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FACTORS AFFECTING TECHNICAL EFFICIENCY OF HARICOT BEAN PRODUCING SMALLHOLDER FARMERS IN BOSAT DISTRICT, OROMIA NATIONAL REGIONAL STATE, ETHIOPIA

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Abstract
Haricot bean is one of the most important cash crops and the least expensive sources of protein in rural Ethiopia and in Oromia regional state in particular. Yet its productivity is very low. This study, therefore, aimed to analyze the level of technical efficiency by smallholder farmers in Boset district of Oromia National state of Ethiopia. Three stage sampling technique was employed to randomly select 149 sample farmers. A structured questionnaire was used to collect cross sectional data in 2018/2019 production year. Secondary data were also utilized for this study. Cobb-Douglas stochastic frontier with a one-step approach was used to estimate levels of the technical efficiency. Our findings showed that haricot bean output was positively and significantly influenced by land, fertilize, oxen and labor in man-days. The mean technical efficiency of farmers in the production of haricot bean was 81.4%. This showed that there exists a possibility to increase the level of haricot bean output by 18.6% through efficiently utilizing the existing resources. Hence, the government should give necessary not only revolving introduction and dissemination of new technology to increase yield, but also more attention should be given to improve the existing level of efficiency.

Key Words: *Haricot-bean, Stochastic-Frontier, Technical Efficiency, Boset District*

Introduction

Agriculture is a backbone of Ethiopian economy. The importance of agriculture in Ethiopia is evidenced by its share in GDP (40%), employment generation (85%), the share of export (77%) (EATA, 2017). Ethiopia is known as the homeland of several crops. It is ranked 13th among pulse producing countries in the World (FAO, 2015). Pulse crops are important components of crop production in Ethiopia smallholder's agriculture, providing an economic advantage to small farm holders as an alternative source of protein and other nutrients, cash income that seeks to address food security (Alemneh *et al*., 2017). Besides, they have been used for many years in crop rotation practices, since they have the capacity to improve the fertility status of the soil through biological nitrogen fixation (Derese, 2012). Pulses had cultivated and consumed in large quantities in Ethiopia for many years and also it covered about 12.61% (1.6 million hectares (ha)) of the grain crop area and 9.73% to production - about 29.8 million quintals (qt.) in 2017/18 production season (CSA, 2018).

Among pulse crops, the current productivity level of haricot bean falls significantly below the demonstrated potential. The current national, regional and zonal productivity of haricot bean was 17 qt. /ha, 18.3 qt. /ha and 16.6 qt. /ha respectively (CSA, 2018). This implies that the productivity of haricot bean in East Shoa was below the average productivity of the country and the region. Moreover, the productivity of haricot bean in the study area was 13.5qt/ha (BDANRO, 2018) which is below the average productivity of haricot bean in Ethiopia (17 qt. /ha), Oromia (18.3 qt. /ha and East Shoa (16.6qt/ha). This shows the existence of inefficiency in the study area. This study is motivated to examine why productivity of haricot bean in Boset district is very low.

There are number of studies conducted to examine efficiencies of different crops. For example, Kusse *et al*. (2018) conducted a study to analyze technical efficiency of sorghum production by smallholder farmers in Konso district, Southern Ethiopia. The study finds that land size, fertilizer (urea and dap), human labor, oxen power and herbicides or pesticides were found to be important factors in increasing the level of sorghum output in the study area. The result further revealed significant differences in technical efficiency among sorghum producers in the study area. The discrepancy ratio, which measures the relative deviation of output from the frontier level due to inefficiency, was about 90%. The estimated mean levels of technical efficiency of the sample households were about 69%, which shows the existence of a possibility to increase the level of sorghum output by about 31% by efficient use of the existing resources. In addition, the study found that level of technical inefficiency was affected by age, education level, family size, off/non-farm activities, extension contact, livestock holding, plots distance and soil fertility status.

Another study by Getachew *et al*. (2018) done on the technical efficiency of barley production of smallholder farmers in the Meket District, Amhara National State, Ethiopia. The trans-log functional form of the production function simultaneously with the single stage estimation approach was used to estimate the production of barley output and technical inefficiency factors. The estimated mean levels of technical efficiency of the sample farmers were about 70.9%, which revealed that, the presence of a room to increase their technical efficiency level on average by 29.1% with the existing resources. In the context of the current study area, there is no such a study. Therefore, the objective of the study is to measure and identify the determinants of the level of technical efficiency of haricot bean producing farmers in the study area.

Methodology

Description of Study Area

This study was conducted at Boset district, East Shoa Zone, Oromia National Regional State, Ethiopia. The district is located at 125 km from the capital city of Ethiopia, Addis Ababa and 25 km from

Adama (East Shoa zone) in east direction. The district has total household number 22,170. The major crops grown in the district are *teff*, haricot bean, maize, and sorghum. The area coverage of haricot bean is 8152 ha with production of 110,052 qt. which is produced by 10, 986 farmers in 2018/19 production year (BDAO, 2018).

Methodology

Source of Data

Primary data were collected from 2018/19 production year using personally administered structured questionnaires. Data gathered from secondary sources were also utilized.

Sampling Techniques and Sample Size Determination

Three stage sampling techniques were applied to select sample households. In the first stage, out of 33 rural *kebeles* administration in Boset district 12 haricot beans producing *kebeles* were purposively selected. In the second stage, out of 12 *kebeles,* 5 *kebeles* were selected randomly. In the third stage, 149 sample haricot bean producing farmers were selected from the total households of five *kebeles* by using simple random sampling technique based on probability proportional to size based on the list of the name of households who cultivate haricot bean in 2018/2019 production year. The population is homogeneous in the agro-ecology and production system, so the sample size was computed using Yamane (1967).

$$n = \frac{N}{1+N(e^2)} = \frac{3425}{1+3425((0.08)^2)} = 149$$

Where: n is sample size; N is the total number of haricot bean producers in the sampled *kebeles* (3425) and e is the desired level of precision. By taking e as 8%, because of limit of financial, time and difficulty to manage large sample size.

Table 1: Number of sample farmers selected per each *kebele*

Name of selected *kebeles*	Total producers	The Proportion of sampled household	Number of HH Selected
Dongore Hurufa	780	0.23	34
Dongore Furda	670	0.19	29
Golbo	710	0.21	31
Sara Arada	650	0.19	28
Konbe Gugsa	615	0.18	27
Total	3425	1	149

Source: BDANRO and own computation (2019)

Model Specification for TE Measurement

The stochastic frontier functional approach requires a priori specification of the production function to estimate the level of efficiency. Among the possible algebraic forms, Cobb-Douglas and trans-log functions were the most commonly used models in the most empirical studies of agricultural production analysis. Cobb-Douglas functional form has advantages over the other functional forms in that it provides a comparison between adequate fit of the data and computational feasibility. It is also convenient in interpreting elasticity of production and it is very parsimonious with respect to degrees of freedom and it is convenient in interpreting elasticity of production.

Besides, Cobb-Douglas production function is attractive due to its simplicity and because of the logarithmic nature of the production function that makes econometric estimation of the parameters a simple matter. Trans-log production function is more complicated to estimate the parameters having serious estimation problems. One of the estimation problems is that as the number of variable inputs increase, the number of parameters to be estimated increase rapidly. Another problem is the additional terms require cross products of input variables, thus making a serious multicollinearity problem (Coelli, 1995). Furthermore, the majority of empirical studies done on TE in Ethiopia analyzed using Cobb-Douglas frontier function (Beyan *et al*., 2013; Solomon, 2014; Ahimad *et al*., 2018, Kusse *et al.,* 2018). This study also tested whether to employ Cobb-Douglas or Trans-log production functional form and the test result revealed that Cobb-Douglas production functional form best fits the data.

Thus, Cobb-Douglas frontier function was specified as follows:

$$Y_i = A{X_1}^{\beta 1}{X_2}^{\beta 2} \dots X_n^{\beta n} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .1$$

The linear form of Cobb-Douglas production functions for this study defined as:

$$\ln(Y_i) = \beta o + \sum_{i=1}^{5} \beta_i \, lnX_i + \varepsilon_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2$$

$$lnY_i = \beta_o + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \varepsilon_i \dots . \dots .3$$

Where: *Ln is* represents natural logarithm, the subscript i represents i^th^ sampled farmer; Y_i is amount of haricot bean produced for i^th^ farmer expressed in qt. per year; X_1 is land allocated to haricot bean production (ha) by i^th^ farmer; X_2 is human labor used by i^th^ farmer in haricot bean production (man-days); X_3 is total amount of Nitrogen Phosphors sulfur Boron (NPSB) fertilizers applied in haricot bean by i^th^ farmer in kg; X_4 is amount of haricot bean seed sown i^th^ farmer on ploughed area measured in kg; X_5 is the total number of oxen power used for haricot bean production i^th^ farmer in oxen day; $\beta_o$is interception; $\beta_1 - \beta_5$ are parameters to be estimated and represents elasticity of production and $\epsilon_i$is the error term of the model consisting of two components Vi and U_i.

$$\varepsilon_i = Vi - Ui, Ui > 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .4$$

V_i is a symmetric error term that captures deviations of actual production from the frontier because of favorable or unfavorable factors beyond the control of the producers such as drought, weather, luck, and measurement error. The frontier production function is said to be stochastic because of this error term and producers can produce beyond the frontier when the value of V_i is positive and large U_i shows the inefficiency of farmers from factors under their control such as technical and economic inefficiency, will and effort of farmers, and possibility of defective and damaged products.

Accordingly, individual farmer technical efficiency is predicted from estimated stochastic production frontiers. The measure of production efficiency relative to the production frontier is the ratio of the observed output to the corresponding maximum output given the available technology and it is defined as:

$$TE = \frac{Y_i}{Y_i^*} = \exp(-U_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

Where: TE is technical efficiency of i^{th} household in haricot bean production; Y_i isthe actual output of i^{th} household in haricot bean production and Yi* is the frontier output of i^{th} household in haricot bean production and takes the value with in interval (0, 1) and 1 indicates a fully efficient farm.

Definition of Variables and Hypotheses

Variable	Definitions	Measurements	Expected signs	Findings by previous studies
Output	Actual quantity of haricot bean produced by i^{th} household in 2018/2019	Quintal	Dependent variable	Dependent variable
Seed used	Total amount of haricot bean seed applied by i^{th} household in 2018/2019	Kilogram	+	Hassen *et al*., (2015) (+)
Fertilizer	Quantity of chemical fertilizer utilized by i^{th} household in 2018/2019 for haricot bean production	Kilogram	+	Endrias *et al*., (2013) (+)
Land	Land devoted to haricot bean production by i^{th} household in 2018/2019	Hectares	+	Tamirat (2017) (+)
Labor	Total labor (family + exchange + hired) utilized various farm activities (plough, sowing and fertilizer application, weeding, harvesting and threshing) devoted to haricot bean production by i^{th} household in 2018/2019	Man-equivalent: computed by taking into account the age and sex of the laborer and using standard conversion factor reported by Strock *et al*. (1991)	+	Strock *et al*. (1991) (+)
Oxen power	Total amount of oxen power used by the i^{th} household from land preparation up to sowing	Total amount of oxen days allocated for ploughing	+	
Tractor hours, quantity of seed & labor	Amount of inputs used	Hours and kg.		Abedullah *et al* (2006) (+)

Result and Discussion

Major Crops Grown by Sampled Household

The major crops grown in the sampled *kebeles* are maize, haricot bean, sorghum and *teff*. The sample households, on average, allocated 0.77 ha, 0.75 ha, 0.125 ha and 0.14 ha for maize, haricot bean, sorghum and *teff* in 2018/19 production year (Table 2). Among these crops, haricot bean was the second dominant crop in terms of area coverage. It accounted for 42% of total cultivated land.

Table 2: Farm allocation for different crops (ha) by sample household farmers

Variable	Mean	Std. Dev.	Min	Max	Total area	Percent
Haricot bean	0.75	0.51	0.12	2.5	111.75	42
Maize	0.77	0.52	0.13	2.56	114.41	43
Teff	0.12	0.08	0.02	0.42	18.62	7
Sorghum	0.14	0.09	0.02	0.48	21.28	8

Selection of Functional Form and Hypotheses Tested

The attractive feature of Stochastic Production Function (SPF) model is that, it is possible to test various hypotheses using maximum likelihood ratio test. Accordingly, three hypotheses were tested, to select the correct functional form for the given data set, for the existence of inefficiency and for variables that explain the difference in efficiency (Greene, 2003).

The first null hypothesis tested was, test for Cobb-Douglas versus Trans-log production function. Here, the null hypothesis that all the interaction and square terms are all equal to zero (H_0: β_{ij}= 0). The test was made based on the value of likelihood ratio (LR) statistics. For the haricot bean producer respondents, the estimated log likelihood values of the Cobb-Douglas and Trans-log production functions were -25.414 and -11.307, respectively. The computed values LR = -2 [(-25.414) – (-11.307)] =27.9 and compared with the critical value of χ^2 at the 10 % level of significance with fifteen df which was 30.58. The test shows the nonexistence of interaction effect of input variables used in the production function.

The next step is a test for adequacy of representing the data using SPF over the traditional mean response function which is Ordinary Least Square (OLS). This hypothesis was tested using the generalized likelihood ratio test based on the log likelihood function under OLS estimation and final maximum likelihood estimation. This null hypothesis also used to test for the existence of the inefficiency component of the composed error term of the Stochastic Frontier Model at one time. If the null hypothesis $H_0 : \gamma = 0$ is accepted against alternative hypothesis $H_1 : \gamma \neq 0$, then the SPF is identical to OLS specification indicating that there is no inefficiency problem within the haricot bean output of sampled farmers. The generalized log-likelihood ratio (LR) statistics was used to test the validity of the SPF over the OLS model. Under the null hypothesis(H_0), the value of the restricted log-likelihood function for the OLS production function is -57.43, while under the alternative hypothesis(H_1), for the stochastic Cobb-Douglas function, the value of the unrestricted log likelihood function is 25.41. The generalized likelihood ratio statistics, LR= -2 [(-57.43 – (-25.41)] =64.04. The critical value of χ^2 at one degree of freedom and 1% significance level is 6.63. Therefore, LR test of $\gamma = 0$ provide a statistic of 64.04 for haricot bean production; which was significantly higher than the critical value of value of χ^2 for the upper 1% at one degree of freedom (6.63). This indicates that the SPF was an adequate representation of the data, given the corresponding OLS production function. Hence, a stochastic frontier approach best fits the data under consideration.

The third null hypothesis are explored that the explanatory variables associated with inefficiency effects are all zero (Ho: $\delta_1 = \delta_2 = ... = \delta_{12} = 0$) was also tested. To test this hypothesis likewise, LR (the inefficiency effect) was calculated using the value of the Log-Likelihood function under the SPF model (a model without explanatory variables of inefficiency effects: H_0) and the full frontier model (a model with explanatory variables that are supposed to determine inefficiency of each: H_1). The calculated value LR = -2 (-25.414314 - 13.079) = 76.98 is greater than the critical value of 24.72 at 11 degrees of freedom. The values of LR implying that, the null hypothesis (H_0) that the explanatory variables are simultaneously equal to zero was rejected at the 1% significance level.

Table 3: Generalized likelihood-ratio test of hypotheses for parameters of SPF

Null hypotheses	LR statistic	Critical value $\chi 2$	df	Decision
H0: $\boldsymbol{\beta}_{ij}=0$	27.9	30.58.	15	Accepted
H0: $\gamma=0$	64	6.63	1	Reject
H0: $U_i=\delta_0=\delta_1...=\delta_{12}=0$	76.98	24.72	11	Reject

Maximum Likelihood Estimation of Parameters

Technical Efficiency Analysis

The maximum-likelihood estimates of parameters of the stochastic production frontier and inefficiency effect models as described with equations 4 and 5 were obtained after treating the dataset with STATA version 13.1. A stochastic production frontier model permits to consider production of haricot bean in the study area with Cobb-Douglas stochastic production was tested and found to be best to fit the data and was used to estimate efficiency of farmers and to identify factors determining the inefficiencies in farming system. Estimation of parameters was carried out with a one-stage procedure under the assumption of half-normal distribution of the error terms. This approach leads us to the final estimates of parameters of the five explanatory variables of the frontier function; and twelve explanatory variables which influence the mean efficiency of haricot bean producers.

Table 4: Maximum-likelihood estimates of the frontier model

Variable	Parameter	Coefficient	Std. error	Z-value
Cons	β_0	0.977 ***	0.383	2.54
lnNPSB fertilizer	β_1	0.120 **	0.056	2.1
Lnseed	β_2	0.078	0.075	1.04
Lnland	β_3	0.688 ***	0.091	7.51
Lnoxen	β_4	0.119 **	0.048	2.45
Lnlabor	β_5	0.151 ***	0.052	2.89
$\boldsymbol{\sigma^2 = \sigma_v^2 + \sigma_u^2}$		0.182	.035	
$\lambda = \sigma_u / \sigma_v$		2.179	.079	
Gamma($\boldsymbol{\gamma}$)	0.826			
Returns to scale	1.155			

*Note: ** and *** shows significant at 5% and 1% respectively*

The maximum-likelihood estimates of the parameters of the frontier production function presented in Table 4. All the coefficients of production function variables were positive. The result of the Cobb-Douglas stochastic production frontier showed coefficients of land and labour force were positive and significant at 1% significance level and coefficients of NPSB fertilizer and oxen power were also positive and significantly at 5% significance level among the total five variables considered in the production function, four (land, labour, NPSB fertilizer and oxen) had significant effect in explaining the variation in haricot bean production among farmers.

The coefficient of labor availability was found to be positive and significant in the technical efficiency. The calculated coefficient of labor was 0.151 which indicates that as the labor increase by 1% output of haricot bean increase by 0.151% assuming other factors remains constant. This implies that technical efficiency increase with the increase in labor availability. Hence, farmers who had more available labor were better managers. This result is similar to the findings by Endrias *et al.* (2011), Wondimu and Hassen (2014) and Getahun and Geta (2017).

NPSB fertilizer is an important factor for haricot bean production and it is measured in terms of quantity in kg. The coefficient of NPSB fertilizer used for haricot bean has expected positive sign with an elasticity of 0.120 and is statistically significant at 5%. This implies that as NPSB fertilizer increased by 1% haricot bean output would increase by 0.120% other factors remains constant. This result is consistent with the finding documented by Endrias *et al*. (2013).

Oxen power is also found to be an important variable for haricot bean production and was again with statistically significant at 5% level of significance. The positive coefficient shows that an increase in the number of oxen day by 1% will tend to increase haricot bean yield by 0.119%; other variable in the model remain constant. The finding is consistent with the finding of Bekele (2013) and Fetagn (2017) who argue that presumably farmers increase oxen days per ha will increase output significantly.

Land is another variable which is found to be positively associated with haricot bean production at 1%. Specifically, a one per cent increase in cultivated land increases haricot bean production by 0.688 per cent keeping all other factors constant. This finding is consistent with a study by Tamirat (2017); Mesay *et al.* (2013) Abedullah *et al.* (2006);

Technical Efficiency Scores and Their Distribution

From the analysis of the survey data, the mean TE of the sampled haricot bean producer households in 2018/19 production year was 81.4 with minimum and maximum efficiency levels of about 21.4 and 99.9% with a standard deviation of 15.8% respectively. This shows that there is a wide disparity among haricot beans producing farmers in their level of technical efficiency which in turn indicates that there is a room for improving the existing level of haricot beans production through enhancing the level of farmers' technical efficiency. The mean level of technical efficiency further tells us that the level of haricot beans output of the sample respondents can be increased on average by about 18.56% if appropriate measures are taken to improve the level of efficiency of haricot beans growing farmers. In other words, there is a possibility to increase yield of haricot bean by about 18.6% using the resources at their disposal in an efficient manner without introducing any other improved inputs and practices.

One way of looking at frequency distribution of the individual efficiency values is taking the mean efficiency as a milestone. According to Stevenson (1980), grouping can be done based on the relative performance of each sample farmer in relation to the mean performance level and the corresponding standard deviation. Hence, three sample farmers categorical groups can be identified as the less efficient, average and more efficient farmers based on their technical efficiency scores. In this respect, farmers are considered as averagely efficient if they were operating in the range of mean efficiency plus or minus one standard deviation, and less efficient or more efficient farmers if they used to operate below or above the average efficiency range, respectively.

Table 5: Frequency distribution of sample farmers by Efficiency groups

Variable	Mean	Std. Dev.	Min	Max
TE	0.814	0.158	0.214	0.999
Efficiency group	Score	Frequency		Percent
Less efficient	< 0.65	27		18.12
Average efficient	0.65-0.97	96		64.43
More efficient	> 0.973	26		17.45

As shown in Table 5 technical efficiency scores and their distribution, about 18.12% of the sample households were categorized into less efficient cluster. On average the households in this cluster have a room to enhance their haricot bean output at least by 35%. While 64.43 % and 17.1% of the sample households were categorized into average and more efficient cluster, respectively. This indicates that most of the sample farmers were grouped into average efficient or operate between 0.65 and 0.97 of the technical efficiency scores.

Conclusion and Recommendation

This study used data collected from 149 haricot bean producing sample. Data were analyzed using both descriptive statistics and econometric model. The estimated stochastic production frontier model indicated that area of haricot bean, fertilizers, labor and oxen power were significant factors of haricot bean output production. The technical efficiency level of farmers in haricot bean production was ranging from 21.4% to 99.9%. The mean technical efficiency level of 81.6 % indicates that production can be increased by 18.4% of the potential in those farmers who grow haricot bean through better use of the available resources, given the current state of technologies. The result indicates that it is possible to improve farm technical efficiency of the households by 18.6% through better allocation of the available resources, especially land, NPSB fertilizers labor and oxen power. Thus, government bodies should work on improving productivity of households by giving especial emphasis for accessibility of labour, oxen and use of technologies such as chemical fertilizers.

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