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Research article

Technical Efficiency Measurement and Their Differential in Wheat Production: The Case of Smallholder Farmers in South Wollo

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ABSTRACT

This study was aimed to measure the level of technical efficiency and identify its determinants in wheat crop for smallholder farmers in south Wollo zone, Ethiopia. A multi-stage sampling technique was employed to select 68 wheat growing sample households. The Stochastic Production Frontier (SPF) result revealed that area allocated under wheat, seed, fertilizer applied and labor in man days were appeared to be significantly influencing wheat production at less than 1 percent probability level. The estimated gamma parameters indicated that 73% of the total variation in wheat output was due to technical inefficiency. The average technical efficiency was 78% while return to scale was 1.17% implying that farmers are operating at an increasing return to scale. Thus, ample scope existed to realize higher output with existing resources and level of production technology. The socio-economic variables that exercised important role for variations in technical efficiency were age, education, farm size, and livestock holding in Tropical Livestock Unit, number of oxen holding, access to irrigation and access to credit. Nevertheless, participation on off farm income, and interaction of off farm income and education was found to decrease efficiency significantly among farm household. Therefore, innovative institutional arrangement, education and farmers training accompanied with more access to fertilizer and improved seed were likely to enhance production efficiency in the study area. Access to irrigation through small and large scale irrigation must be ensured to increase productivity and hence reduce and then alleviate poverty in the region. This would help to adapt to the increasing climate change the country is facing. People are poor due to shortage of resources or inability to use them. Therefore, farm household asset formation and provision of institutional services should be given priority. Such actions may, in turn, alleviate the current problem of food insecurity and lead in the long run to economic development.

Keywords: Technical efficiency, Wheat production, Stochastic Frontier, Ethiopia

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1. INTRODUCTION

The economic development of Ethiopia is highly dependent on the performance of its agricultural sector. Agriculture contributes 43% of the country's Gross Domestic Product (GDP), 85% of all exports (coffee, livestock and livestock product and oil seeds) and provides employment for 85% of the population (FAO, 2007). Agriculture provides also raw material for 70% of industries in the country (MOFED, 2006). The bulk of agricultural GDP for the period 1960-2009 had come from cultivation of crops (90%) and the remaining (10%) from livestock production (FAO, 2007; MoFED, 2010). The industrial sector is small in size contributing, on average, only about 15% of the GDP.

The growth rate of agriculture and GDP is low for several decades mainly due to severe weather fluctuations, inappropriate economic policies and low adoption of improved agricultural technologies and prolonged civil unrest (Hailu, 2008). The average growth rate of the agricultural sector was 1.7%, 3.8% and 5.5% during the Imperial period (1960-1974), socialist period (1975-1991) and the Ethiopia People's Revolutionary Democratic Front (EPRDF) period (1991-2009), respectively. The growth rate of GDP fluctuates with the growth rate of agriculture. The major crops produced in the country include cereals, pulses and oil seeds with 72%, 12% and 7% of area coverage and 69%, 9% and 3% of production, respectively (CSA, 2009a). Data from the Central Statistical Agency indicate that the major cereals produced in the country include Teff, wheat, barley, maize and sorghum. Wheat covered 18.2% of cultivated cereal crop area and 19.8% of cereal crop production (CSA, 2009a). The same source showed that yield of cereal crops on the average was 1.55 tons per hectare. However, the yield of wheat was 1.83 tons per hectare.

The yield of crops in general and cereals in particular is very low because of low utilization of improved technologies. For instance, the amount of inorganic fertilizer applied in the 2008/09 cropping season was 423,000 tons. During the same period, the total area fertilized with inorganic fertilizer for all crops was about 29.6% of total cultivated area in Ethiopia (CSA, 2009b). The cultivated area covered with improved variety was about 3.4% of total cultivated land in Ethiopia. Hence Ethiopian smallholders typically produce with their indigenous seed and are characterized by low adoption of improved technologies. Because of the low productivity of the agricultural sector, Ethiopia has become highly dependent on food import in that domestic food production and supply have consistently been below the national demand (FAO, 2007). For instance, the country received 674,000 metric tons of cereals in the form of food aid in 2006 alone (FAO, 2007).

In the northeast Ethiopia where this study is conducted, crop and livestock productions are highly integrated as a means to generate income, cope up with market and environmental risks and meet household consumption requirements. However, the production and productivity of crop and livestock is very low resulting in food insecurity. The average cultivated area with inorganic fertilizer is 19% of the total cultivated area in south Wollo. The average cultivated area with improved seed is 0.6% of the total cultivated area in the study area and 2.6% of the total wheat area (CSA, 2009a; CSA, 2009b). Due to low use of improved practices the productivity of all crops is below the national average. For example, the yield of wheat in south Wollo is 1.36 ton per hectare for traditional practices but more than 3.0 ton per hectare using improved technologies. Though there have been various empirical studies conducted to measure efficiency and adoption of agricultural technologies in Ethiopia, (for example, Asfaw *et al.*, 1997; Mergia, 2002; Kiflu and Berhanu, 2004; Hassen et al, 2011; Hassen et al, 2012a; Hassen et al, 2012b; Hassen et al, 2013; Hassen, 2011; Hassen, 2013; Hassen, 2014; Hassen, 2014; Wondimu and Hassen, 2014; and Wondimu et al, 2014), to the best of the authors' knowledge, there were no similar studies undertaken on technical efficiency of wheat producing household in the study area. Moreover, since social development is dynamic, it is imperative to update the information based on the current productivity of farmers. However, the productivity of agricultural system in the study area is very low. The poor production and productivity of crop and livestock resulted in food insecurity. Therefore, assessing the factors responsible for low production and productivity of smallholder mixed crop-livestock farmers in Ethiopia in general and in north eastern highlands of Ethiopia in particular was paramount importance. This study aimed at filling this gap. The specific objectives of the study were to: (1) estimate the farm level efficiency of the wheat production system at farm household level; and (2 identify the sources of efficiency differential among the farmers. The study is organized in four sections, section one presents the background information and defines the statement of the problem and objectives of the study. Section two develops the analytical framework and methodologies used in the study. Section four presents the empirical results of the study. Finally, section five summarizes the major findings and draws conclusions.

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2. METHODOLOGY OF THE STUDY

2.1. Description of the study area

This study was carried out in South Wollo. South Wollo is located in the North East highland part of Ethiopia. South Wollo is one of the eleven administrative zones of the Amhara National Regional State. It is situated between the Eastern highland plateaus of the region and the North Eastern highland plateaus of Ethiopia. It is divided into 20 administrative districts (weredas) and has two major towns (Kombolcha and Dessie) and 18 rural districts. Among the eighteen rural districts, Dessie Zuria and Kutaber are selected for this study. South Wollo is located between latitudes $10^{0}10$'N and $11^{0}41$'N and longitudes $38^{0}28$' and $40^{0}5$'E. According to the Central Statistical Agency's population census data, in 2007 the total population of South Wollo was 2,519,450 of which 50.5% were females and 88% were rural residents (CSA, 2008). The total land area in South Wollo, Dessie Zuria and Kutaber is 1,773,681 hectares, 180,100 hectares and 72,344 hectares, respectively. The cultivated land area accounts for 39%, 20% and 35.3% of the total area of Dessie Zuria, Kutaber and South Wollo, respectively.

2.2. Sample size and sampling procedure

Dessie Zuria and Kutaber districts were selected purposively based on their accessibility and relevance of the study. A multistage random sampling method was used for the selection of the sample respondents. In the first stage of sampling, 6 Farmers' Associations (FAs) were selected randomly from a total of 54 FAs (3 from Dessie Zuria and 3 from Kutaber). In other words, as the number of Farmers' Association in Dessie Zuria (28) was equal to that of Kutaber (26), three Farmers' Associations were selected from each district using simple random sampling procedure. In the second stage, a total of 68 farmers were selected using probability proportional to sample size sampling technique (Table 1). Sample household were selected using random table.

Table 1. Distribution of sample farm household heads by district

Name of District	Total household* head	Sample farm household heads
Dessie Zuria	4,609	51
Kutaber	1,755	17
Total	6,364	68

Source: *Kebele Administration Office (Personal Communication)

2.3. Methods and sources of data collection

A structured questionnaire was designed, pre-tested and refined to collect primary data. Experienced numerators were recruited and trained to facilitate the task of data collection. Farm visit, direct observation and informal interview were undertaken both by the researcher and the enumerators. Data on wheat outputs and inputs and inefficiency variables were collected. The secondary data were extracted from studies conducted and information documented at various levels of Central Statistical Agency, Ministry of Agriculture and Rural Development and Finance and Economic Development Offices in the study area.

2.4. Stochastic frontier approach to measure efficiency

The theory and concept of measurement of efficiency has been linked to the use of production functions. Some authors measure performance of firms by computing productivity using output over inputs. However, this is not the appropriate measurement techniques in efficiency. Different techniques have been employed to either calculate (non-parametric) or estimate (parametric) the efficient frontiers. These techniques are classified as parametric and non-parametric methods. Farrell (1957) was the first to formulate a non-parametric frontier method to measure production (economic) efficiency of a firm. According to him, efficiency ratios are calculated from sample observations. He defined technical, allocative and economic efficiencies. Technical efficiency (TE) reflects the ability of a firm to obtain maximum output from a given resources. Allocative efficiency (AE) reflects the ability of a firm to use inputs in optimal proportion given the input prices and production technology. Economic efficiency (EE) is the overall efficiency of a decision making units (firms or farmers). It is the multiplicative effect of technical and allocative efficiencies. This study estimates the overall efficiency of farm households. Hence, the reader could understand for economic efficiency and production efficiency as the same to mean estimating technical, allocative and economic efficiency.

The parametric frontier method can be classified into deterministic and stochastic frontier techniques. The deterministic parametric frontier approach is formulated with the production behavior of firms. It can be expressed as:

$$Y_i = f(X_i;\beta)\exp(-U_i) \quad \text{i=1,2,…,N} \tag{1}$$

Where f (X_i;β) is a suitable functional form, β is vector of unknown parameters, U assesses the socioeconomic, institutional and technological factors that are responsible for low production and productivity of the firm. U_i is a non-negative random variable associated with technical inefficiency of the i^{th} firm which implies that exp ($-U_i$) is bounded between 0 and 1. Y_i is the vector of output.

The stochastic frontier approach splits the deviation (error term) into two parts to accommodate factors which are purely random and are out of the control of the firm. One component is the technical inefficiency of a firm and the other component is random shocks (white noise) such as bad weather, measurement error, bad luck, omission of variables and so on. The model can be expressed as:

$$\ln Y_i = \beta_0 + \ln \sum \beta_i X_{ij} + \exp^{e_i} \tag{2}$$

Where ln denotes the natural logarithm; i represents the i^{th} farmer in the sample, Y_i represents output of wheat of the i^{th} farmer, X_{ij} refers to the farm inputs of the i^{th} farmer, $e_i= v_i-u_i$ which is the residual random term composed of two elements v_i and u_i. The v_i is a symmetric component and permits a random variation in output due to factors such as weather, omitted variables and other exogenous shocks. The v_is are assumed to be independently and identically distributed N(0,σ^2_v), independent of ui. The other component, u_is, is non-negative random variable and reflects the technical inefficiency relative to the stochastic frontier. The uis are assumed to be independently and identically distributed as half-normal, u~N(0, σ^2_v). The parameters β, $\sigma^2= \sigma_v^2+\sigma_u^2$ and $\gamma= \sigma_u^2/\ \sigma^2$ of the above stochastic production function can be estimated using maximum-likelihood method, which is consistent and asymptotically efficient (Aigner *et al.*, 1977). Following Bravo-Ureta and Rieger (1991) for a given level of output (Y_i*), the technically efficient input vector of the i^{th} farmer, X_{it}, is derived by solving (2) and the observed input ratio $X_1/X_i = m_i\,(i>1)$

Estimation of the determinants of wheat technical efficiency

In efficiency analysis, factors that influence efficiency are of paramount importance. Following the quantification of the production efficiency measures, a second stage analysis involved a regression of these measures on several hypothesized socioeconomic, institutional and technological factors that affect the efficiency of the farmers. The most common procedure is to examine the determinants of efficiency, in that the inefficiency or efficiency index is taken as a dependent variable and is then regressed against a number of other explanatory variables that are hypothesized to affect efficiency levels (Bravo-Ureta and Rieger, 1991; Sharma *et al.*, 1999; Arega, 2003; Jema and Andersson, 2006). For the former approach, efficiency estimates were regressed, using Tobit model (Sharma *et al.*, 1999; Jema and Andersson, 2006; Hassen et al, 2012b; Hassen, 2014) or linear regression model (Sharma *et al.*, 1999; Arega, 2003) on the farm specific explanatory variables that might explain variations in efficiency across farms. However, other authors (e.g., Kumbhakar *et al*., 1991; Battese and Coelli, 1995; Wondimu and Hassen, 2014; and Wondimu *et al*, 2014.) used a specific model that allowed researchers to estimate the efficiency scores and simultaneously to test the effects of explanatory variables. And this study had adopted the latter approach.

2.5. Description of variables for efficiency measurement
Production function variables

The variables that were used in the stochastic frontier model were defined as follows.
i. Outputs: physical yield of wheat were used to compute the output of the farm. ii. Inputs: these were defined as the major inputs used in the production of wheat. They were:
Land: This represented the physical unit of cultivated land in hectares;

Human labour: This was man days worked by family, exchange and hired labour for land preparation, planting, weeding, or cultivation, irrigation, harvesting of wheat
Oxen labour: This was oxen days worked by the household using oxen labour for land preparation, planting and threshing;
Seed: This included the amount of improved and local seed used in production of a farm household
Fertilizer: This included the amount of chemical fertilizers, improved and local seeds used by the farm household.

Variables included in the determinants of efficiency model

The dependent variable was the technical efficiency scores, which were computed from parametric methods of efficiency measurement.
iv. Efficiency factors:
Dependent variable: Inefficiency of farmers
Independent variables: these denoted various factors hypothesized to explain differences in technical efficiency among farmers. These were:
Age: this was the age of the household head in years.
Farm size: it was defined as the total area of cultivated and grazing land in hectare.
Education: it was a continuous variable defined as years of formal schooling;
Labour available: it was defined as the total active labour available in the family in man equivalent.
Livestock ownership: it was defined as the total livestock available in TLU.
Off/non-farm income: this included income from off-farm and non-farm activities. It was a dummy variable that the variable was 1 if the household earned off/non-farm income and 0 otherwise.
Credit service: it included access to credits for farm inputs and other farm production activities from formal and semi-formal sources. It was a dummy variable defined as 1 if the farmers have received credit and 0 otherwise.
Extension service: it was defined as whether the farmer had access to the extension service during the survey year or not. It was a dummy variable defined as 1 if the household had access to extension service and 0 otherwise
Technology adoption: this was whether or not the household adopted at least one improved soil and water technology. It was a dummy variable defined as 1 if the farmer had been adopted at least one improved technology and 0 otherwise. The improved agricultural technologies considered were improved wheat seed, chemical fertilizer, improved forage and dairy.
Distance to markets: this was the distance of the household head to market in minutes
Sex: this was the sex of the household head whether a household is male= 1 or female=0
Oxen: this was the number of oxen owned by the household head
Radio: this was the ownership of the household head whether a household owned= 1 or not =0

3. RESULTS AND DISCUSSION

3.1. Socioeconomic Descriptive Characteristics of the Sample Households

The sample farm households realized a mean yield of 18.6 qt/ha of wheat (Table 2). However, productivity varied between a minimum of 5 and a maximum of 63 qt/ha, indicating a considerable scope for improving wheat yields. The two commonly used chemical fertilizers in the production of wheat were DAP and Urea. The average amount of DAP and Urea applied by sample household were average 50 kg and 30.6 kg per ha, respectively. In general, there was high variation in the application of fertilizers in wheat production among the sample households. The average application for seed and fertilizer were 16.7 kg/ha and 46.1 kg/ha, respectively.

Table 2. Descriptive statistics of production function of inputs and output variables

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Area in ha	68	0.11	1.13	0.33	0.30	0.09
Seed in kg	68	4.50	155.00	36.72	39.59	1567.67
Chemical fertilizer in kg	68	0.00	150.00	13.31	33.34	1111.65
Human labour in man days	68	5.00	98.00	32.19	22.81	520.19
Oxen labour in oxen days	68	4.00	43.00	13.25	8.97	80.37

Output of wheat in kg	68	50.00	2450.00	613.24	596.98	356389.38

Source: Own Computation, 2012

The survey results revealed that on average, human labor days used in the cultivation of wheat crop was 19.1 man days per hectare. Similarly the mean use of oxen labor was 46.3 oxen days per ha with the standard deviation of 8.97 oxen days.

The analysis and pattern of cultivated land amongst sample households indicated that the average size of farm owned by the sample household heads were 0.93ha.There were large variations in the distribution of the land holding among sample households. The average age of sample households were 55 years with minimum and maximum of 25 and 88 years, respectively.

Table 3. Descriptive statistics of continuous efficiency variables

	N	Minimum	Maximum	Mean
Distance to market	68	5.00	180.00	90.07
Age of household	68	25.00	88.00	55.01
Education of household	68	.00	14.00	2.68
Number of family	68	2.00	11.00	6.56
Labour force available	68	1.70	9.30	4.57
Household size	68	1.65	9.95	5.52
Farm size	68	0.07	2.50	.93
Oxen number	68	0.00	3.00	1.41
Livestock in TLU	68	1.00	8.64	4.30

Source: Own Computation, 2012

The average education levels of sample households were 3 years with minimum and maximum of 0 and 12+2 years, respectively. The average livestock of sample households were 4.3 TLU with minimum and maximum of 1 and 8.64 TLU, respectively. This implies that farmers are undertaking mixed crop-livestock production system for diversification of various risks. This would stabilize the farm income of households.

The descriptive statistics of discrete efficiency variables indicated that there were very limited household heads of female farmers (Table 4). However, the survey results indicated that 75% of the sample household had access to off-farm employment opportunities. Extension and credit access had a statistical different between participant and non-participant.

Formal and informal institutions were the two main sources of credit in the study district. The major sources of informal credit were friends, relatives and neighbors. Most farmers use such credit to meet family consumption requirements such as food purchases, educational, medical expenses and sometimes to pay taxes. Interest charged on credit received through friends, relatives and neighbors were nil in most of the cases. However, local moneylenders charge very high interest rate while micro financing institutions provided short term credits at a relatively less interest rate. The Amhara credit and saving association provides services to farmers based on group collateral method. Farmers had received credit from these institutions to purchase fertilizer, purchase of oxen and to meet social obligations. Only about 13 percent of the sample households had received credit in the production year.

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Table 4. Descriptive statistics of discrete efficiency variables

Characteristics		Frequencies	Percentages	Chi-Square	Sig.
Sex	female	2	2.9	60.24	0.00
	male	66	97.1		
	Total	68	100.0		
Off-farm access	no	17	25.0	17.00	0.00
	yes	51	75.0		
	Total	68	100.0		
Radio access	no	28	41.2	2.12	0.15
	yes	40	58.8		
	Total	68	100.0		
Extension access	no	16	23.5	19.06	0.00
	yes	52	76.5		
	Total	68	100.0		
Credit access	no	59	86.8	36.76	0.00
	yes	9	13.2		
	Total	68	100.0		
SWC adoption	no	4	5.9	52.94	0.00
	yes	64	94.1		
	Total	68	100.0		

Source: Own Computation, 2012

3.2. Results of the hypotheses test in estimating TE

The formulation and results of different hypotheses (model selection, inefficiency effect, determinants of coefficients) are presented in Table 5. All the hypotheses were tested by using generalized likelihood-ratio (LR). The first hypothesis related to the appropriateness of the Cobb-Douglas functional form in preference to translog model. The computed LR statistic was less than the critical value of chi-square at less than 5% probability level. The null hypothesis was accepted by indicating that the Cobb-Douglas functional form is a better representation of the data. These showed that the coefficients of the interaction terms and the square specifications of the input variables under the Translog specifications were not different from zero. Hence, CD production function was the best to fit the data for estimation of technical efficiency for wheat producing farm household in the study area.

Table 5. Summary of hypotheses for parameters of stochastic frontier and inefficiency effects

Hypothesis	df	LH_0	LH_1	Calculated X^2 (LR)	Critical X^2	Decision
1. Production Function is Cobb-Douglas H_0 : C-D (β6= β6….β_{20}=0); H_1 : Translog production function	14	-31.44	-24.07	14.74	23.68	Accepted
2. H_0: μ=0 distribution assumption	1	-31.49	-31.44	0.1	3.84	Accepted
3. There is no inefficiency component (H_0: γ=0) H_1 : there is difference in efficiency	1	-37.87	-28.53	18.68	3.84	Rejected

4. The coefficients of determinants of inefficiency model equals zero $H0=\delta0=\delta2\ldots\ldots=\delta12=0$ H_1 : at least one of δ's are not zero	7	-31.44	-17.75	27.38	14.07	Rejected

Source: Own Computation, 2012

The second test conducted was, given such functional forms for the sample households; it was considered whether the technical efficiency levels were better estimated using a half normal or a truncated normal distribution of μ_i. The results indicated that the half normal distribution was appropriate for the sample households in the study area as the calculated LR value of 0.1 was less than the critical X^2 value of 3.84 at less than 5% probability level.

The third hypothesis was tested for the existence of the inefficiency component of the total error term of the stochastic production function. In other words, it was concluded whether the average production function (without considering the non-negative random error term) best fits the data. Hence, the third hypothesis stated that $\gamma=0$, was rejected at the less than 5% level of probability confirming that inefficiencies existed and were indeed stochastic (LR statistic 18.68> chi-square =2.71). The coefficient for the parameter γ could be interpreted in such a way that about 79 percent of the variability in wheat output in the study area was attributable to technical inefficiency effect, while the remaining about 21 percent variation in output was due to the effect of random noise. This implies that there was a scope for improving output of wheat by first identifying those institutional, socioeconomic and farm specific factors causing this variation.

The fourth hypothesis which stated the technical inefficiency effects were not related to the variables specified in the inefficiency effect model, was also rejected at the 5% level of significance (LR statistic 27.38> $\lambda^2_{7,0.95}$ =14.07). Thus the observed inefficiency among the wheat farmers in the area could be attributed to the variables specified in the model and the variables exercised a significant role in explaining the observed inefficiency.

3.3 Parameter estimates of the SPF model

Table 6 presents the results of both the OLS and ML estimates. In total 19 parameters were estimated in the stochastic production frontier model including five in the C-D production frontier model, and twelve explanatory variables were hypothesized to influence the technical efficiency scores while the remaining two being the parameters associated with the distribution of μ_i and v_i. Out of the five parameters estimated, four were statistically significant. Two were significant at one percent level while two input variables were significant at less than five percent level of significance.

During the estimation, a single estimation procedure was applied using the CD functional form. The computer program FRONTIER version 4.1 gave the value of the parameter estimations for the frontier model and the value of $\square^2$. The Maximum Likelihood estimates of the parameter of SPF functions together with the inefficiency effects model are presented in Table 6 below.

Table 6. Econometric results of stochastic production function

	OLS			MLE		
Input Name	Coef.	Std. Err.	z	Coef.	Std. Err.	z
Area	0.23**	0.11	2.02	0.24**	0.12	2.07
Seed	0.11	0.11	0.96	0.21**	0.10	2.15
Fertilizer	0.03	0.03	0.82	0.10***	0.04	2.56
Man days	0.32**	0.13	2.35	0.13	0.10	1.26
Oxen days	0.47**	0.19	2.46	0.65***	0.15	4.42
_cons	3.90***	0.51	7.65	3.86***	0.42	9.26
R-squared	0.797					
F***(5, 62)	48.69					

sig2v		-2.59***	0.21	-12.63

Source: Own Computation, 2012

3.4. Input elasticity and returns to scale

As indicated in table 6 above, the results of the Cobb-Douglas Stochastic Production Frontier showed that area allocated under wheat, chemical fertilizer and labor inputs were found to be important variables in increasing the productivity of wheat. Coefficients for land, oxen labor and chemical fertilizer had expected positive signs. Moreover, oxen labor and chemical fertilizer were significant at 1% percent while land and seed were significant at 5% probability level. Land appeared as the single most important factor of production with an elasticity of 0.24 This implies that, ceteris paribus, a 1% increase in area allocated to wheat will increase the output of wheat grain by 0.24 percent.

Moreover, the results showed that the variables specified in the model had inelastic effect on the output of wheat production. The summation of the partial elasticity 1.33 showed that wheat production in the study area was operated at increasing returns to scale. As such a 1% increase in all the specified inputs will lead to about 1.33% increase in output. Therefore, an increase in all inputs by one percent will increase wheat yield by more than one percent.

3.5. Level of technical efficiency and the variability of output due to efficiency differentials

The Maximum Likelihood estimation of the frontier model gave the value for the parameter (γ), which is the ratio of the variance of the inefficiency component to the total error term ($\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2) = \sigma_u^2/\sigma_s^2$). The γ value indicated the relative variability of the one sided error term to the total error-term. In other words, it measured the extent of variability between observed and frontier output that is affected by the technical inefficiency.

Table 7. Descriptive statistics of efficiency scores

Type of statistics	Value of statistics
Mean	0.79
Median	0.80
Std. Deviation	0.07
Variance	0.01
Minimum	0.60
Maximum	0.91

Source: Own Computation, 2012

As a result the total variation in output from the maximum may not have necessarily caused efficiency differentials among the sample households. Hence, the disturbance term had also contributed in varying the output level. In this case, it was crucial in determining the relative contribution of both usual random noises and the inefficiency component in total variability. The TE analysis revealed that technical efficiency score of sample farms varied from 60% to 91%, with the mean efficiency level being 79%. This variation was also confirmed by the value of gamma (γ) that was 0.79. The gamma value of 0.79 suggested that 79% variation in output was due to the differences in technical efficiencies of farm household in south Wollo while the remaining 21% was due to the effect of the disturbance term. Moreover, the corresponding variance-ratio parameter implied that 16% differences between observed and maximum frontier output for wheat was due to the existing differences in efficiency among the sample farms. These provided opportunity for improving wheat output by investigating factors that influence efficiency in order to improve the productivity of wheat in the study

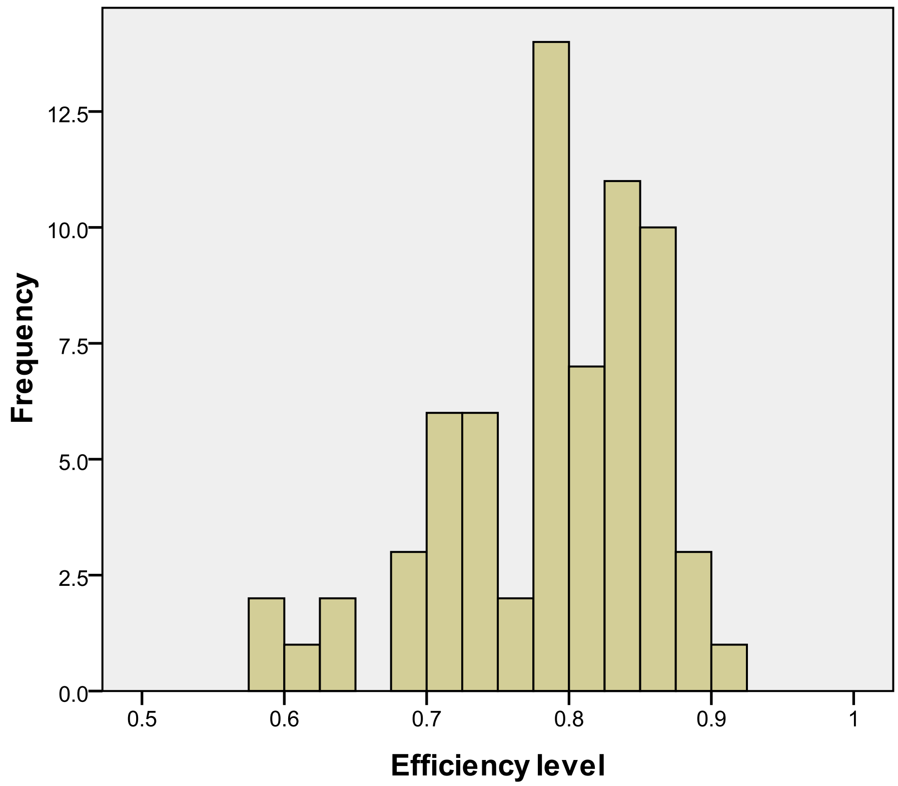

Figure 1. Distribution of technical efficiency scores

The indices of TE indicated that if the average farmer of the sample could achieve the TE level of its most efficient counterpart, then average farmers could increase their output by 13.2% approximately [that is, 1-(79/91)] (Table 6). Similarly the most technically inefficient farmer could increase the production by 34.1% approximately [that is, 1-(60/91)] if he/she could increase the level of TE to his/her most efficient counterpart. Since the mean TE is 79%, it can be deduced that 21% of the output was lost due to the inefficiency in wheat producing system or in the inefficiency among the sampled farmers or both combined. Likewise on average, output can be increased by at least 21% while utilizing existing resources and technology given the inefficiency factors were fully addressed. It also indicated that small farms in the study area, on average, can gain higher output growth at least by 13.2% through the improvements in the technical efficiency. Moreover, from the total sample households, more than two third scored above the mean TE score while almost one third of sample respondent produces less than the mean TE score of farmers in their vicinity.

Potential yield was also calculated for each farm and the results were presented by range of technical efficiency group. In general, for the less efficient farm households the recorded average actual yield was 10 qt/ha. Their corresponding averagely efficient group potential yield was 19qt/ha. The highest difference between actual and potential yield was analyzed for 20% of the sample household. The potential yield for this group was found to almost 50% of their actual yield. On the other hand, the net magnitude of yield improvement through efficient utilization of existing resource for less and averagely efficient farmers were approximately 5.94 and 3.3qt/ha. At district level, working towards improving the efficiency of the farmers could bring additional yield of 60 qt of wheat given 22.44 ha of total land area allocated for wheat production in the study period. These findings may invite attention of the policy makers and district experts to improve the efficiency of the farmers through adoption of right strategy to efficiently utilize the existing resource to improve the food security of the district.

3.6. Determinants of Technical efficiency

The focus of this analysis was to provide an empirical evidence of the determinants of productivity variability/inefficiency gaps among smallholder wheat farmers in the study area. Having knowledge that farmers were technically inefficient might not be useful unless the sources of the inefficiency are identified. Thus, in the second stage of this analysis, the study investigated farm and farmer-specific attributes that had impact on smallholders' technical efficiency.

The parameters of the explanatory variables in the inefficiency model were simultaneously estimated in a single stage estimation procedure using computer program, FRONTIER 4.1. The dependent variable of the model was inefficiency and the negative signs implied that an increase in the explanatory variable would decrease the corresponding level of inefficiency.
Table 8 showed the coefficients of explanatory variables in the inefficiency model. The results showed that most of the signs related to inefficiency determinants were as expected. The model results showed that factors such as age, education, access to credit, and oxen number were negatively related with inefficiency while number of livestock and distance to market were positively related with inefficiency.
Age of farm household heads

The age of the household influenced inefficiency negatively. This suggested that older farmers were more efficient than their young counterparts. The reason for this was probably because the farmers become more skill full as they grow older due to cumulative farming experiences (Liu and Zhung, 2000). Moreover increase in farming experiences leads to a better assessment of the important and complexities of good farming decision-making including efficient use of input. Similar conclusions were made by Omonona (2010) and Awudu and Huffman (2000).

Education

The results showed that farmers with more years of formal schooling were more efficient than their counterparts (Table 26). Education enhances the acquisition and utilization of information on improved technology by the farmers. Similar results had been reported in studies which had focused on the association between formal education and technical efficiency (Nyagaka et al. (2009); Fekadu, 2004 and Kinde, 2005). In general, more educated farmers were able to perceive, interpret and respond to new information and adopt improved technologies such as fertilizers, pesticides and planting materials much faster than their counterparts. This result was consistent with the findings of Abdulai and Eberlin (2001) which established that an increase in human capital will augment the productivity of farmers. Educated farmers will be better able to allocate family-supplied and purchased inputs, select and utilize the appropriate quantities of inputs to achieve the portfolio of household pursuits such as income.

Off farm income

Effect of this variable could be ambiguous. While on the one hand, it increases the income base of the farm household thus helping them to overcome credit and insurance constraints and increase their use of industrial inputs. On the other hand, it reduces the labor available for agricultural production especially if hiring agricultural labor incurs transaction costs or if hired labor is not as efficient as family labor (Feng, 2008).

In this study, off farm income was positive and significant with technical inefficiency. This implied that, farmers who participated in off-farm work were likely to be less efficient in farming as they share their time between farming and other income-generating activities. Productivity suffers when any part of production is neglected. Especially in the study area, many farmers employed in activities related with the off-farm production and the majority neglect weeding of their wheat crop. This finding was in agreement with that of Mariano *et al.* (2010) and Goodness *et al*.(2010).

Moreover, for the wheat producing farmers the inefficiency the coefficient of interaction between off-farm income and education variable was positive, indicating that the farmers who were educated and engaged in generating off-farm income tended to exhibit lower technical efficiency levels in wheat production. Even though such farmers were not financially constrained and can therefore purchase the required inputs for wheat production. The positive

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relationship with technical inefficiency suggests that involvement in off farm work coupled with their academic curiosity in the existence of more profitable venture such as involvement in petty trading and other crop and livestock production might dictate them to reallocate most of their time away from wheat crop management related activities. As a result the farmers use less time for adoption of new technologies and gathering of technical information that is essential for enhancing technical efficiency (Huffman and Zhung, 2000).

Number of livestock

Livestock ownership measured in TLU was considered as an asset that could be used either in the production process or in exchange for the purchase of inputs. Possession of large number of livestock indicated greater wealth and capacity. Livestock in a mixed farming system had many contributions for farm household. It supplied oxen power for ploughing, threshing, sources of food and income for the family. It was hypothesized that number of livestock positively influenced technical efficiency. Nevertheless the coefficient is found to be significant and negative with technical efficiency. This might be attributed to the tendency of the farmers who held large number of livestock reallocated much of their time in herding livestock and hence less time for crop management. Due to this fact, farmers who owned large livestock might be less technical efficient as compared to those who possessed large livestock. The finding was consistent with the findings of Fekadu (2004).

Table 8. Determinants of differential on technical inefficiency among farmers

Inefficiency variable	Coef.	Std. Err.	Marginal effect
Distance to market	0.09	0.06	0.0001
Sex of household	0.41	13.73	0.0033
Age of household	-0.369*	0.21	-0.0007
Education of household	-2.080*	1.25	-0.0026
Labour force available	3.86	2.60	0.0251
Farm size	-13.000**	4.85	-0.0414
Livestock TLU	6.607**	2.45	0.0731
Oxen number	-11.605*	6.63	-0.0231
Radio	-7.553**	2.86	-0.0337
Access to extension	4.90	3.89	0.0098
Access to credit	-10.813**	3.57	-0.0084
Access to irrigation	-15.00***	3.59	-0.0288
Interaction of off-farm and education	0.06***	0.005	0.0054
Access to off-farm	0.026**	0.012	0.002
_cons	56.462*	33.35	0.0078

Source: Own Computation, 2012

Marginal Effects of inefficiency variables

The estimated parameters on the inefficiency model presented in Table 8 only indicated the direction of the effects that the variables had on inefficiency levels. According to Battese and Coelli (1993), quantification of the marginal effects of inefficiency variables on technical efficiency was done by partial differentiation of the technical efficiency predictor with respect to each variable in the inefficiency function.

The marginal effect (0.0731) of livestock number for technical efficiency indicated that, for the sample period and sample households considered an increase in number of livestock by one TLU, on average his technical efficiency will decrease by 7.3%. In contrast the marginal effect of education 0.0026 indicated that for sample farm households an increase in level of year of schooling by one year on average will increase the technical efficiency by 0.26 %.The marginal effect for discrete variable like radio can be interpreted as, if a farmer gained access to radio, his technical efficiency will increase on average by 3.4 % higher than those farmers who did not receive access to radio.

4. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary and Conclusions

The primary objective of this study was to analyze determinants of technical efficiency in smallholder wheat production system in south Wollo at north eastern highlands of Ethiopia. This was achieved by measuring the technical efficiency of smallholder wheat farmers and identifying the determinants of technical efficiency. The results obtained from the stochastic frontier estimation showed that inefficiency was present in wheat production among smallholders. Sufficient evidence of positive relationship between wheat productivity and higher use of intermediate inputs such as fertilizer, seed and land utilization were practiced. The results of efficiency analysis showed that smallholder farmers could improve their efficiency by operating closer to production frontier. Thus, there existed considerable scope to expand output and also productivity by decreasing the average yield gap which was estimated to be around 330 kg/ha if inputs were efficiently utilized. Moreover, for 21% of less efficient sample respondent working towards the improvement of efficiency could increase the yield by more than 50%. At district level, working towards improving the efficiency of the farmers could bring additional gross output of 60 qt of wheat given 22.44 ha of total land area allocated for wheat production for sample household during the study period.

The above mentioned amount of output and efficiency of wheat production could be obtained significantly by paying more attention to the determinants of technical efficiency. Some of the areas which demand more attention where timely providing improved wheat seed and encouraging farmers to use recommended management practices. In addition technical inefficiency decreased (i.e. efficiency increased) with the increased in education on wheat production packages. Thus, it was needed in a priority basis to invest in public education to explore and develop human resources for the farm operation and intensifying training in wheat extension packages. Moreover, the average technical efficiency of wheat production in the study area was 79 percent indicating a good potential for increasing wheat output by 21 percent with the existing technology and levels of inputsThe socio-economic variables that exercised important role for variations in technical efficiency were age, education, farm size, livestock holding in TLU, number of oxen holding, access to irrigation and access to credit. Nevertheless, participation on off farm income, and interaction of off farm income and education was found to decrease efficiency significantly among farm household

In general, the existence of inefficiency level in wheat production and identification of inefficiency variables had important policy implications in improving the productivity in the study area. Thus, integrated development efforts that will improve the existing level of input use and policy measures towards decreasing the existing level of inefficiency will have paramount importance in improving the food security in the study area. Therefore, innovative institutional arrangement, education and farmers training accompanied with more access to fertilizer and improved seed were likely to enhance production efficiency in the study area. Access to irrigation through small and large scale irrigation must be ensured to increase productivity and hence reduce and then alleviate poverty in the region. This would help to adapt to the increasing climate change the country is facing. People are poor due to shortage of resources or inability to use them. Therefore, farm household asset formation and provision of institutional services should be given priority. Such actions may, in turn, alleviate the current problem of food insecurity and lead in the long run to economic development.

4.2 Recommendations

Based on the above results, the followings recommendations are made:

1. Designing policy which encourages the experience sharing among farmers with regard to utilization of intermediate input would help to improve wheat productivity. Nevertheless the attention of policy makers to mitigate the existing level of low wheat productivity and poverty should not stick only to the introduction and dissemination of inputs (esp. fertilizer). Side by side equitable attention has to be given towards improving the existing level of efficiency at least by sharing best practices among farmers through field days and on farm demonstration.
2. More efforts should be intensified on by Agricultural offices in training and encouraging farmers to use improved agronomic practices throughout the study area.

3. There should be timely supply of fertilizer and quality improved seed to improve farmers' efficiency in production of wheat.
4. Strengthening the existing extension services delivered to farmers specific efforts should be made to train and monitor farm household with regard to improved wheat management practices.

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