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Allocative Efficiency and Profitability of Smallholder Wheat Producers in South Eastern Ethiopia: Stochastic Frontier Approach

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Abstract
This study was carried out in major wheat producing agro-ecologies of Ethiopia to measure the level of allocative efficiency and profitability of smallholders in wheat production. Cross-sectional data were collected from 381 randomly selected farm households. Descriptive and inferential statistics and Stochastic Frontier Cobb-Douglas cost function were employed to achieve the objectives of the study. The results reveal that elasticities of total cost of production due to changes in prices of improved seed, pesticides, and wheat output are statistically significant in the lowland. In midland, changes in prices of chemical fertilizers, improved seed, pesticides and output have significant effects on the proportionate change in total cost of production. Increased total cost of production is associated with increased profitability. The average allocative efficiency estimates for the lowland, midland and highland agro-ecologies were 89, 88 and 87 percents, respectively. Relatively, smallholders are more profitable in midland agro-ecology with average profit of 8,039.89 ETB/ha. The profitability of smallholders is the lowest in the lowland (1,083.91 ETB/ha). Increases in the supply (availability) and utilization of improved seeds, chemical fertilizers and pesticides with fair prices increase the profitability of smallholders in wheat production.
Keywords: Allocative efficiency, Profitability, Stochastic Frontier, Wheat in Ethiopia

1. INTRODUCTION

Agriculture is the foundation of rural development and economic growth in developing countries; and it returned to the forefront of development issues because of the impacts of agricultural productivity change on economic growth and poverty reduction (Headey *et al*., 2010). Food crops productivity change is an important issue for most low income countries to ensure food security and reduce poverty more than growth driven by agricultural exports (Diao *et al*., 2006).

Accounting for a fifth of humanity's food, wheat is se*cond only to* rice as a source of calories in the diets of developing country consumers, and it is first as a source of protein (Braun *et al*., 2010). If population growth continues at double the growth of wheat production, there will likely be serious difficulties in maintaining a wheat food supply for future generations (Dixon *et al*., 2009; CIMMYT, 2012). Given that wheat is such a prominent cereal in many developing regions, it is of critical importance to identify ways to enhance wheat productivity growth. However, increasing productivity requires adoption of improved agricultural technologies and efficient utilization of farm inputs (Dorosh and Rashid, 2013).

In Ethiopia, wheat is one of the major food crops. It is the fourth important cereal crop with annual production of about 3.43 million tons produced on area of 1.63 million hectares (CSA, 2013). The low productivity has made the country unable to meet the high demand and it remains net importer of wheat despite its huge potential to produce it (Rashid, 2010). The major challenges facing wheat production are low production and productivity, low use and unavailability of improved farm inputs, increasing and unaffordable input prices and dependency on traditional farming and rainfall.

Therefore, if the country is to feed the rapidly growing population and meet the high demand, it needs to increase the production, productivity and profitability of wheat in major wheat producing areas. One of the options for improving productivity and profitability is through efficient utilization of farm inputs. Efficient production is the basis for achieving overall food security and poverty reduction. Hence, identification of the level of allocative efficiency and profitability in wheat production is essential for targeted decisions on agricultural policy and extension activities of farm input utilization.

Several studies have been conducted on technical efficiencies of smallholders production of wheat in different areas of the country. However, most studies (for example, Kaleab and Brehanu, 2011; Mesay et al., 2013) show technical inefficiency of farmers in wheat production and factors influencing the technical efficiency in production. Documented empirical study is limited on comparative analysis of allocative efficiency and profitability of smallholder wheat producers in selected lowland, midland and highland agro-ecologies of the study area. Therefore, this study estimates allocative efficiency and profitability of wheat producers in major wheat producing agro-ecologies using descriptive statistics, Stochastic Frontier Cobb-Douglas Cost Function and cross-sectional survey data collected from randomly selected 381 farm households. The results of the study helps agricultural extension offices, farmers and other stakeholders to have evidence based information for making decisions in wheat production in each agro-ecology.

2. MATERIALS and METHODS

2.1 The Study Area

The study area, Arsi zone, is found in south eastern Ethiopia. It is located in the central part of Oromia National Regional State. According to Oromia Regional State Bureau of Finance and Economic Development report of 2010, the zone astronomically lies between 7^0 08' 58'' N to 8^0 49' 00'' N latitude and 38^0 41' 55'' E to 40^0 43' 56'' E longitude. Arsi Zone is divided into five agro-climatic zones mainly due to variation in altitude. It is dominantly characterized by moderately cool (about 40 percent) followed by cool (about 34 percent) annual weather. The mean annual temperature of the zone is found between 20-25^{0}c in the low land and 10-15^{0}c in the central highland. About 74 percent of zonal land area falls in moderately cool to cool temperature within the altitude range of 1,500 to 3,200 meters above sea level.

On average, the zone gets a monthly mean rainfall of 85 mm and an annual mean rainfall of 1020 mm (www.oromiabofed.org). These characteristics make the zone good potential for production of various agricultural crops. In addition to wheat, the major cereal crops grown in the zone are barley, maize, teff and sorghum. However, the contribution of wheat to annual total cereal output is the highest (45%) followed by barley (20%). It also accounts for 42% of the total cereal area cultivated in 2012/13 (CSA, 2013).

2.2. Sampling Technique

A combination of purposive and probability sampling procedures were used for sample selection. In the first case, south eastern Ethiopia which is a high potential wheat producer was purposively selected. For sample districts selection, the criteria used were wheat production potential in respective agro-ecology; strong research and extension intervention programs embracing wheat producers; adoption of newly released improved wheat varieties for high, mid and lowland agro-ecologies that were distributed by district agricultural offices and Kulumsa Agricultural Research Center; and better extension activities involving various agronomic practices in the districts. From separate lists of districts of lowland, midland and highland agro-ecologies, one district was randomly selected, and the total selected districts were three. The three districts selected were Lemu-Bilbilo from the highland, Hetosa from the midland, and Dodota from the lowland agro-ecology.

In the second stage of the probability sampling, a list of major wheat growing Farmers' Associations (*kebeles*) within the selected districts were obtained from district agricultural offices. Then, two *kebeles* were selected by simple random sampling technique. Since the purpose of a study includes comparing differences among agro-ecologies, equal number of *kebele* selection from each district is more efficient (Kothari, 2004). In the third and final stage, a list of farm households that planted wheat on their farm and harvested in 2013 cropping season was obtained from the selected *kebeles*' agricultural extension offices. Sample households were randomly selected. The sample size was determined by the formula given by Krejcie and Morgan (1970). Allocation of sample size to each district was determined proportionally to the size of wheat farm household population of each district and kebele.

2.3. Data Collection

The data for this study was collected from both primary and secondary sources. Cross-sectional data was collected from the survey of randomly selected sample farm households. Structured and pre-tested questionnaire was used to collect the primary data. Enumerators were employed and trained and the interview was conducted in 2013. Both quantitative and qualitative information were collected. The data collection included households' demographic and socioeconomic characteristics (household sizes, age and sex structures, education, etc), land holding (agricultural, grazing, wheat land, and others), farm inputs utilization (seeds, fertilizers, herbicides and fungicides, labor utilization, credit, extension services), farm outputs, input and output prices, livestock holding, income sources, etc.

2.4. Analytical Methods

The data were analyzed using descriptive (cost-benefit analysis) and inferential statistics, and econometric methods. Allocative efficiency was analyzed using Stochastic Frontier Cobb-Douglas Cost Function. For the analysis, STATA software version 11 was used by employing frontier command to estimate coefficients and post estimation predict command to predict allocative efficiency scores. Stochastic Frontier Model was introduced by Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977); and it is specified as follows:

$$Y_i = f(X_i;\ \beta) + \varepsilon \qquad (1)$$

Where Y_i is wheat output of the jth household's farm, i = (1, 2, 3,……, n) are sample household farms, X_{ij} is the i^{th} input used by the j^{th} household and β is a vector of unknown parameters and ε is composed of error term which can be written as:

$\varepsilon = v_i - u_i$, (2)

where v_i is a symmetric random error which represents random variations, or random shocks in the production of the i^{th} household, outside the control of the farmer assumed independently and identically distributed as $N(0, \sigma^2)$. The error term u_i is a one-sided non-negative variable which measures technical inefficiency of the i^{th} household, the extent to which observed output falls short of the potential output for a given technology and input levels. Allocative efficiency measures farm efficiency. To attain allocative efficiency, a household should choose the optimal combination of inputs so that output is produced at a minimal cost. To maximize profit from wheat production, farmers have to choose the best combination of inputs given the prices of inputs and output. For the present study allocative efficiency was estimated from a single output (wheat) four inputs Cobb-Douglas cost function (Equation 3). Stochastic Frontier Cobb-Duglas cost function was estimated by maximum likelihood method. The four inputs were land used for wheat production, labor utilization in production, chemical fertilizers used in production and, seed and pesticides used in wheat production.

To estimate allocative efficiency, the following Stochastic Frontier Cobb-Douglas Cost Function was used.

$$lnC_i = \beta_0 + \sum_{i=1}^{n} \beta_i \, lnx_i + v_i + u_i \quad (3)$$

Where C_i is cost of production in ETB in natural logarithm, X_i are prices of land, labor and, seed and pesticides. Wheat output is also represented in X_i. β_0 *and* β_i are parameters to be estimated. V_i and U_i are as specified earlier but with positive sign of the inefficiency term since inefficiency factors raise the cost of production. Price of land was estimated based on the rental value of land in ETB per hectare in respective study kebeles. Labor wage was estimated in ETB per day, and price of fertilizer was in ETB per kilogram. Average other input price (seed and pesticides) per kilogram was estimated based on the proportionate weight of each input in total cost of production. Before fitting the Cobb-Douglas cost function, all data on each variable were transformed into natural logarithms.

The estimation of equation (3) gives β_i. Then, β_i can be expressed as:

$$\frac{\partial lnY}{\partial lnX} = \left[\frac{\frac{1}{Y}\times\partial Y}{\frac{1}{X}\times\partial X}\right] = \left[\frac{X}{Y}\times\frac{\partial Y}{\partial X}\right] = \beta_i \quad (4)$$

Using the coefficient estimates from (4), the marginal product (MP_i) of the i^{th} factor X was calculated as:

$$MP_i = \frac{\partial Y}{\partial X_i} = \beta_i \frac{Y}{X_i} \quad (5)$$

But average product (AP) = $\frac{Y}{X_i}$

Where Y is the mean of natural logarithm of wheat output; X_i is the mean of natural logarithm of input *i;* β_i is the estimated coefficient of input *i*. The value of marginal product of input *i* (VMP*)* can be obtained by multiplying marginal physical product (MP_i) by the price of output (P_y). Thus,

$$VMP_i = MP_i \times P_y \quad (6)$$

$$\text{Allocative Efficiency (A.E)} = \frac{VMP_i}{P_i} \text{ but } P_i = \text{Marginal cost of the } i^{th} \text{ input.} \quad (7)$$

Allocative efficiency was determined by comparing the value of marginal product of input *i* (VMP_i) with the marginal factor cost (MIC_i). Since farmers were price takers in the input market, the marginal cost of input i approximates the price of the factor *i*, P_{xi}. Hence, if $VMP_i > P_{X_i}$, the input was underused and farm profit could be raised by increasing the use of this input. But, if $VMP_i < P_{X_i}$, the input was overused and to raise firm profits its use should be reduced. The point of allocative efficiency (maximum profit) is reached when $VMP_i = P_{X_i}$.

3. RESULTS and DISCUSSION

3.1. Descriptive Results

Table 2 shows average cultivated wheat area. It was almost the same (1.6ha) in lowland and midland areas. But wheat yield was different in the two areas. Yield was about 16 and 31 quintals per hectare in lowland and midland districts respectively. The average yield of midland district was almost equal to double of average yield of lowland district. However, the yield of the highland area i.e. Lemu-Bilbilo (25q/ha) was higher than the lowland (Dodota) yield (16q/ha).

Farm inputs and outputs were quantified. Prices of inputs and output were used to estimate the total costs and returns per hectare. The inputs include land, labor for various farm operations, and all other variable inputs. Table 3 presents cost of wheat production and the net returns per hectare. The average cost of wheat production ranges from ETB 6,807.89 to ETB 16,930.54 per hectare with an average of ETB 10,406.53. Average profit was ETB 1,083.89; 8,039.89 and 4,547.29 per hectare for lowland, midland and highland districts, respectively. The highest average profit was earned in midland, and the lowest profit was obtained in lowland district (Table 3). Average cost was the highest in midland and the lowest in lowland district. This indicates that more cost of production was associated with more returns or profit. Increasing farm input utilizations could increase farm profit.

Therefore, one of reasons for the disparity of returns among districts was the variations in input utilizations in wheat production. There was statistically significant difference in average profit among districts with F-value of 81.96 and p-value of 0.0000. Bartlett's test for equal variance also gave significantly different variance of profit among districts at 0.1 level of significance (Chi-square = 5.309, and prob > chi-square = 0.07).

3.2. Econometric Estimation Results

Table 4 gives the estimates of the coefficients of Cobb-Douglas stochastic frontier cost function. The wald test gives significant chi-square statistic for the three agro-ecologies or districts (Table 4) and proves the rejection of the null hypothesis that all the coefficients except the constant are equal to zero. That is, the effects of the coefficients are significantly different from zero. The maximum likelihood estimation of the coefficients of Cobb-Douglas stochastic cost function shows that the coefficients (elasticites of cost due to change in prices of inputs) of seed and pesticide, and output were statistically significant in their effects on the cost of production in lowland district. That is, proportionate change in cost of production decreases due to proportionate change in prices of seed and pesticides in lowland. It seems that households tend to use less or no of these inputs if their prices increase. In midland, except the coefficients of labor wage, all input prices of cost function were statistically significant. It was only the effect of seed and pesticides price that was negatively related to the cost of production in midland district. All other input prices had positive effects on the level of cost of wheat production. This shows that farmers reduce or avoid the use of improved seed and pesticides when their prices increase in the midland. It appears that with increasing prices of improved seed, farmers tend to use local varieties and hence its effect on cost of production is negative.

The variables indicated by sigma_v and sigima_u are the standard deviations of random variation term and the inefficiency factors, respectively. Sigma2 is the total error variance and lambda is the ratio of the variance of random variation (v) to inefficiency term (u). The mean of allocative efficiency scores (Table 5) shows that households in lowland, midland and highland districts were allocatively efficient by about 89 percent, 88 percent and 87 percent, respectively i.e. households were allocatively inefficient in all agro-ecologies.

This implies that households could increase their allocative efficiency on average by 11 to 13 percents with current technology and input price levels. Households need to reallocate and fully exploit farm inputs with their current prices to enhance allocative efficiency and the consequent profitability. One way analysis of variance was used for testing the difference of the mean of allocative efficiency scores among the districts. The test result shows significant F-value (2.73) at 10 percent level of significance (prob > F is equal to 0.095). Bartlett's test for equal variance also shows significant chi-square statistic (10.24) at 1 percent level of significance (prob > chi2 = 0.006), indicating no equal variance of the means of allocative efficiency scores among agro-ecologies.

The efficiency analysis implies that there is scope for increasing allocative efficiency with the current technology and input prices. Smallholders were allocatively inefficient in wheat production in the study areas. Improvement in efficiency is needed through increased utilization and reallocation of farm inputs based on prices for enhancing profitability. More cost of production is associated with more returns or profit. Therefore, households need to increase farm inputs utilization especially improved seed, chemical fertilizers and pesticides to increase profitability in all agro-ecologies. However, increased prices of these inputs especially prices of improved seed, chemical fertilizers and pesticides discourage the increased utilization of the inputs. Therefore measures need to be taken to increase the supply (availability) of improved seeds, chemical fertilizers and pesticides with fair prices in order to increase the profitability of smallholders in wheat production.

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LIST OF TABLES

Table 1. Descriptions of variables used in allocative efficiency analysis

Variables	Descriptions of the labels of variables (all were in natural logarithms)
ln(cost)	Cost of production in ETB
ln(land)	Price (rental value) of land in ETB
ln(wage)	Wage of human labor in ETB
ln(fertilizers)	Price of chemical fertilizers in ETB
ln(inputs)	Average price of seed and pesticides used in production in ETB
ln(output)	Wheat output in kilogram

Table 2. Average cultivated area, output, and yield of wheat

Average	Lowland n=83	Midland n=133	Highland n=165	Total N=381
Cultivated area (ha)	1.58	1.59	0.50	1.12
Production (quintal)	25.45	50.19	12.43	28.44
Yield (qt/ha)	15.63	30.89	24.84	24.95
Quantity sold (quintal)	12.12	26.06	4.71	13.78

Table 3. Average revenue, cost and profit of wheat production (ETB*/ha)

Variables	Lowland n = 83	Midland n = 133	Highland n = 165	Total N = 381
	Mean (Std.Dev)	Mean (Std.Dev)	Mean (Std.Dev)	Mean (Std.Dev)
Revenue	10,233.89 (3146.59)	19,250.75 (4384.89)	14,937.57 (3864.74)	15,418.54 (5,135.50)
Cost	9,149.99 (1324.28)	11,210.86 (1369.91)	10,390.28 (1444.1)	10,406.53 (1,581.70)
Profit	1,083.91 (3351.31)	8,039.89 (4236.94)	4,547.29 (3948.35)	5,012.00 (4,696.84)

*ETB is Ethiopian birr, and 1 USD was about 19.50 birr in 2013.

Table 4. Estimates of coefficients of stochastic Frontier Cobb-Douglas cost function

	Lowland		Midland		Highland	
ln (cost)	Coef.	Std. error	Coef.	Std. error	Coef.	Std. error
ln (land price)	-0.238	0.726	1.295*	0.702	-1.515***	0.581
ln(wage)	-0.004	0.119	0.153	0.110	0.134*	0.074
ln (Fertilizer price)	-1.160	1.209	2.337***	0.452	0.665	0.442
ln (seed/pesticides)	-0.110**	0.049	-0.111***	0.039	0.041	0.042
ln (output)	0.137***	0.047	0.124***	0.042	0.056	0.036
Constant	13.201*	7.754	-9.139	6.150	18.48***	4.383
Log likelihood	63.650		112.280		104.16	
Wald chi-squared	20.99***		46***		14.69**	
Prob > chi-square	0.0008		0.0000		0.012	
lnsig2v	6.018***	0.566	-5.070***	0.388	-4.60***	0.302
lnsig2u	-3.422***	0.246	-4.356***	0.568	-3.98***	0.482
sigma_v	0.049	0.014	0.079	0.015	0.100	0.015
sigma_u	0.181	0.022	0.113	0.032	0.136	0.032
sigma2	0.035	0.007	0.019	0.005	0.028	0.006
Lambda	3.660	0.032	1.429	0.046	1.359	0.046
Likelihod-ratio test of sigma_u = 0	15.8***		1.29		2.15*	
Prob >=chibar2	0.000		0.128		0.071	

*p <0.10, ** p< 0.05, *** p< 0.01.

Table 5. Summary of allocative efficiency scores of households in wheat production

Study area	Mean	Std. dev.	Min	Max
Lowland	0.895	0.063	0.549	0.968
Midland	0.885	0.052	0.723	0.968
Highland	0.877	0.068	0.675	0.977
Total	0.884	0.063	0.559	0.977
F-value	2.37; Prob > F = 0.095.			
Chi-square value	10.24; Prob > chi2 = 0.006.			