from Kenyan smallholder potato producers found that membership in a farmers' association positively and significantly influences technical efficiency.

Among the demographic variables, age of household head (*age*), significantly and positively contributes to technical inefficiency ($P < 0.1$). This implies that as household head gets older and older, technical inefficiency significantly increases. Perhaps, farmer's age influences the farm practices directly or indirectly through labor, management and adoption of new methods of production systems and technology. Young and middle-aged farmers are more willing to adopt a new technology while older farmers are conservative, risk averse, and, therefore, are less likely to embark on new technology (Temu, 1999). However, Binam et al. (2003) found that in a study of Coffee Farmers in Cote d'Ivoire older farmers are more likely to be efficient. The difference in the effect of age on efficiency could be due to difference in the nature of agriculture which suggests the necessity of tailored interventions to ensure older household heads to be efficient in agricultural production.

On the other hand, family size (*familysize*) contributes positively and significantly to economic inefficiency ($P < 0.05$), suggesting that larger families are likely to be economically inefficient. Perhaps, this might be due to the fact that labor allocation for small plot of land of larger families might have caused disguised unemployment which increases the actual cost of production. Inefficiency in resource use in the rural areas could be reduced through absorbing the excess labor force to nonfarm sectors without negatively affecting farm output and productivity (Lien et al., 2010). The finding is consistent with that of Binam et al. (2003) and Coelli et al. (2002) where larger families are found more inefficient.

Furthermore, gender of the household head (*gender*) affects economic inefficiency positively and significantly ($P < 0.1$) implying that male headed households are more likely to be economically inefficient compared to their female-headed counterpart households. Female-headed households might have superior managerial skills, better allocate agricultural labor and other physical and financial inputs, or they might be relatively effective in choosing a crop mix with higher marketed surplus which positively affect their allocative efficiency (Udry, 1996; Chavas et al., 2003) and hence contributed to increase in their economic efficiency. On the other hand, given female-headed households have greater access to land rights; the finding suggests that the intra-household allocation of labor and land rights led to higher level of allocative efficiency in female-headed households which also increased their economic efficiency levels.

4. Conclusion and policy implications

The study established that smallholder mixed crop-livestock farmers are resource use inefficient in the production of chickpea, *teff* and wheat crops with mean technical, allocative and economic efficiency levels of 0.74, 0.68 and 0.50, respectively. A Tobit regression analysis results reveal that livestock ownership resulted in significant reductions of technical and economic inefficiencies. This positive effect of livestock ownership on crop production efficiency could be through improving farmers' liquidity position, thereby ensuring that farmers are able to respond rapidly to demands for cash to buy inputs and other factors. It is also established that households' participation in off-farm activities associates with increase in technical and economic efficiencies. The study, however, reveals that farmers who are members to associations and cooperatives are less likely to benefit from their membership. Moreover, while households who have older heads are found technically more inefficient, male headed households are more likely to be economically inefficient compared to their female-headed counterpart households. Finally, it is found that households with large family size are likely to be economically inefficient.

Findings of the study implies that there should be strategies to integrate smallholder livestock and crop productions and strengthen the linkage so as to further improve the crop production efficiency of mixed crop-livestock farmers in the central highlands of Ethiopia. Moreover, policies and strategies should also support expansion and promotion of nationwide off-farm activities which provide off-farm employment and reduce the negative effect of large family size in crop production efficiency. Furthermore, farmers' associations should also be re-structured in personnel and technology in order to ensure member households are benefited from their membership and improve their resource use efficiency.

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Endnotes

[a]It is usually named as peasant association and is the lowest administrative unit in the country.

[b]ETB is Ethiopian Currency and it is called Birr. In mid 2009 the exchange rate was 1 USD=11.78 Birr

[c]A Tropical Livestock Unit (TLU) is a live-weight based measure that is used to convert different livestock classes into a common unit. In general 1 TLU = 250 kg live-weight. The conversion factors are adjusted for the local tropical breeds.