Stochastic Production Frontier Analysis Of Small Holder Farmers' Technical Efficiency: Evidence From Womberma District Wheat Producers', Amhara Regional State, Ethiopia

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ABSTRACT: *The research analyses the efficiency of farmers in the production of wheat in Womberma District in west Gojjam, Amhara regional state using cross sectional data collected in 2016 production year. Cobb-Douglas functional result indicates that there is inefficiency in the production of wheat in the study area. The estimation of the frontier model with inefficiency variables shows that the mean technical efficiency of farmers in the production of wheat is 70.79%. This implies that production can be increased by 29.21 percent given the existing technological level. The estimated stochastic production frontier model indicates that area of the plot, amounts of fertilizer and amount of improved seed are significant determinants of production level. The positive coefficients of these parameters indicate that increased use of these inputs will increase the production level to a greater extent. Hence given these inputs are used to their maximum potential, introduction and dissemination of these inputs will enhance the production level of wheat in the area. The inefficiency parameters shows that age square, education and family labor are statistically significant to determine efficiency level positively. While the inefficiency variables of age and hired labor cost indicate that increments in these factors increase farmers' inefficiency. The analysis also implies variables such as extension training , distance from plot and extension frequency by extension workers are statistically insignificant indicating that the current ongoing extension service is losing its momentum and it calls for reformulation.*

Key Words: *Cob Douglas, stochastic, Technical efficiency, Amhara Regional state*

INTRODUCTION

1.*1 Background*

Wheat is one of Ethiopia's most important cereal crops by production. About 4.7 million farmers produce 3.9 million tons of wheat across 1.6 million hectares of land with average productivity of 2.4 ton/ha (CSA, 2014). Wheat contributes an estimated 12% to the daily per capita calorie intake, making it the third most important contributor to national calorie intake, after maize and sorghum (Guush, *et al., 2011).* Over the last decade, consumption of wheat in Ethiopia has been consistently above local production, and since 2008, on average about 1.0 million MT of wheat have been annually imported(USDA in wheatatlas.org;2014). Total wheat production reached 3,925,174 metric ton in 2013/14 showing a remarkable 55% and 69%growth from what it was in 2008/9 and 2007/8 respectively(ATA,2014). Despite this remarkable growth in total production, more recently, compared to other countries, yield per hectare in Ethiopia still stands considerably lower.

In the period 2010-2013 the wheat yield per hectare in Ethiopia was 20.86 Qt/ha, while in the same period the average yield per hectare in Egypt, South Africa, Kenya and the world were 3.0, 1.6, 1.3 and 1.5, times higher than that of Ethiopia respectively (FAOSTAT,2015).

With the realization that population in Ethiopia is growing at an alarming rate, while food supply is slow coupled with the wide spread poverty among the population and the erratic rainfall distribution, the Amhara National Regional State Seed Enterprise has started projects to work with Womberma farmers to sustainably increase the income of those users through increasing output. Yet, the issue of increase food productivity has not been achieved to its maximum potential. This may be due to low area of land utilized or inefficient use of resource in its production and there is no evidence in the study area as to reach the level of technical efficiency. This paper had tried to measure the gap between the actual output and the potential output and also identifies the main determinants of this gap and therefore answer the question of inefficient resource use by Womberma beneficiary wheat producer farmers.

1.2. *Statement Of The Problem*

Since the start of extension services some 70 years ago, a lot of efforts have been made to increase productivity of grain. Though, a lot of efforts were made to introduce different technologies to improve

productivity, the country could not yet feed the population in a sustainable way.

Agricultural production in Ethiopia was not stable and this is evidenced by the simple fact that there were recurrent food shortages in the country. Various efforts were made in the past to improve the productivity level of wheat and cereal crops mainly through the introduction and dissemination of agricultural technologies especially fertilizers and improved seeds. This can be evidenced by rapid increase of the use of these inputs in the study area.

In fact various efforts that have been made over the past 1-3 decades and brought increased use of chemical fertilizers, improved seeds, pesticides & herbicides. Especially the use of fertilizer brought significant change in the yield of wheat. This technology has at least curved the deterioration of productivity of land that could have otherwise declined due to land degradation.

Further efforts in the introduction as well as dissemination of fertilizers in the area would increase production as well as productivity.

Theoretically, introducing modern technologies can increase agricultural output. However, according to Tarkamani and Hardarkar, (1996, cited in Getu, 1997) in areas where there is inefficiency, trying to increase a new technology may not have the expected impact and "there is a danger of trying to rediscover the wheel" if the existing knowledge is not efficient. This implies the need for the integration of modern technologies with improved level of efficiency. But what is the existing level of efficiency of farmers? Is there any room for improvement in the level of efficiency? What are the main causes for the existing level of inefficiency? What are the main possible solutions to improve the existing level of inefficiency? is not well addressed in the study area.

1.3. *Objective Of The Study*

The overall objective of this study is to understand the level of technical efficiency of small-holder farmers in the production of wheat in Womberma district of west Gojjam zone.

The specific objectives are:

1. To measure the level of technical efficiency in the production of wheat; and
2. To identify the sources of technical efficiency differences in the study area.

2. METHODOLOGY

2.1. Description of the Study Area

Womberma district is known for its wheat production among wheat producer areas of the country and has 19 rural and one urban kebele in West Gojjam Zone of the Amhara National Regional State, Northwestern Ethiopia, which is located mid-way between Debre Markos and Bahir Dar with the total population of Womberma District is about 113,244 in which the total male population comprises 56,761 and remaining 56,483 are females (CSA, 2005). The mean annual rainfall ranges from 1200 to 1360 mm for the periods from 2003 to 2006 (National Meteorological Agency, 2011). Annual mean temperature of the study area ranges from 14 to 24 ^{o}C.

2.2. Types, Sources and sample size determination of Data

A one year cross-sectional data for the period from Jnuary1, 2016 to December 30, 2017 was collected by January 2017 from sample of smallholder wheat producer farmers. The study used both primary and secondary data sources. The population from which sample drawn is finite, the formula provided by Kothari, 2004 is applied to determine the sample size.

That is:-

$$n = \frac{z^2.p.q.N}{e^2(N-1)+z^2.p.q} = \frac{3.8416*0.05*0.95*3650}{3.4592+0.1825} = 142 \qquad (2.1)$$

Systematic random sampling technique was used to select sample from sampling frame of 3650 wheat producer households. Systematic random sampling is a random sampling technique in which the researcher selects every n^{th} element after randomly selecting the first n^{th} element as a starting element purposively.

2.3. Specification of Empirical Model

Wheat production in particular and crop production in general in the study area are likely to be affected by random shocks such as weather, pest infestation and drought. In addition, measurement errors are likely to be high. Thus a stochastic frontier model was specified in the analysis of technical efficiency of wheat production in Womberma District. This is due to the fact that one of the appealing features of SPF is that it accounts for random shocks and measurement errorsand the model and according to Aigner et al. (1977) and Meeusen and ven den Broeck (1977)is specified as follows:

$$y_i = f(x_i;\beta)e^{\epsilon} \quad i = 1,2,3,\ldots\ldots\ldots N \qquad (2.2)$$

The empirical stochastic frontier for Womberma wheat crop farmers is given by:

$$\ln Y_i = \beta_o + \beta_1 \ln LAB + \beta_2 \ln LAND + \beta_3 \ln FER + \beta_4 \ln SEED + \beta_5 \ln AGC + \beta_6 \ln OTCS + V_i - U_i \qquad (2.3)$$

It is assumed that the technical inefficiency effects are independently distributed and U_i arises by truncation (at zero) of the normal distribution with mean, μ_i and variance σ^2, where μ_i is defined by:

$$\mu_i = \sigma o + \sigma_1 GEN + \sigma_2 AGE + \sigma_3 EDU + \sigma_4 FAMLAB + \sigma_5 LABCOST + \sigma_6 EXTN + \sigma_7 DISTANCE + \sigma_8 EXTNFREQ \quad (2.4)$$

The one-stage estimation procedure of the inefficiency effects model together with the production frontier function was implemented in the study.

3. RESULT AND DISCUSSION

3.1. Descriptive Result

The descriptive result indicates that the age of the sampled households ranges from 24 to 68 years of minimum and maximum respectively with mean age of 43.6 years. The educational status of the sample respondents is grade zero(illiterate) of minimum and grade 11 of the maximum status and the average is 3.68. The average family size of the sampled households in the study area is 5.4, with the maximum of 10 and minimum of 1. The number of family labor participated in agricultural activities ranges from 0 to 6.8 person days with the average of 3.51. This does not consider the occasional supply of inactive labor forces (child and aged persons), which is a usual circumstance to use these labor especially during the peak agricultural times. Moreover, the land holding of the household varies from 0.375 hectare to 12.5 hectare with the average being 2.487 hectare of cultivated land per household.

Table 1. Descriptive results of continuous variables

Variable	Obs	Mean	Std. Dev.	Min	Max
age	142	43.66197	9.687959	24	68
education	142	3.683099	3.251557	0	11
familysize	142	5.409155	1.646053	1	10
familylabor	142	3.152113	1.163494	0	6.8
landsizeinha	142	2.487676	1.414159	.375	12.5

Source: own computation(2017)

3.2. ECONOMETRICS ANALYSIS

Among the variables included in the model in the production frontier, the parameter estimates of land holdings of the household, amount of labor, fertilizer and improved seed were found to be significant. The result obtained is in conformity with similar studies by Abay and Assefa, (1996), Corppenstedt and Abbi,(1996), Getu et al, (1998) and Desta(2004). The other two variables, chemical and other inputs were turned out to be insignificant. The input variable total labor of the production function is significant at 5% confidence level and positive sign indicating that the amount of labor required in farm production is highly affecting the amount of wheat output positively.

Total cultivated land of the production function is significant at1% confidence interval and has positive sign as of my expectation and parameter coefficient is 0.537. This result is in conformity with similar studies conducted by Abay and Assefa(1996), Getu et al.(1998), Desta (2004). Besides these, the result indicates that the amount of improved seed and fertilizer are the main inputs in determining the output level of wheat at the best practice. Whereas, the elasticity of fertilizer and labor are very low implying that these values have no greater impact in determining the output level at the best practice.

In Cob-Douglas production function the parameter estimates measure the elasticity of production which imply that keeping other variables constant, a one percent increase in cultivated land input shall increase a 0.537 percent in wheat output. Given the current prevailing condition in the study area, the marginal productivity of land , keeping all other factors constant, is the highest followed by improved seed and then labor and fertilizer respectively have to increase wheat output. The bigger marginal productivity of land with respect to wheat output reflects the greater need of land by farmers.

Table 2. Cob Douglas production frontier and inefficiency variables wheat producers

variable	coefficient	Standard error
constant	2.111	0.277
Lnlabor	0.228 **	0.012
Lnlandsize	0.537 ***	0.057
Lnfertilizer	0.172 ***	0.035
Lnseed	0.302 ***	0.008

Lnchemical	0.0037	0.029
Lnother	-0.0047	-0.047
Maximum Likelihood Estimates of Inefficiency variables		
constant	-3.547	1.556
gender	-0.117	-0.117
Age	0.079***	0.023
agesquare	-0.004**	0.002
education	-0.018 **	0.043
familylabor	-0.415**	0.185
laborcost	0.100**	0.002
extension	0.181	0.766
Distance from plot	0.1002	0.080
Extension frequency	-0.045	0.096
Sigma-squared	0.139	0.017
gamma	0.753	0.030
Log-likelihood function	-45.6844	
Returns to scale	1.229	
Mean efficiency	70.79	
Number of households	142	

****, **, * are significant at 1%, 5% and 10%*

Source: own computation(2017)

The mean technical efficiency of wheat producer farmers is 70.79 percent. There can be potential for efficiency improvement with in wheat producer farmers. On average the respondents were able to obtain 70.79% of the potential income from a given mix of inputs for wheat producer farmers. This implies also that 29.21% wheat producer farmers farm output was foregone due to technical inefficiency which reflects the inefficient use of the factors of production that were within the control of the farmers. The result strengthens the finding of Fekadu(2004), Tewodros(2001).

3.2.1. Technical efficiency scores

Table 3. Frequency distribution of technical efficiency level of sample respondents

Technical efficiency score ranges	Wheat producer households		
	frequency	percent	Com. distribution
< 0.50	14	9.8	9.8
0.5 to 0.60	22	15.5	25.3
0.60 to 0.714	21	14.7	40
0.71 to 0. 80	44	30.9	70.9
0.80 to 0.90	16	11.3	82.2
> 0.90	25	17.8	100
Total obs.	142	100	
Minimum score		0.34	
Maximum score		0.99	
Mean score		0.7079	

Source: Own computation of survey data(2017)

As shown in the table 3, the mean efficiency of the respondents was found to be 70.79% with a maximum of 99.29% and minimum of 34.9% and the result is consistent with the finding of Thiam et al (2001). This disparity shows either there exists the room for improving the current production performance or achieving the current performance with a lesser input. Moreover, there is a considerable difference in technical efficiency among farmers that ranged from a minimum of 0.34 to a maximum of 0.99.This is an indication that most farmers are still using their resources inefficiently in the production of wheat.

3.2.2. Determinants of technical inefficiency

The major interest behind measuring technical efficiency level is to know what factors determine the efficiency level of individual farmers. The technical inefficiency effect estimates represented revealed, age of the household head, age square, education level of the household head, family labor, are found to be significant in explaining the determinants of efficiency (Table 2).

The negative and significant coefficients of age square, education level of the household head and family labor shows that these variables determine the level of efficiency positively. As these variables increased positively, the efficiency of farmers will improve. On the contrary, the positive sign of age and labor cost shows that these variables will affect the efficiency level negatively.

Gender is included in the model as a dummy variable that it has positive contribution to efficiency demonstrating good management capacity that most agricultural activities are accomplished by farmers because women are most likely engaged in homemade activities and child care (Tadele, 2016). The result shows that being male headed household has no significant contribution in increasing technical efficiency of the farm.

Age of the household head is a proxy variable showing farming experience of the farmer and shows a negative effect on technical efficiency of the farm and significant indicating that an increase in farmer's age by one year reduces the level of technical efficiency by 0.079%. This implies that aged farmers were less technically efficient when compared to their counterparts because it is believed to be reluctant to change their traditional method of production system as age of the farmer increases. This result is conveyed with the findings of Bekele(2013), Bernadette(2011) in Zambia, and Ahmed et al (2002) in Pakistan. However, the impact of age on technical efficiency turned out non-linear which have been captured by the quadratic variable age square. The coefficient of age square was negative and significant at 5% level. This indicates that technical efficiency first decreased with increase in age up to a certain level beyond which it had positive impact on technical efficiency. This may attributed to the fact that farmers with more years of experience are aged people that have better efficiency because they capture better farm technical efficiency learning-by-doing. Therefore, as age coefficient was positive, age square was negative and this result substantiates the findings of Padilla-Fernandez and Nuthall(2009), and Mohhamed et al (2014).

The variable education is used as a proxy for managerial input. Increased farming experience coupled with higher level of education achievement may lead to better assessment of good farming decision including efficient use of inputs which conforms with the findings of Bekele(2013), Kidanemariam(2013),and Haileselasie(2005). As the age of schooling for the household head is increased by one year, technical inefficiency is reduced by 0.018% cetrus paribus. Family labor is one important variable for agriculture during the previous times in the study area. In any agricultural activity the basic source of input in production process is labor and the source of this labor is mostly family labor that has significant contribution in improving the technical efficiency of farm outputs. Hence the model result shows family labor is statistically significant for contribution of farm efficiency. The result conforms with the findings of Mbanasor et al (2008), Mohammed et al (2014).

The basic institutional factors such as distance of the plot from the farmers' house, extension training and extension service frequency delivered by the development agent are insignificant to increase the level of efficiency of the farmers.

4. CONCLUSION

This paper analyzed the technical efficiency of farmers in production of wheat in Womberma District. The analysis used stochastic frontier model with inefficiency effects model are included in the full model using data obtained from 142 sample farmers in 2016 production year. The efficiency of farmers is measured at plot level. Various socio-economic variables that are expected to determine efficiency of farmers are estimated simultaneously with the stochastic frontier model.

The estimated stochastic production frontier model indicates that amount of labor, land size. amount of fertilizer and amount of improved seed are significant determinants of production
level. The positive coefficient of these parameters indicates that increased use of these inputs
will increase the production level to a greater extent. Hence given fertilizers are used to their maximum potential, introduction and dissemination of these inputs will enhance the production level of wheat in the area. Therefore, timely supply with reasonable price of improved seed and fertilizer will increase the production level.

The test result indicates that the traditional average response function is not an adequate representation of production frontier. The significant proportion of the residual variation in the SPF is due to technical inefficiency. This implies that there is a room for improvement through better technical efficiency. The estimated Cobb-Douglas stochastic production frontier shows that there is considerable inefficiency among plots in wheat production. And this may also be true in other crops. The mean efficiency level of 0.7079 indicates that production can be increased by 29.21 percent. There is also considerable difference in their efficiency level among plots. Hence if inputs are used to their maximum potential, there will be considerable

gain from improvement in technical efficiency.

In conclusion, the stochastic production frontier model shows that production can be improved by increasing the use of inputs especially improved seed and fertilizer. And the presence of technical inefficiency alone reveals that there would be much higher improvement in output for the same level of inputs if these inputs were used efficiently. The implication is that, there will be considerable gain in production level if introduction and dissemination of improved seed and fertilizers (increment in the use of these inputs) is coupled with improvement in the existing level of efficiency.

This inefficiency however, can be improved if factors that determine efficiency level of farmers in the production of wheat in the study area are identified. The generalized likelihood ratio test proved that variables considered in the inefficiency effects model simultaneously explained the existing efficiency differentials among plots.

The estimated SPF model together with the inefficiency parameters show that age, age square, education status of household head, family labor and labor cost are determinants of efficiency level of the farmer in wheat production. The negative coefficient of age square, education and family labor means these factors positively affect efficiency of farmers. While the positive coefficient of age determine efficiency negatively. However, gender, extension training, distance from the plot and extension frequency are not statistically significant to affect farmers' efficiency.

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