Technical Efficiency of Wheat Production by Smallholder Farmers in Soro District of Hadiya Zone, Southern Ethiopia

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Abstract: Productivity of what in Ethiopia is below potential. This could be attributed to a number of factors among which is lack of knowledge on how to use new wheat crop production technologies. Therefore, this study was conducted to estimate the technical efficiency of smallholder wheat producers and identify its determinants in Soro district of Hadiya zone, southern Ethiopia. Cross sectional data from a random sample of 125 wheat producing farmers were collected during the 2015/16 main production season and analyzed. A Cobb-Douglas Production Function and Stochastic Frontier Analysis were employed to achieve the objectives. The results revealed that the mean technical efficiency of wheat producing farmers was 72%. The discrepancy ratio gamma (γ), which measures the relative deviation of output from the frontier level due to inefficiency, was about 63%. This implies that about 63% of the variation in wheat production among the sample farmers was attributed to technical inefficiency effect. The estimated inefficiency parameters showed that age, education level, land ownership, fertility status of the plots and extension contact negatively and significantly affected technical inefficiency of wheat production showing that an increase in the value of the variable attached to the coefficient means the variable negatively contributed to inefficiency level or conversely it contributed positively to efficiency levels. However, land fragmentation positively and significantly affected technical inefficiency showing that this variable has a negative influence on technical efficiency.

Keywords: Cobb-Douglas; Soro; Stochastic frontier analysis; Technical efficiency; Wheat.

1. Introduction

Agriculture is the main economic pillar of the Ethiopian economy. The sector accounts for about 36.3% of the Gross Domestic Product (GDP), provides employment opportunities to more than 73% of total population that is directly or indirectly engaged in agriculture, generates about 70% of the foreign exchange earnings of the country and 70% raw materials for the industries in the country (UNDP, 2018).

Ethiopia is the largest wheat producer in Sub-Saharan Africa and has a favorable climate for wheat production. Wheat is the fourth important cereal crop in the country and predominantly grown by subsistence farmers under rain-fed conditions. However, , the country is reliant on foreign wheat imports to satisfy its annual domestic demand (FAO, 2014). Wheat is cultivated in the highlands of Ethiopia, mainly in Oromia, Amhara, Southern Nations and Nationalities Peoples (SNNP) and Tigray regions and it is the first most important cereal crop in Hadiya zone, especially Soro district.

According to the report of Central Statistical Agency, for the crop year of 2015/2016, from the total land allocated for cereal crops, wheat stands in fourth by covering 13.33% of the total areas preceded by *teff*, maize, and sorghum. In the production year, the total area covered by wheat was 1.66 million hectares with a production of 42.19 million quintals and yield of 25.35 qt/ha from 4.78 million holders.

Despite the importance of wheat as a food and industrial crop and the efforts made so far to generate and disseminate improved production technologies, its productivity remains far below its potential. The average wheat yield was about 2.1 tons per hectare in 2012/2013 cropping season (CSA, 2013).

According to previous research conducted in Ethiopia, there exists a wide cereal yield gap among the farmers that might be attributed to many factors such as lack of knowledge and information on how to use new crop technologies, poor management, biotic, climate factors and more others (Sisay *et al*., 2015; Ahmed *et al*., 2013; Mesay *et al*., 2013).

If the existing production system is not efficient, introduction of new technologies could not bring the expected improvements in the productivity of wheat and other crops. Given the existing technology, improvements in the technical efficiency will enable farmers to produce the maximum possible output from a given level of inputs. Hence, improvements in the level of technical efficiency will increase productivity.

Yet empirical data on the farm level technical efficiency is limited and level of knowledge of farmers' on what production remain scantly known particularly in Sub-Saharan Africa. Hence, given that developing countries have scarce resources to undertake new investments on modern agricultural technologies, improving the technical efficiency of farmers is indispensable i.e. there is a wide room for increasing agricultural productivity and production in these areas by improving technical efficiency of farmers at the existing resources.

Therefore, from the perspective of formulating effective agricultural policies, undertaking research to generate empirical data on farm level technical efficiency has a paramount importance for providing valuable information to policy makers which will be used to enhance agricultural productivity. Equally important is to examine the principal factors that affect technical efficiency of farmers since these factors can be influenced by public policies. In the study area, there is lack of pertinent research on technical efficiency of the smallholder farmers and the determinants of the variability in the efficiency levels among farmers. This study is aimed at assessing and analyzing the technical efficiency of the farmers in the study area and bridging the prevailing information gap on factors contributing to efficiency differences in wheat production.

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2. Research Methodology

2.1. Description of the Study Area

The study was conducted in Soro district. It is located in Hadiya Administrative Zone in southern Ethiopia and is lies between $7^0$23'00" and 7^0 46'00" North Latitude and $37^0$18'00" and $37^0$23'00" East Longitude. The district has an altitude that ranges between 840-2850 meters above sea level. According to SWADO report, (2015/16) the district has three basic agro-climatic conditions, namely *Dega* (cool) (14.2%), *Woyinadega* (semi-cool) (53.1%) and *Kola* (warm) (32.7%). The mean annual rainfall of the area is 1260 mm and the average temperature is 19^0C. Farming system of Soro is mixed crop-livestock farming. The main types of crops grown are wheat, *teff*, barley, maize, sorghum, etc. Wheat is the most important crop grown in terms of area coverage and volume of production in the district. Wheat, being one of the major crops grown in the study area, is mostly used as a staple food and source of income.

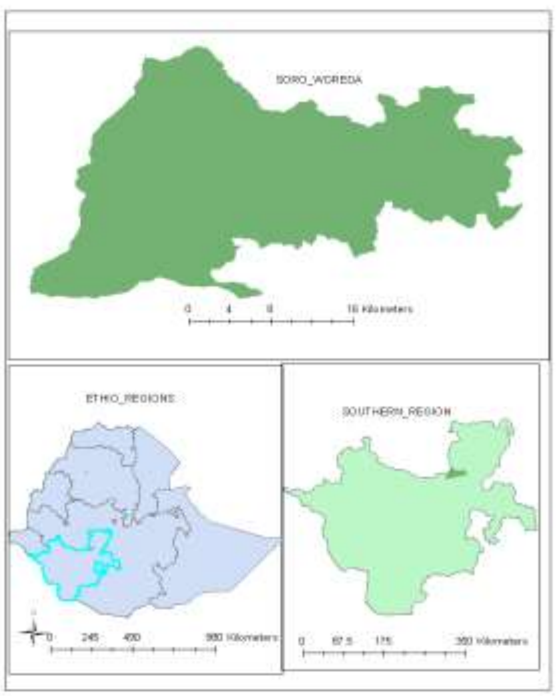

Figure 1: Map of the study area.

2.2. Data Sources and Sampling Technique

In this study, both primary and secondary data were used. The primary data were collected from randomly selected sample respondents using a structured questionnaire. In order to support primary data, secondary data were also collected from different published and unpublished documents about the study area from the district's agricultural development offices, governmental and non-governmental agencies and websites. Thus, purposive and two-stage random sampling techniques were employed for this study. The study district was purposively selected based on the extent of wheat production. In the first stage, out of 28 major wheat producer *kebeles,* three *kebeles* were selected randomly. In the second stage, the lists of wheat producing farmers in the production year 2015/16 in the selected *kebeles* were identified in collaboration with Woreda Agricultural and Development Office experts. Finally, 125 sample farm households were selected by a simple random sampling technique based on Probability Proportional to Size (PPS). The sample size for the study was determined based on Becker (1997) that suggested the procedure of drawing an adequate sample size from a given population at 5 percent error and 95 percent confidence level. This is given by:

Maximum error of margin at 5%

$$= \sqrt{(p*(1-p*))/n} \qquad (1)$$

Where n is the minimum sample size to be drawn, Z is the value corresponding to 95 percent level of confidence, and p* is the proportion that belongs to the target population out of total population. The population of wheat producing farmers in the 28 *kebeles* of the district is about 24,388 in which the size of wheat farmers in the three sample *kebeles* is about 8.95 percent and Z-score that corresponds to the 95 percent level of confidence is 1.96.

Table 1. Sample from the randomly drawn *kebeles* using PPS.

No	Name of *kebele*	No. of wheat farmers	Sample size
1	Kecha	1015	46
2	Bure	820	38
3	Sundusa	890	41
Total	3	2,725	125

2.3. Data Analysis

To achieve the objectives of the study, both descriptive and econometric methods were employed. Accordingly, in the descriptive part, simple measures of central tendency, frequency and percentages are used to describe the socio-economic, demographic and institutional characteristics of the sample wheat farmers. The stochastic frontier production function and the inefficiency model are simultaneously estimated with the maximum likelihood method using the econometric software, FRONTIER 4.1 computer programme.

2.4. Econometric analysis

Efficiency measurements are usually done using frontier methodologies, which shift the average response functions to the maximum output or to the efficient firm. These methodologies are broadly categorized under two frontier models; namely parametric and non-parametric. First, they differ on assumptions of the distribution of the error term that represents inefficiency. Second, they differ in the way the functional form is imposed on the data. Parametric methods use econometric approaches to impose functional and distributional forms on the error term whereas the non-parametric methods do not (Coelli *et al.*, 1998).

Agricultural production is inherent to variability due to random shocks such as drought, weather, pest infection, fires, diseases, etc. Furthermore, because many farmers are smallholders whose farm operations are managed by family members, therefore keeping of accurate records is not always a priority. Thus, much data available on production are likely to be subject to measurement errors (Tim and George, 1996). Due to these errors and random shocks which makes variation in output the stochastic production frontier will be used for its key features that the disturbance term is composed of two parts, a symmetric and a one-sided component. The symmetric component captures the random effect outside of the control of the decision maker including the statistical noise contained in every empirical relationship particularly those based on cross- sectional household survey data. The one-sided component captures deviations from the frontier due to inefficiency.

Therefore, the general stochastic frontier model developed independently by Aigner *et al.* (1977) and Meuse and ven den Broeck (1977) in which an additional random error, (vi), is added to the non-negative random variable, (μ_i), is specified as follows:

$$\ln(y) = x_i\beta + v_i - \mu_i, \qquad i = 1, 2, \dots N \qquad (2)$$

There are different functional forms to represent the production frontier. The two commonly used functional forms are Cobb-Douglas and Translog, each having their merits and demerits. Both models overwhelmingly dominate the applications literature in stochastic frontier and econometric inefficiency estimation (Coeil *et al.*, 2005). However, the work by Kopp and Smith (1980) confirmed that if the interest lies in measuring technical efficiency and not in the analysis of general structure of the production function, the functional form will have insignificant impact on measurement of efficiency. In order to identify the specific functional forms which will fit with our data, generalized likelihood ratio test was used. Therefore, Cobb-Douglas was selected for this study.

$$\ln(OUTP) = \beta_0 + \beta_1\ln(AREA) + \beta_2\ln(LAB) + \beta_3\ln(SEED) + \beta_4\ln(DAP) + \beta_5\ln(UREA) + \beta_6\ln(OXPW) + \beta_{7\ln(HERB)} + v_i - ui \qquad (3)$$

Where: OUTP - is the total output of wheat produced in quintal by the i[th] household; AREA - is the total area covered by wheat in hectares of the i[th] household; LAB - the total labor force used for plowing, planting, weeding and cultivation which are all measured in terms of man-day; SEED - is the total quantity of wheat seed used by the i[th] household measured in kilogram; UREA/DAP - is the total amount of UREA/DAP fertilizer in kilogram applied by the i[th] household for wheat production; OXPW - the amount of draught power used for different farming activities for wheat production is measured in oxen day. HERB-this is the total expenditure the farmer on herbicide purchase for wheat production and measured in Birr. v_i- is the disturbance error term, independently and identically distributed as N(0, σ_v^2) intended to capture events beyond the control of farmers; and μ_i - is a non-negative random variable, independently and identically distributed as N (μ, σ_μ^2) intended to capture technical inefficiency effects in the production of wheat measured as the ratio of observed output to maximum feasible output of the i[th] household.

The technical inefficiency effects model in which both the stochastic frontier and factors affecting inefficiency (inefficiency effect model) are estimated simultaneously is specified in Equation (4) as a joint estimation of a stochastic frontier production function:

$$\ln(OUTP) = f\{\beta_0 + \beta_1\ln(AREA) + \beta_2\ln(LAB) + \beta_3\ln(SEED) + \beta_4\ln(DAP) + \beta_5\ln(UREA) + \beta_6\ln(OXPW) + \beta_{7\ln(HERB)} + v_i - (\delta_0 + \delta_1 EDUC + \delta_2 AGE + \delta_3 SEX + \delta_4 FAMS + \delta_5 \text{TOTCULTLND} + \delta_6 FERTY + \delta_7 LIVES + \delta_8 EXTEN + \delta_9 SLOP + \delta_{10} CREDITT + \delta_{11} FRAG + \delta_{12} OWNL + wi)\} \qquad (4)$$

Where the variables used in the above inefficiency model are defined as follows: μ_i - is the inefficiency score of the i[th] household; δ_i - is a vector of parameter to be estimated; w_i - is error term;

The one-stage estimation procedure of the inefficiency effects model together with the production frontier function was used in the study. The two-stage procedure produces inconsistency in the assumption (Coelli *et al.,* 1998). Moreover, one-stage procedure is the most commonly used method in the analysis of technical efficiency. Thus one-stage procedure was selected for this study.

The maximum likelihood estimates of the parameters of the frontier model are estimated, such that the variance parameters are expressed in terms of the parameterization;

$$\sigma_s^2 = \sigma^2 + \sigma_v^2 \quad \text{and} \quad \gamma = \frac{\sigma^2}{\sigma_s^2} = \frac{\sigma^2}{\sigma_s^2 + \sigma^2} \qquad (5)$$

Where the γ parameter has a value between 0 and 1. A value of γ of zero indicates that the deviations from the frontier are entirely due to noise, while a value of one would indicate that all deviations are due to technical inefficiency. σ^2 - is the variance parameter that denotes deviation from the frontier due to inefficiency; σ_v^2 - is the variance parameter that denotes deviation from the frontier due to noise σ_s^2 - is the variance parameter that denotes the total deviation from the frontier. In the prediction of firm level technical efficiencies, Battese and Coelli (1995) pointed out that the best predictor of exp (-μ_i) is obtained by:

$$E[\exp(-\mu_i)/e_i] = \frac{1-\phi(\sigma_A + \gamma e_{i/\sigma_A})}{1-\phi(\gamma e_i/\sigma_A)} \exp(\gamma e_i + \sigma^2/2) \qquad (6)$$

Where $\sigma_A = \sqrt{\gamma(1-\gamma)\sigma_s^2}$; $e_i = \ln(y_i) - x_i\beta$; $\phi(.)$ is the density function of a standard normal random variables.

For the frontier model defined by equation (5), the null hypothesis, that there are no technical inefficiency effects in the model is conducted by testing the null and alternative hypothesis H0: γ = 0 versus H1: γ > 0. The hypothesis involving γ are considered due to the fact that, the Battese and Cora (1977) parameterization was adopted for this study and the test must be performed as a one-sided test because γ cannot take negative values. As a result, the One-sided Generalized Likelihood Ratio Test suggested by Coelli (1995) should be performed when maximum likelihood estimation is involved. This test statistic requires the estimation of the model under both the null and alternative hypotheses. Under the null hypothesis H0: γ = 0, the model is equivalent to the traditional average response function, without the technical inefficiency effect, Ui.

A number of tests were made in this study using the Likelihood Ratio (LR) test given by equation (7).

$$LR = \lambda = -2\ln[L(H0)/L(H1)] \qquad (7)$$

$$\lambda = -2[\ln L(H0) - \ln L(H1)]$$

Where, λ is the likelihood ratio (LR), L(H0) = the log likelihood value of the null-hypothesis; *L*(H1) = the log likelihood value of the alternative hypothesis; and ln is the natural logarithms. This test statistics is asymptotically distributed as a Chi-square (or mixed Chi-square) random variable with degree of freedom equal to the number of restrictions involved (Coelli *et al.*, 1998).

Table 2. Variables used in the inefficiency model and their expected sign.

No	Variables	Description	Measurement	Expected sign
1	AGE	Age of the household head	Years	-
2	EDUC	Years of schooling of farm HH	Years	-/+
3	SEX	Sex of farm HHH	1=male;0=female	-
4	FAMS	Number of family members working on farm	Number	-
5	TOTCULT LND	Total operational land holding	ha	-/+
6	FERTY	Fertility status of the soil	1=fert;0=otherwise	-
7	LIVES	Number of TLU	Number	-
8	EXTEN	Farmers contact to extension service	Number	-
9	SLOP	Slope of the plot	1=plain;0=otherwise	-
10	CREDIT	Harmer access and use of formal credit	1=access&use;0=otherwise	-
11	FRAG	Number of plots of all annual crops	Number	+
12	OWNL	Ownership of plots	1=owned&hired;0=otherwise	-

3. Results and Discussion

3.1. Descriptive Statistics

The summary of the descriptive statistics related to the entire variables used for the analysis is presented as mean, minimum, maximum and standard deviation values for continuous variables and frequencies and percents for discrete variables (Table 3). The results show that the average wheat output produced in the study area was 1315 kg. The land allocated for wheat production, by sampled farmers during the survey period was on average of 0.59 ha and the amount of seed that sample households used was on average 54.88 kg. The sample farmers on average applied 49.69 kg of DAP, 46.60 kg of Urea, 28.68 man-days, and 12.24 oxen days; and incurred Birr 154.07 for cost of herbicide for the production of wheat during 2015/16 production season.

Average age of sample household heads was 44.1 years, average family size was 5.18 and educational level on average, was 3.33 years. The average land holding of the sample households in the district was 0.93 ha and a farmer on average has 2.25 plots with the number of plots varying from one to five. The livestock holding was measured in terms of Tropical Livestock Unit (TLU) and sample farmers on average owned livestock of 3.74 TLU and average frequency of extension contacts during the production season was about 3.19 times.

Table 3. Descriptive statistical for the variables used in the analysis

Continuous variables	**Unit**	**Minimum**	**Maximum**	**Mean**	**St. Deviation**
Output	kg	200	4500	1315	986
Seed	kg	20	135	54.88	30.22
DAP	kg	15	130	49.69	29.90
Urea	kg	10	125	46.60	29.00
Area	ha	0.13	1.5	0.59	0.32
Human labor	Man-days	15	62.50	28.68	11.82
Oxen	Oxen day	2.50	31.63	12.24	7.29
Herbicide	Birr	27	300	112.16	58.88
Age	years	25	72	44.12	10.46
Education	years	0	12	3.33	3.68
Total cultivated land	ha	0.25	3.5	0.93	0.66
Fragmentation	number	1	5	2.25	0.97
Livestock	TLU	1	18.1	3.74	2.64
Family size	number	2	9	5.18	1.58
Extension	frequency	0	7	3.19	1.66
Discrete variables	Labels		Frequency		Percentage
Sex	Male=1		106		84.8
	Female=0		19		15.2
Land ownership	Owned or rented=1		96		76.8
	Otherwise=0		29		23.2
Fertility perception	Fertile=1		67		53.6
	Otherwise=0		58		46.4
Slope	Plain=1		64		51.2
	Otherwise=0		61		48.8
Credit	Used=1		79		63.2
	Not used=0		46		36.8

Source: Own computation (2016)

3.2. Econometric Results

3.2.1. Hypotheses Testing

One attractive feature of SPF method is that it is possible to test various hypotheses using maximum likelihood test ratio. Therefore, before presenting and discussing about parameter estimates of production frontier function and the inefficiency effects, it is advisable to run hypotheses tests in order to choose an appropriate model for further analysis and interpretation. Tests of hypotheses for the parameters of the frontier model were conducted using the generalized likelihood ratio statistics, λ, defined by equation (7). Accordingly, the following hypotheses were tested, namely to select the correct functional form for the given data set, for the existence of inefficiency and finally for variables that explain the difference in efficiency.

The first null hypothesis was H_o: $\gamma = 0$, which specifies that the inefficiency effects in the SPF were not stochastic. The generalized likelihood ratio statistics, λ= 42.62, presented in Table 4 is found to be greater than the critical value of 6.63. Hence, we reject null hypothesis (H_o) at 1% level of significance showing that the average response function is not an adequate representation of the data.

The second test was the null hypothesis that identifies an appropriate functional form between restrictive Cobb-Douglas and the non restrictive Translog production function which specifies that square and cross terms. The test result show that the calculated value of λ = 44.64 is less than the critical value of 48.27, thus the null hypothesis is not rejected at 1% level of significance implying that Cobb-Douglas functional form best fit the data set.

Table 4. Generalized likelihood ratio tests of hypothesis for the parameters of the SPF.

Null hypothesis	DF	LH_o	LH_1	Calculated $\chi 2$ (LR) value	Critical value ($\chi 2$, 0.01)	Decision
Ho: $\gamma = 0$	1	-7.47	35.15	42.62	6.63	Reject
Ho: $\beta_8 = \beta_9$ - - - = β_{35}=0	28	35.15	57.47	44.64	48.27	Not reject
H_0: $u_i = \delta_1 = \delta_2 = \ldots = \delta_{12} = 0$	12	-6.17	35.15	82.64	26.21	Reject

Source: Own computation (2016)

3.2.2. Input Parameter Estimates of the SPF Model

The stochastic Cobb-Douglas production function maximum likelihood estimates of the parameters defined by equation 3 are presented in Table 5. The diagnostic statistics of inefficiency component reveals that sigma squared (σ^2) was statistically significant which indicates goodness of fit, and the correctness of the distributional form assumed for the composite error term. The estimated value of Gamma (γ) is 0.63 which indicates that 63% of total variation in wheat output among sample farmers is due to technical inefficiency. In addition to this, the results showed that the estimated coefficients for DAP, UREA, oxen power, herbicide and area are all positive and significant which confirm that, these inputs significantly increase output. The MLE values of the coefficients can be interpreted as elasticity of production. The coefficients of inputs indicate that on average a 1% increase in DAP, UREA, oxen power, herbicide and area increases the output of wheat by 0.13%, 0.17%, 0.29%, 0.12% and 0.48%, respectively.

3.2.3. Technical Efficiency Scores

The mean technical efficiency of the sampled wheat producer households in 2015/16 production year in the area was 72%, with minimum and maximum efficiency levels of about 37% and 96% respectively (Table 6). This shows that there is a wide disparity among wheat producer farmers in their level of technical efficiency which in turn indicates that, there exists a room for improving the existing level of wheat production through enhancing the level of farmers' technical efficiency. The mean level of technical efficiency further tells us that the level of wheat output of the sample respondents can be increased on average by about 28% if appropriate measures are taken to improve the level of efficiency of wheat growing farmers. In other words, there is a possibility to increase yield of wheat by about 28% using the resources at their disposal in an efficient manner without introducing any other improved (external) inputs and practices.

Table 5. MLEs for parameters of the Cobb-Douglas stochastic production function.

Variables	Coefficient	Standard-error	t-ratio
Constant	5.09***	0.62	8.16
lnSeed	-0.08	0.09	-0.82
lnDAP	0.13***	0.05	2.57
lnUREA	0.17***	0.05	3.31
lnLabor	0.11	0.09	1.19
lnOxen	0.29***	0.09	2.99
lnHerbicide	0.12**	0.05	2.20
lnArea	0.48***	0.13	3.52
Diagnostic statistics			
Sigma-squared (σ^2)	0.06***	0.08	4.86
Gamma (γ)	0.63*	0.32	1.94
Log likelihood Function	35.15		

Source: Own computation (2016)
Note: *, ** and *** significant at 10%, 5% and 1% significance level, respectively.

The next the null hypothesis that the explanatory variables associated with technical inefficiency effect model are all zero, (H_0: $U_i=\delta_0 = \delta_1 = \delta_2$ - - - $\delta_{12} = 0$). To test this hypothesis likewise, λ was calculated using the value of the log likelihood function under the stochastic frontier model (a model without explanatory variables of inefficiency effects, H_0) and the full frontier model (a model with variables that are presumed to determine inefficiency of each farmer, H_1). The calculated value of $\lambda = 82.64$ is greater than the critical value of 26.21, thus the null hypothesis that variables in the inefficiency effects model are simultaneously equal to zero is rejected at 1% level of significance. Hence, these variables explain the difference in inefficiency among farmers.

Table 6. Estimated technical efficiency scores.

Descriptive statistics	Technical efficiency scores
Mean	0.72
Maximum	0.96
Minimum	0.37
Standard Deviation	0.17

Source: Own computation (2016)

4.2.4. Determinants of Technical Inefficiency

The main interest behind measuring technical efficiency level is to know the factors that determine the technical efficiency level of individual farmers. The parameters of the various hypothesized variables in the technical inefficiency effect model that were expected to determine efficiency differences among farmers were estimated through MLE method using one-stage estimation procedure.

Table 7 illustrates the socio-economic, demographic, farm characteristics and institutional factors that affect efficiency in wheat production. Out of the twelve variables used, six variables (age, education, land fragmentation, land ownership, fertility status of the plot and extension contact) were found to affect significantly the efficiency of wheat farmers.

The age of respondents has a significant negative effect on inefficiency of wheat producing farmers at 10% level of significance. This indicates that as the age of farmers increases their inefficiency reduces which leads to improvement in the level of technical efficiency. This may be due to the fact that age can serve as a proxy variable of farming experience, in which farmers with more years of experience are expected to be less inefficient. The result is in conformity with the results of Endalkachew (2012) and Shumet (2012) and in contradiction with the study by Mesay *et al.* (2013).

Education was measured in years of formal schooling. As expected, the sign of education was negative and significant at 10% level of significance implying that less educated farmers are not technically efficient than those that are relatively better educated. Hence, education can be a proxy variable for managerial ability of the farmer and improves the ability of the household to make informed decision about production inputs. Educated farmers more often have better access to agricultural information and higher tendency to adopt and utilize improved inputs (like fertilizers and crop varieties) more optimally and efficiently. This result is in line with results of the studies by Endrias *et al.* (2013) and Mesay *et al.* (2013).

Land fragmentation was hypothesized that plots in the area are highly fragmented and scattered over many places that would make undertaking farming activities on time and efficiently difficult. The positive and significant value of the coefficient of fragmentation in Table 7 at 1% level of significance is consistent with the previous expectation. This may be because if the number of plots operated by the farmer increases, it may be difficult to manage these plots. Thus, farmers that have a large number of plots may waste time in moving between plots. This finding is in line with empirical findings of Fekadu (2004) and Wondimu (2010).

Table 7 shows land ownership measured in terms of dummy, which was found to determine the efficiency level of farmers in producing wheat positively and significantly at 1% of significance. Farmers who used their own land or hired land for wheat production were more efficient than farmers who managed sharecropped land. This may be due to the fact that operator farmers might not perform each farming activity on time especially during peak periods. In addition, the sharecropping arrangement would not encourage the operator farmer to take risk as the risk on loss of returns on inputs is solely taken by the operator farmer. The result is consistent with the results obtained by Fekadu (2004).

As can be seen from Table 7, perceived soil fertility had a significant and positive impact on technical efficiencies at 10% level of significance. This implies that farmers having fertile land were more efficient than those who have less fertile land. This may be associated with the fact that fertile lands require application lower amounts of fertilizers which leads to reduction in cost and time, leading to reduction in the inefficiency of farmers. This result is similar with the findings reported by Shumet (2012), Hassen *et al.* (2014) and Hailemaraim (2015).

Finally, the results showed that extension contact determined the inefficiency level of farmers negatively and significantly at 5% level of significance. This is consistent with the priori expectation that the more the farmer has extension visits, the less he/she will become inefficient. The improvement in the production system of wheat in the study area is one of the major focuses of extension. In the study area, the contact farmers had with extension workers played a significant role in improving the level of technical efficiency. The findings are consistent with earlier results of Berhan (2013).

Table 7. Maximum likelihood estimates of the factors determining technical inefficiency.

Inefficiency variable	Coefficient	Standard-error	t-ratio
Constant	0.90***	0.18	4.84
Age	-0.05*	0.02	-1.91
Sex	-0.06	0.07	-0.90
Education	-0.02*	0.09	-1.84
Total cultivated land	0.02	0.04	0.55
Land fragmentation	0.07***	0.03	2.87
Land ownership	-0.13***	0.05	-2.35
Fertility	-0.18*	0.07	-2.69
Slope	-0.02	0.05	-0.44
Livestock	-0.02	0.01	-0.18
Family size	-0.01	0.02	-0.85
Credit	-0.04	0.05	-0.90
Frequency extension contact	-0.04**	0.02	-2.17

Source: Own computation (2016)

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

4. Conclusions

The results of this study demonstrated that that the traditional average response function is not an adequate representation of production frontier. The study revealed that a significant proportion of the variation in the stochastic frontier production function was due to technical inefficiency. This implies that there is a room for improvement in output through improving the inefficiency of farmers. The mean technical efficiency level of 72 percent indicates that production can be increased by 28 percent. Hence, if inputs are used to their maximum potential, there will be considerable gain from improvement in technical efficiency.

The estimated SPF model together with the inefficiency parameters showed that age of farmers, education level, land ownership, soil fertility, and frequency of extension contact had a negative and land fragmentation had a positive and significant influence on the inefficiency of farmers. These factors have important policy implications for mitigating the existing level of inefficiency of farmers in the production of wheat and other crops, and hence, development programs should exploit these variables.

Therefore, the results of this study have relevance for policy makers on how to improve the technical efficiency and optimal use of resources for crop production in the study area. The following general policy recommendations could be drawn based on the results of the study.

First, the local government should arrange field days, cross-visits, creating forum for experience sharing elder households and provision of short-term training programs so as to share the knowledge of elder households to young farmers. Second, it is important to give due attention for farmers education through strengthening and establishing both formal, informal type of farmers' education by using the available human and infrastructural facilities like extension agents and Farmers Training Centers.

Third, development programs need to strengthen improved land management practices to improve and maintain the fertility of farm land to increase efficiency of farmers. The result reveals that there is land shortage in the study area as a result of high population pressure. Hence, serious intervention is required for intensive and efficient use of farming practices by improving the fertility of land and by adopting other improved crop production technologies.

Fourth, given the existing technologies at hand, bringing farmers under extension contact and rendering them the necessary advisory services can enhance the level of their technical efficiency in wheat production.

Fifth, land policy that would increase the ownership right would not only increase the efficiency of farmers but also increase the use of improved technologies since it minimizes the risk aversion behavior of farmers to invest on technologies.

Finally, farmers that operate a larger number of plots are less efficient than others. This implies that land policy that favors unfragmented land holding increases the efficiency of farmers.

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