



Determinants of Technical Efficiency in Wheat Production in Ethiopia

Daniel Hailu

Department of Agricultural Economics, Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia

Email address:

danielhailu19@yahoo.com, dahagm19@gmail.com

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Abstract: Ethiopia is the second largest wheat producing countries in Sub-Saharan Africa and most people rely on rain fed agriculture for their livelihoods. Wheat production has increased from 2,176,603 tons in 2005 to 4,219,257 tons in 2016 with 51.6% production volume increment. However, this production cannot meet the consumption demand and obliged to import wheat because of rapid population growth. This study intended to determine the technical efficiency of smallholder wheat farmers in Ethiopia. The main objective of study was to examine the effect of demographic, socioeconomic and institutional factors on technical efficiency of small holder wheat farmers in Ethiopia. The study used household level cross sectional data collected in 2015/16 cropping season from 1611 sample farmers selected by multistage sampling technique. A stochastic production frontier and two-limit Tobit regression models were used to estimate level of technical efficiency and identify factors affecting technical efficiency respectively. The study indicated that the average technical efficiency level of wheat producing farmers was 62% implying that there was technical efficiency variation among smallholder farmers in the study area. The result implied that there is an opportunity for wheat producers to increase output at existing levels of inputs with present technologies. By shifting the average farmer to the production frontier, the average yield would increase by 0.5 tons per hectare. The two-limit Tobit regression model results showed that experience of growing wheat, family size, own farm labor, livestock size, extension contact and training had positive and significant effect on technical efficiency. However, distant wheat plot have a negative and significance effect on technical efficiency level of the farmers. This suggests attention to productivity gains arising from efficient use of existing technologies is necessary. Therefore, the study suggested, policies and strategies should be directed towards increasing productivity through improving efficiency of the production process.

Keywords: Yield Gap, Efficiency, Production, Productivity, Improved Variety, Ethiopia

1. Introduction

Developing countries will demand food and account for about 85 percent of the 690 million ton increase in the global demand for cereals between 1995 and 2020 [1]. Empirical studies suggest that most under developed and developing countries are still facing the problem of high poverty levels. Most farmers in these countries practice subsistence farming with low productivity.

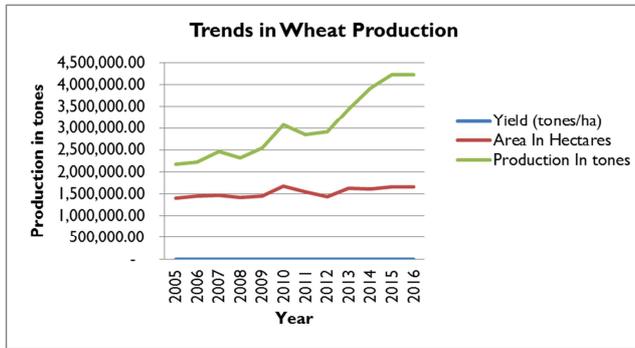
In Ethiopia most people rely on agriculture for their livelihoods. However, agricultural system in the country is primarily rain fed and the sector is still exposed to droughts and flooding. According to Federal Democratic Republic of Ethiopia [19], in Ethiopia over 7 million people still face food insecurity.

Ethiopia is the second largest wheat producing countries in sub-Saharan Africa, after South Africa [2]. For the crop year of 2015/2016, from the total land allocated for cereal crops, wheat stands in fourth by covering 13.3% of the total areas preceded by Teff, maize and sorghum.

In the last 12 years, there was a progression of wheat productivity by 61.4% and total area of production by 84%. The production has increased from 2,176,603 tons in 2005 to 4,219,257 tons in 2016 with 51.6% production volume increment.

A number of variety trials were conducted by national wheat research program in different areas of the country to address problems of different agro-ecologies production

constraints. Accordingly, as of 2016, 76 improved wheat varieties with high-yielding potential, wide adaptation and resistance/tolerance to diseases and pests have been released [21]. However, average national productivity of wheat is 2.54 ton/hectare which is too low compared to the potential productivity of 5 ton/hectare at farmers' field [20]. This shows that production growth is largely attributed to area expansion than increased productivity.



Source: own computation

Figure 1. Trends of wheat production and productivity from 2005 to 2016.

Crop yield per area (amount of crop harvested per amount of land cultivated) is the most commonly used impact indicator for agricultural productivity. Productivity can change due to differences in production technology, differences in the efficiency of the production process and differences in the environment in which production takes place. Efficiency is a very important factor of productivity growth, especially in developing agricultural economies

where resources are insufficient and opportunities for developing and adopting better technologies are declining. Such economies can benefit greatly by determining the extent to which it is possible to raise productivity or increase efficiency, at the existing resource base or technology.

Several recent studies on the technical efficiency (TE) of crop production for wheat indicated the existence of a yield gap. This gap refers to the difference in productivity between best practice farms and other farms that operate with comparable available resources under similar circumstances [3].

The presence of shortfalls in efficiency indicates that output can be increased with given inputs and existing technologies. If this is the case, then empirical estimations of efficiency are important to determine the gain that could be obtained by improving the performance in production with existing technology. It also helps to find out whether the yield variability is due to random influences beyond the control of the farmers or to the factors under the control of the farms.

2. Materials and Methods

2.1. The Study Area

The study was conducted in four major wheat producing regions in Ethiopia. The regions share the larger volume in terms of producers, the area they are planted and volume of production obtained from private peasant holdings.

Table 1. Description of the study area.

Regions	Number of holders	Area in Hectare	Production in tonnes
Ethiopia - All regions (2015/16)	4,780,267	1,664,564.62	4,219,257.22
1 Amhara	1,750,963	545,106.10	1,221,904.31
2 Oromia	1,951,975	872,252.80	2,459,375.14
3 Tigray	382,304	102,847.97	176,096.64
4 SNNPR	677,054	133,419.80	334,633.93
Four regions (2015/16)	4,762,296	1,653,626.67	4,192,010.02
Share	99.6%	99.3%	99.4%

Source: Organized by the researcher [4].

2.2. Data Type and Sources

Farm household survey which was collected through structured questionnaires was used for the analysis. The data was collected by Ethiopian Institute of Agricultural Research (EIAR) and the International Maize and Wheat Improvement Center (CIMMYT) during 2015/16 cropping season. Secondary data gathered from country's statistical report, crop variety register, annual reports, research papers, website, books and unpublished reports also used in the analysis..

2.3. Sampling Techniques

Multistage sampling procedure combining both purposive and simple random sampling was used to identify farmers to include in the sample. Sixty one districts from four regions

were selected purposively from different 13 agro ecological zones based on wheat production, cultivated land and number of wheat farmers. Finally, respondents were selected in proportion with the frame by using systematic random sampling techniques from 123 peasant associations.

2.4. Method of Data Analysis

Descriptive and Econometric analysis were used to analyze the data. Descriptive statistics were employed to describe the demographic, socio-economic and institutional characteristics of the wheat farmers. Technical efficiency measurements are basically carried out using frontier methodologies, which shift the average response functions to the maximum output or to the efficient firm. A stochastic

frontier model (SFM) and a two-limit Tobit regression model were employed to derive efficiency scores for the wheat producers and to determine technical inefficiency factors respectively.

A stochastic frontier model (SFM)

A Parametric Stochastic Frontier Production Function was used to assess technical efficiency of wheat producers in the study area. Following [5] and [6] the stochastic frontier production functions model will be specified as follows:

$$Y_i = f(X_i; \alpha_i) + \varepsilon_i \quad (1)$$

Where, Y_i is the output of farmer i , X_i are the input variables, α_i are production coefficients and ε is the error term that is composed of two elements, that is:

$$\varepsilon_i = v_i - u_i \quad (2)$$

Where, v_i represents randomness (or statistical noise) and u_i represents technical inefficiency. From the error term component ($v_i - u_i$), v_i is a two sided ($-\infty < v < \infty$) normally distributed random error ($v \sim N [0, \sigma^2 v]$) that represents the stochastic effects outside the farmer's control. (example weather, natural disasters etc), measurement errors, & other statistical noise while U_i is a one-sided ($u_i \geq 0$) efficiency component which is independent of v_i and is normally distributed with zero mean and a constant variance ($\sigma^2 u$) allowing the actual production fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

The technical efficiency (TE) of an individual farm is defined in terms of the ratio of the observed output (Y_i) to

$$\ln L = \sum_{Y_i=L_{oi}} \ln \phi \left[\frac{L_{oi} - X_i' \beta}{\sigma} \right] + \sum_{Y_i=Y_i^*} \ln \cdot \frac{1}{\sigma} \phi \left[\frac{Y_i - X_i' \beta}{\sigma} \right] + \sum_{Y_i=L_{ui}} \ln \left[1 - \phi \left(\frac{L_{ui} - X_i' \beta}{\sigma} \right) \right] \quad (5)$$

Where $L_{oi} = 0$ (lower limit) and $L_{ui} = 1$ (upper limit) where ϕ and Φ are normal and standard density functions.

The Marginal Effects

The marginal effects of changes in explanatory variables from Tobit regression analysis were computed following the procedure proposed by [10] and later developed by [11]. McDonald and Moffitt showed that a change in the independent variable x has three effects. The marginal effects of these conditional expectations respectively are given as:

1) The unconditional expected value of the dependent variable: The marginal effects for the unconditional expected value of the dependent variable,

$$\frac{\partial E(y | \chi)}{\partial \chi} = \beta \Phi \left(\frac{\chi \beta}{\sigma} \right) \quad (6)$$

2) The expected value of the dependent variable conditional upon being between the limits: The influence of explanatory variables on the expected value of the dependent variable conditional on it being larger than the lower bound.

the corresponding frontier output (Y_i^*), conditioned on the level of inputs used by the farm and mathematically expressed as:

$$TE = \frac{Y_i}{Y_i^*} = \frac{E(Y_i / u_i, X_i)}{E(Y_i / u_i = 0, X_i)} = e^{-[E(u_i / e_i)]} \quad (3)$$

A two-limit Tobit regression model

The determinants of technical efficiency were estimated using a two-limit Tobit model with the dependent variable, as the technical efficiency indices.

Following [7] and [8], the two-limit Tobit model was defined as;

$$Y_{i TE}^* = \delta_0 + \sum_{j=1}^n \delta_j z_{ij} + u_i \quad (4)$$

Where Y_i^* is latent variable representing the efficiency scores, $\delta_0, \delta_1, \dots, \delta_n$ are parameters to be estimated, and TE is, technical efficiency of the i^{th} farmer. Z_i - demographic, socioeconomic and institutional factors that affect efficiency level. And u_i - an error term with mean zero and variance δ^2 ($u_i \sim \text{IN} (0, \delta^2)$) and farm specific efficiency scores for the smallholder wheat producers range between zero and one.

Two-limit Tobit model allows for censoring in both tails of the distribution [9]. The log likelihood that is based on the doubly censored data and built up from sets of the two - limit Tobit model is given by;

$$\frac{\partial E(y^* | \chi)}{\partial \chi} = \beta \quad (7)$$

3) The probability of being between the limits: The influence of explanatory variables on the probability of dependent variable to fall in the uncensored part of the distribution.

$$\frac{\partial \text{Pr}(y > 0 | \chi)}{\partial \chi} = \phi \left(\frac{\chi \beta}{\sigma} \right) \frac{\beta}{\sigma} \quad (8)$$

The study explained the conditional and unconditional marginal effects of changes in explanatory variables.

3. Results and Discussion

3.1. Descriptive Results

Descriptive statistics of production function of inputs and output variables

The sample farm households realized a mean yield of 1.65 tones/ha of wheat (Table 2). However, productivity varied

between a minimum of 0.03 tones/ha and a maximum of 6.81 tones/ha, indicating a considerable scope for improving

wheat yields. The two commonly used chemical fertilizers in the production of wheat were DAP and Urea.

Table 2. Descriptive results of Input and Output.

Inputs and output Variables	N	Minimum	Mean	Maximum	Std. Deviation
Area in ha	1611	0.01	0.7	12.5	.7202974
Seed in kg/ha	1611	7	175.91	2,884.62	120.5052
Fertilizer in kg/ha	1611	0	132.85	925	103.9898
Chemical in kg/ha	1611	0	0.57	30.77	1.109355
Labor days/ha	1611	1	59.46	729.17	74.07052
Oxen days/ha	1611	0	25.35	224	14.82379
Output of wheat in kg/ha	1611	26.32	1,653.75	6,814.16	1034.386

Source: Own Computation, 2015/16

Descriptive statistics of continuous efficiency variables

Sampled age of respondents was aged between 18 to 90 years. Most of the sampled HHHs were relatively old. Farmer's experience in wheat activities were ranged from 1 to 72 years. About 66% of the total sampled HHHs had at least 6 persons in the household.

Table 3. Descriptive results continuous efficiency variables.

Variables	N	Minimum	Mean	Maximum
Distance to market (km)	1611	0.01	9.1	42
Age of household	1611	18	45.9	90
Labor force available	1611	1	1.4	6
Household size	1611	1	6.6	19
Farm size (Ha)	1611	0.04	1.5	21.3
Number of Livestock (TLU)	1611	0	5.4	31.5
Experience of growing wheat	1611	1	17.8	72
Extension contact	1611	0	3.6	50
Plot distance (Minutes)	1611	0	13.4	360

Source: Own Computation, 2015/16

Descriptive statistics of discrete efficiency variables

The majority (91.6%) of sampled respondents were male headed households. Eighty four percent of the farmers were owner-operated. While, 16 percent of the farmers were farming with contracted land (either cash rented, sharecropped, gifted or borrowed).

Table 4. Descriptive results of discrete variables.

Characteristics	Category	Frequencies	Percentages
Sex	Female	136	8.4
	Male	1475	91.6
Education of household	No	98	6.1
	Yes	1513	93.9
Rely on government support	No	323	20
	Yes	1288	80
Ownership of plot	No	257	16
	Yes	1354	84

Source: Own Computation, 2015/16

3.2. Empirical Results

3.2.1. MLE of the Variance Parameters

The maximum likelihood estimates (MLE) of the Cobb-Douglas based stochastic production function was specified to determine the possible relationships between the production of wheat and inputs used. The estimated values of output elasticities for all inputs are positive and significant

influence on wheat output growth. Oxen power is found to have the highest elasticity, followed by plot area, labor, seed, fertilizer and chemical.

Table 5. The MLE of the Variance Parameters.

Input Variables	coefficient	standard-error	t-ratio
Plot Size	0.49765446	0.34357930	0.14484413
Amount of seed	0.38775795	0.28673704	0.13523120
Amount of fertilizer	0.25387508	0.38354919	0.66191009
Amount of chemicals	0.19479395	0.45912556	0.42427163
Labor days	0.21638875	0.18566331	0.11654901
Oxen days	0.69783035	0.26306705	0.26526711
sigma-squared	0.64647112	0.39373086	0.16419113
Gamma	0.75378949	0.33012270	0.22833616
log likelihood function = -0.13865120			

The results of MLE of variance parameters explain that variance parameter gamma (γ) is the ratio of variance of farm specific technical efficiency to the total variance of output and has a value 0.75 which shows that out of total variation in wheat production 75 percent variation is due to technical inefficiency u_i while remaining 25 percent is due to the uncertainty v_i . By shifting the average farmer to the production frontier, the average yield would increase by 0.5 tones/ha and the most technically inefficient farmer would have an efficiency gain of 0.53 tones/ha using the available resources.

3.2.2. Technical Efficiency Level

The TE among the households ranges from 11% to 92%, with standard deviation of 0.1493906. The mean TE of sample households during the survey period was 62.2%. The Southern region of the country scored minimum TE. The results of the efficiency scores indicate that there were wide ranges of differences in TE among wheat producing farmers.

Table 6. Technical Efficiency (TE) Levels.

No.	Regions	No. of Farmers	Technical Efficiency Level		
			Minimum TE	Mean TE	Maximum TE
1	Amhara	509	0.11	0.58	0.92
2	Oromia	837	0.15	0.65	0.91
3	Tigray	84	0.25	0.67	0.88
4	Southern Ethiopia	181	0.10	0.62	0.87
	Ethiopia	1611	0.11	0.62	0.92

Source: developed by the researcher

Distribution of TE Scores

TE scores showed that the majority (more than 58%) of the sample households had TE score between 50%-75% TE scores. But there were 326 households whose TE levels were below 50%. Out of the total sample households, only 21% had TE greater than 75%. Generally there is a considerable amount of efficiency variation among wheat producer farmers in measure of technical efficiency.

Table 7. Distribution of TE scores.

Efficiency Category	TE	
	Freq.	Percentage
0.00 ≤ E < 0.25	26	1.61
0.25 ≤ E < 0.50	300	18.62
0.50 ≤ E < 0.75	942	58.47
0.75 ≤ E < 1.00	343	21.29
Total	1611	100.00

Source: developed by the researcher

3.2.3. Factors Influencing Technical Efficiency

The results obtained from the first stage estimations indicated that the average efficiency scores were low and there existed efficiency variations among farmers. The TE estimates derived from the model were regressed on factors that explain variations in efficiency across farm households using Tobit model (Table 8).

Tobit regression model estimated to assess the determinants of technical efficiency. As shown in the table 8, among the farmer-specific characteristics, higher levels of experience in growing wheat, holding larger family size, own farm labor, holding livestock, farmers who have contacts with agricultural extension agents and those farmers received training were a positive and significant effect on technical efficiency level of the farmers. However, distant plot have a negative and significance effect on technical efficiency level of the farmers.

Table 8. Tobit Regression (determinant factors in Technical efficiency).

Variables	Coef. (TE)	Std. Err.	t	P> t
Experience of growing Wheat	0.0116717**	0.0045518	2.56	0.010
Family size	0.0180865**	0.0091265	1.98	0.048
Wheat plot size	0.0013865	0.0039817	0.35	0.728
Own farm labor	0.0221635***	0.0080781	2.74	0.006
Ownership of plot	-0.0011455	0.0009514	-1.20	0.229
Tropical livestock unit (TLU)	0.0315087***	0.0019150	16.45	0.000
Plot distance	-0.0030913***	0.0009295	-3.33	0.001
Rely on government support	-0.0008264	0.0008703	-0.95	0.342
Extension contact	0.0018939**	0.0008334	2.27	0.023
Received training	0.0237985***	0.0016271	14.63	0.000

Note: *** Significant at 1%, ** Significant at 5% and * Significant at 10%

The results from the Tobit model were subjected to post estimation test using marginal effect analysis in order to estimate the trivial change from each factor that influences TE. Quantification of the marginal effects of these variables is important in order to estimate the change that will occur with respect to a change in one unit of that variable.

The marginal effect analysis:

Quantification of the marginal effects of these variables is important in order to estimate the change that will occur with respect to a change in one unit of that variable (Table 9).

Table 9. The marginal effects of change in explanatory variables (TE).

Variables	dy/dx	
	∂ E (y)	∂ E (y*)
Experience of growing Wheat	0.0116521	0.0114851
Family size	0.0180560	0.0177973
Wheat plot size	0.0013842	0.0013644
Own farm labor	0.0221261	0.0218091
Ownership of plot	-0.0011436	-0.0011272
Tropical livestock unit (TLU)	0.0314555	0.0310049
Plot distance	-0.0030860	-0.0030418
Rely on government support	-0.0008250	-0.0008132
Extension contact	0.0018907	0.0018636
Received training	0.0237584	0.0234181

Experience of Growing Wheat: had a positive effect on Technical efficiency level of farmers at 5% significant level. A unit change in the year of production experience of the household head in an increasing order would increase the probability of a farmer being technically efficient by about 1.17% and the mean level of TE by about 1.15%. Results revealed that experienced farmers had the managerial capability to carry out farming activities as experience increases. The finding was consistent with [12].

Family Size: had a positive effect on Technical efficiency level of farmers at 5% significant level. A unit change in the number of household member in an increasing order would increase the probability of a farmer being technically efficient by about 1.81% and the mean level of TE by about 1.78%. Results revealed that a farmer owing larger family size can better manage the farm timely because family is the main source of labor supply. The finding was consistent with [12, 13].

Own Farm Labor: had a positive effect on Technical efficiency level of farmers at 1% significant level. A unit change in spending own farm labor in the household head in an increasing order would increase the probability of a farmer being technically efficient by about 2.21% and the mean level of TE by about 2.18%. Results revealed that Farms managed under hired labors may not get more energetic and active workers because of labor price competition and unable to get labor force in seasonal farming activities. Farmers who have more active family labor force enable them to allocate the required labor for different farming and production activities and become more productive. The result is in conformity with other findings of [14, 15].

Tropical Livestock Unit (TLU): had a positive effect on Technical efficiency level of farmers at 1% significant level. A unit change in the number of owning livestock in an increasing order would increase the probability of a farmer being technically efficient by about 3.15% and the mean level of TE by about 3.1%. Results revealed that farmers who kept livestock were efficient in production. Owning livestock enables farmers to plough their plot and thresh timely, provides manure as fertilizer, source of cash to purchase input expenses and draught power. This result is similar with the study by [12, 16].

Plot Distance: had a negative effect on Technical efficiency level of farmers at 1% significant level. A unit change in the year of production experience of the household head in an increasing order would decrease the probability of a farmer being technically efficient by about 0.31% and the mean level of TE by about 0.3%. Results revealed that distant plots require additional time to travel to farm as compared to the closer plots and made follow-up and farm management activities difficult resulting in less production and efficiency. Tadele Mamo et al. [17] found for the same.

Extension Contact: had a positive effect on Technical efficiency level of farmers at 5% significant level. A unit change in the extension contact of the household head in an increasing order would increase the probability of a farmer being technically efficient by about 0.19% and the mean level of TE by about 0.19%. Results revealed that Extension workers play a central role in informing, motivating, and educating farmers about available technology in that influenced farm efficiency positively and significantly. Hunde and Abera [12] and Fekadu Gelaw and Bezabih Emana [13] found for the same.

Training: Received training had a positive effect on Technical efficiency level of farmers at 10% significant level. A unit change in number of production training received by the household head in an increasing order would increase the probability of a farmer being technically efficient by about 2.38% and the mean level of TE by about 2.34%. Results revealed that training provides technical knowledge on farming and improves the ability of farmers in choosing appropriate combination of inputs to produce the maximum output. This result is similar with the study by Fekadu Gelaw and Bezabih Emana [13] and K. M.

Zahidul Islam et al. [18].

4. Conclusion and Recommendation

National wheat average yields are still far below attainable yields which is 2.54 tons per hectare. The yield gap of over 2.46 tons per hectare suggests that there is a potential for increasing production and productivity of smallholder wheat farmers. The results of MLE of variance parameters explain that variance parameter γ shows that out of total variation in wheat production 75 percent variation is due to technical inefficiency. Wheat producers in the study area are not operating at full TE level (62%) because of level of experience in growing wheat, family size, family labor, number of livestock farmers owned, access to extension agents, training offered and distance of wheat plot. By shifting the average farmer to the production frontier, the average yield would increase by 0.5 tons per hectare which implied that there is an opportunity for wheat producers to increase output at existing levels of inputs with present technologies. Therefore, attention should be given to improve the technical efficiency level of less efficient farmers by adopting the practices of relatively more efficient farmers in the study area and yield advantage gained in national average yield. Policies and strategies of the government should give attention towards the above mentioned factors affecting technical efficiency in the study area through training and other agricultural services.

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