academicJournals

Vol. 8(29), pp. 3930-3940, 1 August, 2013
DOI: 10.5897/AJAR12.2189
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Source of technical inefficiency of smallholder wheat farmers in selected waterlogged areas of Ethiopia: A translog production function approach

Mesay Yami[1]*, Tesafye Solomon[1], Bedada Begna[1], Fekadu Fufa[2], Tolesa Alemu[1] and Dawit Alemu[3]

[1]Wheat Regional Center of Excellence (WRCoE), Ethiopian Institute of Agricultural Research (EIAR), P. O. Box 2003, Addis Ababa, Ethiopia.
[2]The World Vegetable Center Regional Center for Africa, P. O. Box 10, Duluti-Arusha Tanzania.
[3]Ethiopian Institute of Agricultural Research (EIAR), P.O. Box 2003, Addis Ababa, Ethiopia.

Accepted 14 June, 2013

This study was undertaken to investigate the technical inefficiency and factors affecting efficiency of wheat production in water-logged areas of Arsi-robe and Digelu-tijo districts of Arsi zone in southeastern Oromia region, Ethiopia. Both purposive and two-stage sampling techniques were used. Primary data was collected from 157 randomly selected wheat producing farmers through a structured questionnaire. The translog production function analysis revealed that the mean technical efficiency of wheat producers in the study areas in the season were 55%. Given the present state of technology and input level, the result of the study suggests that there is plenty of scope to increase the output of wheat commodity by up to 45%. Education, gender, fragmentation (number of wheat plots), and access to input and output markets have negative coefficients in the inefficiency model. In addition to this, the study indicates scaling up/out of best farmers' practices in the use of recommended integrated soil, water and nutrient management practices is essential for improving the productivity of commercial wheat varieties grown under water-logged vertisols. Furthermore, sharing the benefits of improved technologies through informal education and field days in demonstration plots could be important possible interventions for obtaining maximum achievable wheat yield under the difficult growing conditions of water-logged vertisols in Ethiopia.

Key words: Technical inefficiency, stochastic frontier, production function, wheat farmers, Vertisols.

INTRODUCTION

With the rapid increase in population and urbanization, the demand for wheat production has been increasing. To meet up growing demand without importing wheat, area under wheat should be increased (Kamruzzaman and Mohammad, 2008). Ethiopia is one of the largest grain producing countries in Africa, although it is still a food insecure country and a net importer of grain, it is the second largest wheat producer in sub-Saharan Africa, after South Africa. For the crop year of 2011/2012, from the total land allocated for cereal crops, wheat stands in

*Corresponding author. E-mail: mesay44@gmail.com. Tel: +251-911791063.

fourth by covering 15.3% of the total areas preceded by Tef, maize and sorghum. Despite its potential for wheat grain production, much of the domestic wheat demand of flour mill factories is met through imports. Productivity of wheat varies from 1.7 to 2 t/ha which is relatively low as compared to the genetic potential of wheat varieties released by the research centers (CSA, 2011).

Many physiological, agronomic, socio-economic and management factors are responsible for low wheat yields in Ethiopia. Poor management is more conspicuous of all the factors. Since managerial skill and access to resources vary from region to region, productivity also varies widely across the farming regions. Moreover, biotic factors like the occurrence of yellow (stripe) rust reduce the productivity of wheat significantly.

In crop year 2010, the extended rainfall both in the short (“Belg”) and long rainy seasons (‘Meher”) all over the country created conducive environment for the outbreak of yellow rust. According to the report made by Global Agricultural Information Network, the epidemic significantly affected wheat production and reduced the annual production of wheat by -8.13% in 2010 (GAIN, 2012). Major wheat producing regions of central and southeastern part of Ethiopia including the study area of Arsi zone, were badly affected.In Ethiopia 75% of wheat is grown in the regions of Arsi, Bale, and Shoa*,* a belt stretching from just north of Addis Ababa to the southeast. The study area, Arsi zone is part of the wheat belt and considered as “wheat basket” of Ethiopia. Obviously, any improvement in the productivity of wheat in the region largely influences.

In Arsi zone, wheat productivity can be increased either by increasing the usage of appropriate and recommended inputs or through introducing improved wheat varieties. Nevertheless, besides spending precious foreign currency on wheat imports, the country also lacks infrastructural support to handle large volumes at port and in inland transport. Consequently flour mills depend heavily on small holder wheat farmer. The region has adopted improved wheat varieties as indicated by Mesay et al. (2012), more than 10 wheat varieties entered in to production (with the exclusion of recently released high yielding, rust tolerant and end use quality wheat varieties).

The next step is, improving the efficiency level of the released wheat technologies and encouraging the adoption of the recommended crop management practice at farmers’ level. According to Ishtiaq et al. (2010), there is a wide yield gap between progressive and common farmers which may be attributed to many factors like poor seed rate, weed infestation, inadequate irrigation water, improper dosage of chemical fertilizers, inappropriate use of herbicides and fungicides and less access to wheat information technology pathways like extension services contact, field days, etc. Yield difference under similar conditions necessitates analysis of factors, which may help reveal the type and magnitude of variation in causative factors. These underline the importance of knowing the efficiency level of small-scale farmers in order to design appropriate development strategies for them. Since the pioneering work of Farrell (1957), various studies have been conducted to examine the issues of productivity and technical efficiency using wheat crop data for different countries. These studies can be classified into three groups based on the methodologies used. First group applied non-frontier approach incorporating non-conventional inputs directly in the response function to see their impact on productivity (Salam, 1976; Butt, 1984; Jamison and Moock, 1984; Feder et al., 1987; Azhar, 1991; Iqbal and Azeem, 2001). The second group of studies used frontier function approach to measure technical inefficiency (Battese et al., 1993; Ahmad and Ahmad, 1998). The third group of studies including Battese et al. (1996) and Battese and Coelli (1995) criticized this two-step modeling approach on the ground that it violates one of the basic assumptions that of ‘identically independently distributed technical inefficiency effects in the stochastic frontier’. They proposed a one-stage modeling approach in which technical inefficiency effects are function of various observable factors such as age, education, access to extension services and credit, etc. Applications of this methodology can be found Battese et al. (1996), Battese and Broca (1997) and Ngwenya et al. (1997).

Likewise, different studies were also attempted to estimate the level of technical efficiency of smallholder farmers in Ethiopia (Mulat, 1989; Abrar, 1995; Assefa and Franz, 1996, Getu, 1997; Asmare, 1998; Seyoum et al., 1998; Mohammad et al., 2000; Fekadu, 2004; Temesgen and Ayalneh, 2005).

The above empirical studies in different parts of Ethiopia have indicated the existence of efficiency differentials among small-scale farmers. Efficiencies ranging from as low as 0.39 to as high as more than 0.95 were observed. Most importantly, the causes of inefficiency in these studies vary considerably. This necessitates investigation of efficiency levels and their causes in different parts of the country so as to provide information to policy makers.

The physical characteristics of Vertisols, coupled with the limited resources of small farmers, limit wheat production on these soils in Ethiopia. The productivity of wheat is low in such difficult growing conditions of water-logged vertisols in Ethiopia. To this end, it is important to investigate the causes of low productivity so as to suggest means of improvement. There has been no study undertaken in identifying the technical efficiency of smallholder wheat farmers in water-logged districts of Ethiopia.

Therefore, the present study was designed to assess how resources were efficiently used in order to increase the level of wheat output obtained from water-logged areas through estimating the level, extent and determinants of technical inefficiency of wheat production in water-logged areas of Arsi-robe and Digelu-tijo districts of Arsi zone, Ethiopia.

Table 1. Average area cultivated, yield and productivity of crops grown in the study areas.

Crops	Digalu-tijo			Arsi-robe		
	Mean area	Mean yield/t	Productivity (t/ha)	Mean (area/ha)	Mean (yield/t)	Productivity (t/ha)
Wheat	1.348	2.58	1.9	0.7	1	1.45
Teff	0.12	0.25	2.1	0.61	0.4	0.63
Field pea	0.65	0.722	1.1	0.05	0.03	0.54
Food barley	0.53	1.667	3.2	0.085	0.1	0.12
Malt barley	0.77	2.183	2.8	0.02	0.034	0.17
Faba bean	0.4	0.486	1.2	0.15	0.12	0.8
Maize	0.14	0.237	1.7	0.2	0.52	0.26
Linseed	0.5	4.7	0.9	0.1	0.04	0.4
Potato	0.27	2.237	8.3	0.001	0.006	0.6
Grass pea	0.467	0.375	0.8	0.04	0.024	0.6
Oats	0.25	0.2	0.8	0.01	0.01	0.9
Shallot	0.26	0.175	0.7	0.003	0.002	0.67

Source: Fekadu et al. (2013).

Table 2. The number of farm households selected from each PA.

District	Sampled peasant association (PA)	Sample household drawn
	Sagure-mole	18
Digelu-tijo	Mankula-negele	32
	Kechema-murkicha	30
	Total	80
	Gado-lamen	16
Arsi-robe	Meraro	26
	Sebro-chafe	35
	Total	77

Source: own computational result.

METHODOLOGY

Description of the study sites

The two districts, Digelu-tijo and Arsi-robe are mainly characterized by prolonged water storage in the Vertisols due to water-logging problem. On the bases of information obtained from the districts' agricultural office, the land in Arsi-robe district has Vertisol, Daro and Reddish brown with the proportion of 68, 22 and 10%, respectively. The soil type of Digelu-tijo comprises of Vertisol (35%), Daro (21%) and Reddish brown (44%), respectively.

Wheat production status

In both study districts, farmers cultivated various wheat varieties, malt and food barley, tef, highland maize, pulses and vegetable crops (Table 1). Based on average cultivated area allocated for different crops and their yield, wheat was the major cereal crop cultivated in the two districts on average household allotted 1.02 ha of land for wheat cultivation (46% of the total cultivated land for the 2010 cropping season) with mean productivity of 1.66 t/ha followed by tef (0.6 ha), field pea (0.37 ha), food barley (0.3 ha) and malt barley (0.27 ha) (Fekadu et al., 2013). The low productivity of wheat was the combined result of water-logging problem and high incidence of yellow or striped stem rust which reduced the productivity of wheat significantly in that particular year.

Sampling procedure

Purposive and two-stage sampling techniques were employed for this study. Based on the presence and severity of water-logging problem Digelu-tijo and Arsi-robe districts were purposively selected from among 41 Eastern Africa Agricultural Productivity Program (EAAPP) districts in Ethiopia. From the purposively selected districts, three peasant associations (PAs) were randomly selected from each district (Table 2), and accordingly, six PAs were selected and used for the survey. At the final stage of sampling procedure, lists of Head of Household Heads (HHH) with in a PA was made and total of 157 farm households were selected by simple random sampling technique with Probability Proportional to Size Sampling techniques (PPS).

Data types and collection methods

The data used for this study were collected from both primary and secondary sources. Primary data pertaining to demographic and socio-economic characteristics, agricultural inputs and outputs of wheat were collected from sampled farm households using structured questionnaire. Close field supervision of the process of the data collection and on spot checking and correction of major mistakes in data- recording have been made. Primary data collection was done during May and June 2011 by the researcher of Kulumsa Agricultural Research Centre. To supplement the primary data secondary data were also gathered from concerned Zonal and district Bureaus of Agriculture and Rural Development and from published data (CSA, 2011; Assefa and Franz, 1996; Mohammad et al*.,* 2000; Temesgen and Ayalneh, 2005; Kamruzzaman and Mohammad, 2008).

Input variables

The variables used for the estimation of frontier model are selected based on observing the farming system tradition of the areas and through review from previous works on wheat efficiency studies. A total of 4 input variables were used for estimation of the frontier production function which includes land allocated for wheat (ha), cost of wheat seed, cost of agro-chemicals, and cost of traction power. Cost of wheat seed is a composite of the costs which farmers incurred either for purchasing local or improved wheat varieties, since farmers in some cases obtain wheat seed from research centers and Ministry of Agriculture (MoA)on revolving basis for demonstration and pre-scaling up activities, so in this case opportunity costs have been used to estimate the seed cost.

Cost of agro-chemicals include costs of fertilizer for DAP and Urea application during planting time as well as fertilizer used for top dressing. Cost of herbicides and fungicides is also included in agro-chemicals. Similarly traction power cost includes cost of hiring tractor and oxen power. Nine socio-economic variables (family labor[1] (man-equivalent), age, sex, education status, livestock ownership (TLU), fragmentation, ownership of farm equipment, access to input and output market facilities) were assumed to influence wheat productivity.

Family labor was converted into man-equivalent as used by Storck et al. (1997), whereas, livestock is a proxy for wealth status in rural farm household and was measured using the Tropical Livestock Unit conversion factors (where 1TLU = 250 kg). In some cases depending on the profitability and number of quality improved breeds ownership, livestock enterprises compete with the crop enterprises and have a positive effect on the crop production. But in the study areas crop production is the major source of livelihood. Fragmentation stands for total number of wheat plots that has been managed by the farm households. In the study areas, some farmers have many plots of wheat fields for one crop production based on the fertility status of the plots as well as the characteristics or responsive nature of the wheat varieties for different farm lands. Education level of the household head was incorporated as a dummy variable representing the household as literate and illiterate.

Modeling inefficiency effects in the stochastic frontier

In micro-economic theory, production technology is represented by a production function that defines the maximum possible attainable output from a different combination of inputs. Therefore, the production function describes a frontier. If the production frontier is known, the efficiency of any particular farm can be assessed easily by computing the position of the farm relative to the frontier (Getu et al., 1998).

A number of methods have been developed for the empirical measurement of frontier production function. These methods can be grouped in to deterministic and stochastic approaches. In the case of the deterministic frontier functions, all firms share a common family of production frontiers, and all variations in firms' performance are attributed to variations in firms' efficiencies relative to the common family of frontiers. The notion of a deterministic frontier shared by all firms ignores the possibility that a firm's performance may be affected by factors entirely outside its control (such as a bad weather, input supply breakdowns, *etc.*) as well as by factors under its control (that is, technical inefficiency).

The stochastic frontier production function, which was described by Aigner et al. (1977), and Meeusen and Broeck (1977), decomposes the error term into two components. A systematic component permits random variation of the frontier across firms, and captures the effects of measurement errors, caused from outside the firms' control, random shocks and other statistical 'noise'. A one sided component captures the effects of inefficiency relative to the stochastic frontier.

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. However, the work by Kopp and Smith (1980), Taylor et al. (1986), Krishina and Sohota (1991), and Banik (1994), confirmed that if the interest rests in technical efficiency measurement and not in the analysis of general structure of the production function, then the functional form will have a very small impact on the measurement of efficiency. In order to identify the specific functional forms which will fit with our data, generalized likelihood ratio test[2] was used.

In the agricultural economics literature, the stochastic frontier (econometric) approach has generally been preferred. The assumption that all deviations from the frontier are associated with inefficiency, as assumed in deterministic frontier approach (Data Envelopment Analysis (DEA)), is difficult to accept, given the inherent variability of agricultural production, due to weather, fires, pests, diseases, *etc.* Furthermore, because many farmers are smallholders in whose farm operations are managed by family members, therefore keeping of accurate records is not always a priority. Thus much available data on production are likely to be subject to measurement errors (Tim and George, 1996). There have been many applications of frontier production function to agricultural studies over the years. For example, Getu et al. (1998), Mohammad et al. (2000), Temesgen and Ayalneh (2005) in Ethiopia, and Kamruzzaman and Mohammad (2008) in India, among others used stochastic frontier models to estimate technical efficiency of farms. Similarly, this study used the parametric approach of the stochastic frontier production function to incorporate the uncertain nature of agriculture, especially in developing countries.

Following Aigner et al.(1977), and Meeusen and Broeck (1977), the stochastic frontier production function for wheat production in Arsi-robe and Digelu-tijo districts with two error terms can be modeled as:

$$\ln Y_i = \beta_o + \sum_{j=1}^{4} \beta_{jk} \ln x_{ij} + \sum_{j \le k=1}^{4} \beta_{jk} \ln x_{ij} \ln x_{ik} + (\nu_i - \upsilon_i) \quad (1)$$

Where the subscript, *I* indicates the *i*-th farmer in the sample (*i*= 1, 2, ..., 157), *Y,* represents amount of wheat produced in (kg); X_1 represents size of wheat farm land on which wheat was grown (ha);

[1]The farm operations were aggregated in to pre-harvest, harvest and post-harvest operations independently. The pre-harvest labor including labor utilization for land preparations and weeding have an impact on wheat yield. However, labor utilization for harvest and post-harvest operations have not as such an impact on wheat yield. Since the study sites are relatively mechanized, farmers have long tradition of using tractor for field operations and also replaced the use of family labor for weeding by using herbicide applications. To this end, family labor was excluded as determinant of wheat output in the stochastic frontier production function.

[2]LR = -2 $[\ln(L(H_0)/L(H_1)] \sim \chi^2_{(n)}$, where, $L(H_0)$, is the likelihood value for the restricted estimate, $L(H_1)$, likelihood value for the unrestricted estimate, n is the number of restrictions imposed by the null hypothesis.

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

Continuous variable	Unit	Mean	Minimum	Maximum	Standard error
Yield	kg	1557	0.01	9300	153
Wheat land	ha	1.029	0.01	5	0.07
Wheat seed cost	Birr	1013	3.75	5230	75.6
Agrochemical costs	Birr	2233	0.01	5092	1003
Oxen and tractor cost	Birr	1050	0.01	7200	93.5
Labor	Man-equivalent	3.9	0.6	9.8	0.14
Age	Years	43.6	20	76	1
Livestock ownership	TLU	6.9	0.01	18.33	0.32
Fragmentation	Number of plots	4.65	1	12	0.18
Farm equipment	Birr	936	50	8060	93
Categorical variable	**Labels**	**Frequency**		**Percent**	
Education	Illiterate	31		19.6	
	literate	126		79.7	
Gender	Male=0	142		90.4	
	Female=1	15		9.6	
Access to output	Yes=1	148		94.3	
	No=0	9		5.7	
Access to input	Yes=1	27		13	
	No=0	130		83	

Source: Own computational result.

X_2 is agro-chemicals cost (fertilizer cost for planting, top dressing and chemical application) (ETB/ha); X_3 is total traction cost (oxen and tractor); X_4 is total seed cost (local, improved and seed used as demonstration and pre-scaling up activities) (ETB/ha); In is natural logarithm (that is, logarithm to base e); $\ln X_{ij} \ln X_{ik}$i includes the squares and interaction terms of the input variables; β_j's are unknown parameters to be estimated; v_i's are symmetric component of the error term and assumed to be independent and identically distributed having $N(0, \sigma^2_v)$ – distribution; the u_i's are the inefficiency component of the error term, which are assumed to be independently distributed such that u_i is defined by truncation (at zero) of the normal distribution with mean μ_i and variance σ^2 (Temesgen and Ayalneh, 2005), where μ_i is defined by:

$$\mu_i = \delta_0 + \sum_{j=1}^{9} \delta_j Z_{ji} + W_i \quad (2)$$

Where, δ_j is parameter to be estimated; Z_1, family size of the household (Man-equivalent); Z_2- livestock holding of the household (TLU), Z_3, is dummy variable for education (0 illiterate and 1 literate); Z_4, Age of the household head; Z_5, Fragementation (number of wheat plots used); Z_6, value of ownership of farm equipment in terms of monetary value; Z_7, is dummy variable for sex (0 if male and 1 female); Z_8- is dummy variable for access to input market facilities (0 if no and 1 yes); Z_9, is dummy variable for access to output market facilities (0 if no and 1 yes) To estimate the frontier production function it must be estimated from a sample of observed yield of each farm which is the 'best practice' farm. It is therefore indicates the maximum potential output for a given set of inputs, x_i which can be expressed as:

$$Y^* = f(X_i;\beta).\exp(v_i) \quad (3)$$

Each farm's performance is then compared with the estimated frontier. the purpose of estimating the frontier is to estimate the level of technical efficiency of each observation that is given by;

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i;\beta).\exp(v_i - u_i)}{f(X_i;\beta).\exp(v_i)} = \exp(-u_i) \quad (4)$$

Where exp ($-u_i$) lies between zero and one and is inversely related to the level of the technical inefficiency effect. The parameters of the stochastic frontier production function model were estimated by the method of maximum likelihood, using the computer program FRONTIER Version 4.1 (Coelli et al., 1998).

The variance parameters were also estimated in terms of $\delta^2 = \delta_u^2 + \delta_v^2$ and $\gamma = \delta_u^2 / \delta^2$. The γ parameters have the value between 0 and 1. The discrepancy parameter γ is an indicator of the relative variability of the two error terms (δ_u^2 and δ_v^2). If γ approaches to zero, it implies that the random effect dominates the variation between the frontier output level and the actually obtained output level. Conversely, as γ approaches to one, it can be assumed that the variations in outputs are determined by technical inefficiencies (Abate and Kebebew, 2011).

RESULTS AND DISCUSSION

Descriptive statistics

The summary of the descriptive statistics related to the variables used for the analysis is presented in Table 3. The result indicates that wheat productivity in the study areas were 1.56 t/ha and which was relatively lower than the national average productivity of 2.29 t/ha (CSA, 2011). Farmers in the study areas on average incurred ETH/ha for agro-chemicals, and 1050 ETH/ha for oxen and tractor cost, respectively.

Table 4. Hypothesis tests for model specification and statistical assumptions.

Item and *H*0	Likelihood ratio test (LR)	Mixture $\chi 2$ (0.05) Critical value	Degrees of freedom	Decision
Testing the null hypothesis that the translog SFPF can be reduced to a Cobb-Douglas SFPF				
H_0; βij= 0	34.72	18.31	10	Reject *H*0
Testing the null hypothesis that the distribution of inefficiency can be reduced from truncated normal to half normal distribution μ=0				
H_0; μ=0	*20.3*	3.84	*1*	Reject *H*0
The null hypothesis that technical inefficiency effects are not in the model (H0: γ = 0)				
H_0; $\gamma = \delta 0 = \delta 1 = \delta 2 = \delta 3 = \delta 4 = \delta 5 = \delta 6 = \delta 7 = \delta 8 = \delta 9 = 0$	173.74	*19.045*[4]	*11*	Reject *H*0

Source: Own computations.

Estimates of stochastic frontier production function

In order to select the model that best fits the data, likelihood ratio test was conducted. The test results rejected the null hypothesis of Cobb-Douglas at 5% level of significance, which means the Translog Stochastic Frontier Production Function (SFPF) is more suitable to the wheat farmers' survey data in the study areas (Table 4). Hence, this study uses the translog SFPF specification to derive for the conclusion. Testing the null hypothesis that the distribution of inefficiency can be reduced from truncated normal to half normal distribution μ=0. As Table 4 shows the null hypothesis (H_0: μ = 0) that the half normal distribution of the inefficiency effect with is rejected. This implies the distribution of the inefficiency term is truncated (at zero) normal distribution which are significant at 5%. The other hypothesis test conducted was the existence of the inefficiency factor. The null hypothesis was that technical inefficiency effects are not in the model (H0: γ = 0), ($H0$: $H0$: $\gamma = \delta 0 = \delta 1 = \delta 2 = \delta 3 = \delta 4 = \delta 5 = \delta 6 = \delta 7 = \delta 8 = \delta 9 = 0$) (all wheat producer farmers in both study sites were efficient) was tested against the alternative hypothesis that inefficiency factors were in the model ($H1$: $\gamma > 0$ and $\delta i \neq 0$ for i=0,1,2,..,9). The likelihood ratio test also rejected the null hypothesis H_0 at 5% level of significance. This implies the existence of inefficiency in the study areas and the traditional average response function was not an adequate representation of the data.

Parameter estimates

Table 6, shows the maximum likelihood estimates of the parameters in the translog stochastic frontier and inefficiency model for the wheat producer farmers of the study sites. In the frontier model the coefficient of wheat land was significant and positive, implying that an increase in land allocation for wheat would increase the wheat output. The coefficient of wheat seed cost was negative and significant at 5%, indicating that the availability of the required wheat seed at affordable price for farmers would increase wheat production. Therefore, the wider scale expansion of the current integration of the formal and informal seed exchange system of seed distribution by research center for demonstration and pre-scaling up activities needs to be continued for serving the smallholder seed demands. This needs to be complemented by enhancing the multiplier effects of improved seed beneficiaries using revolving seed model for reaching pro-poor smallholder farmers.

The coefficient of interaction between wheat land and agro-chemical costs was positive and significant. A plausible explanation for the positive interaction between wheat production and agro-chemical costs is these two inputs have a complementary relationship. To this end, by keeping other factors constant, an increase in both land allocation for wheat and agro-chemical costs, increases the wheat yield. Based on this result, the combined increase applications of agro-chemical and land allocation for wheat were substantially contributed to the increment of wheat yield. However, the increased application of inorganic fertilizer at this changing environment will cause negative yield for wheat production, this is because as rainfall diverges from the optimum level (both upward and downward), increased application of fertilizer will burn the crop and have a negative consequence on the output of the crop. According to Kassahun (2011), when rainfall diverges from its mean; fertilizer adoption may burn seeds and increase the probability of crop failure. Therefore, increased adoption and application of integrated soil, water and nutrient management practices in wheat will also be the right step for increasing the wheat production without incurring too much cost for agro-chemical cost applications.

The Gamma (γ) was estimated to be 0.99 and statistically significant at one percent level. The ratio parameter γ^* as calculated by, $\gamma^* = \gamma/\{\gamma + [(1-\gamma)\pi/(\pi-2)]\}$ where $\gamma^* = \sigma_u^2/\sigma_\varepsilon^2$ (Coelli et al., 1998), is 0.973. This implies that farm specific technical inefficiency is important in explaining the total variability of output produced and dominates the measurement error and other random disturbances. Hence, farm productivity differentials predominantly relate to the variance in wheat management at farmers level. In other words, only the remaining portion 0.027 (that is, $1-\gamma^{*}$) is due to measurement errors, specification biases, and factors which are not controlled by farmers themselves like outbreak of diseases (yellow, stem and leaf rust), erratic rainfall, inputs supply breakdown and statistical noise.

Determinants of technical efficiency of wheat

Here, the analysis of technical efficiency, in which the objective is to identify factors which are affecting efficiency of farmers was dealt with. There are two basic approaches to account for the effects of exogenous (independent) variables. The present study employs the one-stage procedure, in which the parameters of the stochastic frontier production function and the inefficiency effects model are estimated simultaneously. This approach differs from the usual practice of predicting farm-level inefficiency effects and then regressing these upon various factors in a second- stage of modeling (Coelli and Battesse, 1996).

In estimating the inefficiency effects model, out of the nine variables used, six variables were found significantly affecting the inefficiency of wheat farmers (Table 6). The age coefficient in the inefficiency model is positive and significant at 1% which indicates that older farmers tend to be more inefficient in wheat production than younger ones. This is congruent to the findings of Ahmad et al. (2002), Coelli and Battese (1996), they asserted that older farmers are likely to be more conservative and hesitant to adopt new innovations and evade frequent experimentation with the new technologies.

The parameter estimates of the education dummy variables carry negative signs and are statistically significant at 5% significance level. This result very clearly demonstrates that the farmers' education emerges as an important factor in enhancing agricultural productivity. This finding is in line with empirical findings of Getu et al. (1998), Mohammed et al. (2000), Ahmad et al. (2002), Khairo and Battese (2005) and Kamruzzaman and Mohammad (2008), while Hussain (1989) found no association between education and wheat farm inefficiency. Educated farmers usually have better access to information about prices, and the state of technology and its use. Better-educated people also have higher tendency to adopt and use modern inputs more optimally and efficiently (Ghura and Just, 1992). It is more likely that the farmers with higher educational status are more perceptive to agriculture expert advice.

The coefficient estimated for gender dummy is significantly negative at 1% significance level, which was not as expected, indicating that Female Headed Households (FHH) operates more efficiently than their Male Headed Households (MHH). This result is in line with study by Oladeebo and Fajuyigbe (2007) in Nigeria and it is in contrast with Omumah et al. (2010) in Ghana. In Arsi zone one of the prime constraints for low productivity of wheat is the existence of grass weeds (especially *Bromus pectinatus*). FHH due to the small size of their farm plots as well as financial constraints they usually use hand weeding which was relatively more efficient compared to herbicides application by MHH. Due to lack of knowhow and high cost of herbicides, farmers tend to apply fewer amounts of herbicides below the recommended rate which in turn reduce the effectiveness. For instance 1 L of Palace Herbicides costs farmers as high as ETB 3000, as result of this farmers apply ½ liter/ha which is below the required level 1 L/ha.

As expected the number of wheat plot used (fragmentation) is appearing on the inefficiency model at the hypothesized negative sign and significant at 1% significance level, stating that those farmers who do have a large number of wheat plot have the chance to allocate suitable and fertile wheat plot for the different wheat varieties based on the characteristics or responsive nature of the wheat varieties for different farm lands. For instance 'Digelu' wheat variety relatively requires fertile wheat plot for high wheat production. If you grow this wheat variety in less fertile wheat farm it will have shorter spike length and consequently lower wheat yield and straw quality. However, 'K 6295-4A' wheat variety is red head and red seed color wheat variety is suitable to grow in some difficult wheat growing farm plots like water-logging areas. Therefore, the larger fragmented wheat plot you have the higher likelihood of allocating different wheat plots for different wheat varieties that have different responsive natures, which is most likely increases the efficiency of wheat production.

The mean comparison in Table 5 indicate that farmers operating a large number of wheat plots, greater than 7 scored an average efficiency level of 0.61 while farmers with less than 7 plots scored an average efficiency of 0.54. The difference is significant at 10%. In the study area at particular and in Ethiopia in general, increment of wheat production through land expansion is limited; hence to increase their farm land, farmers needs to acquire multiple plots of land through sharing and renting. However, this result is incongruent to what Fekadu (2004) found in Ethiopia. He stated that as the number of wheat plots operated by the farmer increases, it may be difficult to manage these plots. Hence, farmers that has large number of wheat plots may waste time in moving between plots.

Access to input and output markets are negative and significant in the inefficiency model which conforms to the priori expectation. It is well-established fact that access to input and output markets play a critical role in determining crop profitability, choosing appropriate production technologies and the supply of agricultural commodities (Ahmad et al., 2002; Chhibber, 1988; Ghura and Just, 1992) argue that only the price incentives are

Table 5. Mean technical efficiencies by number of plots.

Number of plot/ fragmentation	Mean technical efficiency	Standard deviation
Below 7 plots	0.54	24.1
Above and equal to 7	0.61	21.4

Source: Own computations.

Table 6. Maximum likelihood estimates of the stochastic frontier production and factors influencing inefficiency of wheat production in the study area.

Variable	Parameter	Estimated value	*t*-Statistics
Constant	β0	11.18***	6.31
In(LW)	β1	1.85*	1.76
In(WSC)	β2	-1.17**	-2.30
In(FC)	β3	0.051	0.100
In(OTC)	β4	-0.866	-1.58
[In(LW)]2	β11	-0.024	-0.171
[In(WSC)]2	β22	0.097 *	1.69
[In(FC)]2	β33	-0.003	-0.273
[In(OTC)]2	β44	0.015	1.05
In(LW)In(WSC)	β12	-0.480	-3.28
In(LW)In(FC)	β13	0.206**	2.00
In(LW)In(OTC)	β14	0.003	0.036
In(WSC)In(FC)	β23	-0.029	-0.384
In(WSC)In(OTC)	β24	0.063	0.749
In(FC) In(OTC)	β34	0.080	1.77*
Inefficiency model			
constant	δ0	-2.60**	-2.14
Labor	δ1	-0.653	-1.61
Age	δ2	0.398***	3.90
Education	δ3	-1.06**	-2.12
Gender	δ4	-3.46***	-2.89
Livestock	δ5	-0.038	-0.240
Fragmentation	δ6	-0.874***	-2.86
Access to output	δ7	-7.58***	-3.00
Access to input	δ8	-7.52***	-3.35
Farm equipment	δ9	0.0003	0.590
Sigma-squared	δ_S^2	15.41	4.29***
Gamma	γ	0.99	216.88***

*,**, *** indicate significant at 10, 5 and 1% respectively; Source: Own computations.

not adequate to boost productivity and supplies of agricultural commodities unless these measures are supplemented with continued investment in rural infrastructure (that is, markets, roads and financial institutions (input providers like fertilizer, seed, credit etc.). The results of our study strongly supportive of these arguments and call for attention of the policy-makers and the planners to give top priority to strengthening of rural and agricultural input and output marketing institutions in order to enhance agricultural productivity. The coefficients of family labor and livestock variables are not significant although they have the expected signs.

Range of technical efficiency

The mean technical efficiency of wheat farms was found to be 0.55, indicating that farmers were only producing 55% of their maximum possible wheat output level given the state of the technology at their disposal. The wheat

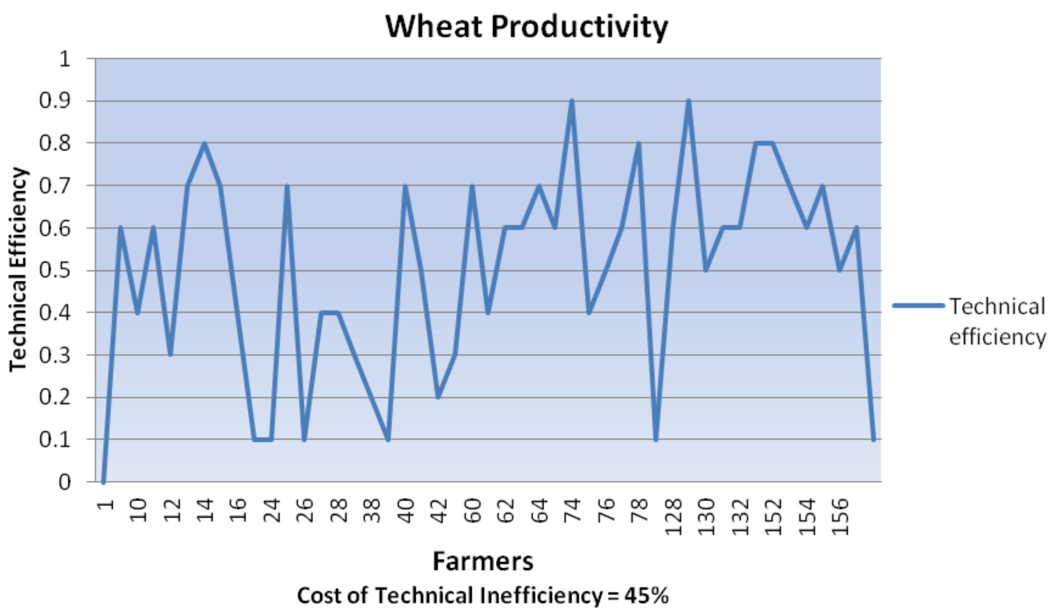

Figure 1. Range and cost of technical inefficiencies.

efficiency level ranges from as low as 1% to as high as 93%, showing a wider difference in the individual farms' efficiency level. In other words the cost accrued to the wheat farmers due to the existence of technical inefficiencies is huge ranging from 99 to 7% in terms of loss in wheat output (Figure 1). More than 50% of the farmers have less than 50% of technical efficiency. Many studies in Ethiopia have indicated low level of technical efficiency for smallholders (Getu, 1997; Mohammed et al., 2000; Fekadu, 2004; Temesgen and Ayalneh, 2005).

CONCLUSION AND POLICY IMPLICATIONS

The study uses the farm-level survey data from 157 wheat producer farm households and estimates the SFPF incorporating inefficiency effects. This study finds that the SFPF fits the 2010 wheat farm data better than the Cobb–Douglas frontier production function. Besides, the traditional average response function is not an adequate representation of the data. The results of efficiency analysis show that the average technical efficiency was about 55% and thus an average farmer was producing 45% less than the achievable potential wheat output.

The most important policy implications drawn from this study include access to input and output market has a positive effect on efficient wheat production thereby integration of improved wheat production with the input and output market plays a significant role in enhancing the technical efficiency of wheat producer farmers. Thus provision of input (improved seeds, fertilizer, pesticides herbicides and fungicides) and output market facilities raises farmers' wheat production efficiency level. Furthermore, scaling up/out of those efficient farmers' experience via training and field demonstrations will raise farmers' awareness in the adoption of integrated soil, water and nutrient management practices contributing positively towards efficient wheat production.

Older farmers with less education can increase their productivity if they can acquire the skill from educated farmers, and this may be accomplished through arranging farmers' field days, informal education, field visits and demonstration by extension staff could be the right steps in this direction. The study finally recommends further empirical work to be conducted on comparison analysis of farm household heads between female and male managed wheat farms using a large sample observation to capture clearly gender differential effects on efficiency.

ACKNOWLEDGEMENT

Special gratitude goes to Eastern Africa Agricultural Productivity Program (EAAPP) for the financial support of this study. We also acknowledge the then technical team of EAAPP, Dr. Fekadu Fufa and Dr. Dawit Alemu (Agri-economics, extension and farmers linkage directorate of Ethiopian Institute of Agricultural Research) for their technical comments on the output of the studies and socio-economic and extension teams of Kulumsa Agricultural Research Center for their active involvement in data processing stages. Finally, our acknowledgment extends to farmers of the study sites for their patience and enthusiastic participation during the data collection.

REFERENCES

Abate B, Kebebew A (2011). Estimating profit and technical efficiency of small scale irrigation shallot farming: a case study of Godino Peasant Association in Ada district, Oromia region, Ethiopia. Ethiopian J. Cr. Sci. 2:28-36.

Abrar S (1995). Evaluating the efficiency of farmers in Ethiopia. Ethiopian J. Econ. 4(2):47-66.

Ahmad M, Ahmad AZ (1998). An analysis of the sources of wheat output growth in the Baraniarea of the Punjab. Pak. Dev. Rev. 37(3):231–249.

Ahmad M, Chaudhry GM, Iqbal M (2002). Wheat productivity, efficiency, and sustainability: a stochastic production frontier analysis. Pak. Dev. Rev. 41(4):643–663.

Aigner DJ, Knox LC, Schmidt P (1997). Formulation and estimation of stochastic models. J. Econ. 6:21-37.

Asmare H (1998). The impact of farm size on efficiency of the farmers' producers' cooperatives: the case of Harar-ZuriaAwuraja. M.Sc. Thesis, Alemaya University of Agriculture, Ethiopia.

Assefa AD, Franz H (1996). Estimation of technical efficiency of smallholders in the central highlands of Ethiopia. Ethiopia J. Agric. Econ. 1(1):15-37.

Azhar R (1991). Education and technical efficiency during the green revolution in Pakistan. Econ. Dev. Cultural Change 56:651–665.

Banik A (1994). Technical efficiency of irrigated farms in a village of Bangladesh. Ind. J. Agric. Econ. 49(1):70-78.

Battese GE, Broca SS (1997). Functional forms of stochastic frontier production functions and models for technical efficiency effects: a comparative study for wheat farmers in Pakistan. J. Prod. Anal. 8:395–414.

Battese GE, Coelli TJ (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Econ. 20:325–332.

Battese GE, Malik SJ, Broca SS (1993). Production functions for wheat farmers in selected district of Pakistan: an application of a stochastic frontier production function with time-varying inefficiency effects. Pak. Dev. Rev. 32:233–268.

Battese GE, Malik SJ, Gill MA (1996). An investigation of technical inefficiencies of production of wheat farmers in four districts of Pakistan. J. Agric. Econ. 47:37–49.

Butt MS (1984). Education and Farm Productivity in Pakistan. Pak. J. Appl. Econ. 3:65–82.

Chhibber A (1988). Raising agricultural output: price and non-price factors.Finance and Development. pp. 44-47.

Coelli TJ, Battese GE (1996). Identification of factors which influence the technical inefficiency of Indian farmers. Aust. J. Agric. Econ. 40:103-128.

Coelli TJ, Rao DS, Battese GE (1998). An introduction to efficiency and productivity analysis.Kluwer Academic Publishers, Boston. pp. 134-249.

CSA (2011). Agricultural sample survey report on area and production of major crops (private peasant holdings, meher season) 2011 / 2012, Vol. 2. Central Statistical Agency, Addis Ababa.

Farrell MJ (1957). The measurement of productive efficiency. J. Roy. Stat. Society. 120:253-290.

Feder GL, Lau J, Slade RH (1987). Does agricultural extension pay? The training and visit system in northwest India. Am. J. Agric. Econ. 69:677–686.

Fekadu F, Bedada B, Mekonnen M, Workiye T, Mesay Y, Firdissa E, Karta K, Solomon G, Bedada G (2013). Exploring existing wheat technologies and speeding-up transfer to farmers: experience of EAAPP-wheat commodity. Wheat for food security in Africa: science and policy dialogue about the future of wheat in Africa 1:28.

Fekadu GM (2004). Analysis of technical efficiency of wheat Production: a study in Machakeld district, Ethiopia. M.Sc. Thesis, Alemaya University of Agriculture, Ethiopia.

GAIN (2012). Ethiopia grain and feed annual report. Global Agricultural Information Network, Addis Ababa.

Getu H (1997). Analysis of performance variations: the case of smallholder farms in Eastern Hararghe region. M.Sc. Thesis, Alemaya University of Agriculture, Ethiopia.

Getu H, Vera B, Belay K, Storck H (1998). Technical efficiencies of small holder annual crop production in moisture stress area of Eastern Oromia of Ethiopia: A Stochastic Frontier Analysis. Ethiopia J. Agric. Econ. 2(2):91- 113.

Ghura D, Just RE (1992). Education, infrastructure and instability in east African agriculture: implications for structural adjustment programmes. Finan. Econ. Dev. 1(1):85–105.

Hussain SS (1989). Analysis of economic efficiency in northern Pakistan: estimation, causes and policy implications. A Ph.D. Dissertation, University of Illinois at Urbana-Champaign, USA.

Iqbal M, Azeem MK (2001). Determinants of higher wheat productivity in irrigated Pakistan. Pak. Dev. Rev. 40(4):753–766.

Ishtiaq H, Muhammad BC, Tajamal HC, AnjumMA (2010). Factors affecting wheat yield: A case study of mixed cropping zone of Punjab. J. Agric. Res. 3:48-56.

Jamison DT, Moock PR (1984). Farmer education and farmer efficiency in Nepal: the role of schooling, extension service, and cognitive skills. World Dev.12:67–86.

Kamruzzaman M, Mohammad HI (2008). Technical efficiency of wheat growers in some selected sites of Dinajpur district of Bangladesh. Bang. J. Agric. Res. 33(3):363-373.

Kassahun A (2011). The impact of climate variability on crop production in Ethiopia: which crop is more vulnerable to rainfall variability? Ethiopian Economics Association.

Khairo SA, Battese GE (2005). A study of technical inefficiencies of maize farmer within and outside the new agricultural extension program in the Harari Region of Ethiopia. S. Afr. J. Agric. Ext. 34(1).

Kopp RJ, Smith VK (1980). Frontier production function estimates from steam electric generation: A comparative Analysis. S. Econ. J. 47:1049-1059.

Krishina KL, Sohota GS (1991). Technical efficiency in Bangladesh manufacturing industries. Bang. Dev. Stu.19 (1&2):89-105.

Meeusen W, Broeck JV (1977). Efficiency estimation from Cobb-Douglas production function with composed error. Int. Eco. Rev.18:435-444.

Mesay Y, Fekadu F, Terefe F, Sultan U (2012). Prospects and challenges of wheat production in Ethiopia: Evidence from major wheat producing regions of the country. Wheat for Food Security in Africa: Science and Policy Dialogue about the Future of Wheat in Africa 1:49-51.

Mohammad H, Farah H, Mwangi W, Belay K (2000). Factors influencing technical efficiency of barely production in Asassa district of southern Ethiopia. Ethiopia J. Agric. Econ. 4 (2):1-22.

Mulat D (1989). The production efficiency of food grain producers in Ethiopia: the case of small farmers in Arsi province, PhD. Dissertation, department of Economics, University of Strathclyde.

Ngwenya SA, Battese GE, Fleming EM (1997). The relationship between farm size and the technical inefficiency of production of wheat farmers in Eastern free state, South Africa. Agrekon 36:283–301.

Oladeebo JO, Fajuyigbe AA (2007). Technical efficiency of men and women upland rice farmers in Osun State, Nigeria. J. Hum. Ecol. 22(2):93-100.

Omumah E, Bummer B, Horstgen SG (2010). Elements which delimitate technical efficiency of fish farms in Ghana: J. W. Aqua. Soc. 41(4):506-518.

Salam A (1976). Resource productivity in the Punjab's agriculture.The Pak. Dev. Rev. 15:115–133.

Seyoum ET, Battese GE, Fleming EM (1998). Technical efficiency and productivity of maize producers in Eastern Ethiopia: A study of farmers within and outside the Sasakawa-Global- 2000 project. Agric. Econ. 19:341-348.

Storck H, Berhanu A, Bezabih E, Begander R, Getu H (1997). Management strategies for farming systems in uncertain environment and approaches for their improvement, Farming systems and resource Economics in the Tropics. 11. Wissenschafts.

Taylor TG, Drummond HE, Gomes AT (1986). Agricultural credit programs and production efficiency: analysis of traditional farming in South Eastern Minas Gerais, Brazil. Am. J. Agric. Econ. 68(1):110-119.

Temesgen B, Ayalneh B (2005). Technical efficiency of resource use in the production of irrigated potato: a study of farmers using modern and traditional irrigation schemes in Awi Zone, Ethiopia. J. Agric. R.

Dev. Trop. Sub-trop. 106:59–70.
Tim C, George B (1996). Identification of factors which influence the technical inefficiency of Indian farmers. Aus. J. Agric. Econ. 40(2):103-128.