COMPARISON OF DATA ENVELOPMENT AND STOCHASTIC FRONTIER MODELS IN ANALYSIS OF EFFICIENCY AND ITS FACTORS IN GINGER FARMS IN KADUNA STATE, NIGERIA

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ABSTRACT

Nigeria is trending below the top ginger producing countries of the world in terms of yield per hectare and national output. Technical Inefficiency due to poor combination and utilization of physical resources in the production of ginger is a major factor for low yield/output. Previous studies employed either Stochastic Frontier Analysis (SFA) or Data Envelopment Analysis (DEA) to measure technical efficiency. So, the question arises as whether the technical efficiency estimates from both methods are similar or not. The present study deployed the two common approaches (SFA and DEA) in estimation of technical efficiency and its determinants in order to ascertain the similarity or otherwise of the estimates. Two hundred and five (205) ginger farmers were randomly sampled for primary data collection. Analyses of the data were done through Descriptive Statistics, DEA, Tobit regression and SFA. The results show that means of the efficiency scores from both models namely DEA (0.70) and SFA (0.88) were significantly different at 1% probability level. However, estimates from both method suggest that the ginger farmers were operating at suboptimal level or below frontier. Also, the results of determinants of efficiency from two estimation methods (SFA and DEA-based Tobit regression) were dissimilar. While SFA method shows that household size, level of education and farming experience were responsible for enhancing the efficiency of ginger farms, none of these variables influenced the farmers' efficiency under Tobit regression. Therefore, it is recommended that selection of efficiency estimation method between SFA and DEA by the researcher should be based on study objective rather than consideration on the premise of alternative opportunity. Also, greater output level or potential output can be achieved, given the current production technology, by educating ginger farmers on how to ensure that production inputs are combined and managed efficiently.

Keywords: *Comparison, DEA, SFA, Efficiency, Ginger Farms.*

INTRODUCTION

Globally, Nigeria is ranked fifth in ginger crop production. According to FAO (2017), the global production of ginger was about 1.8 million tonnes, with India, topping the producing countries, accounted for 38% of the world's total ginger production. China is the second next country and accounted for 26% of the global ginger production, followed by Nepal in third place with 16 % contribution. The other two top producing countries of ginger are Indonesia and Nigeria accounting for about 16% and 4%, respectively. Ginger has both economical and nutritional benefits. Research has confirmed that consumption of ginger helps in reducing nausea and

vomiting which mostly affects pregnant women and chemotherapy (Lete and Allue, 2016). It can also be used to prevent stomach ulcers, reduce muscle pain and soreness (Barrett, 2012).

In Nigeria, about 10% of the ginger produce is consumed locally as fresh ginger while the remaining 90% is dried for both local consumption; 20% of the dried ginger is consumed locally for various uses and 80% is exported (Ezeagu, 2006). Kaduna state accounts for highest production of ginger in the country. Ginger production, processing and marketing are big businesses that guarantee high returns on investment.

Ginger production in the country is characterized by low yield when compare to other producing countries. Figure 1 shows that Nigeria is trending below the top ginger producing countries of the world in terms of yield per hectare. The national average yield of ginger as indicated in Figure 1 shows that China is leading with 11000 Kg per hectare, followed by Nepal with 8900 Kg/ per and Indonesia with 8700 Kg/ha. India and Nigeria has 3200 Kg/ha and 1300Kg/ha respectively.

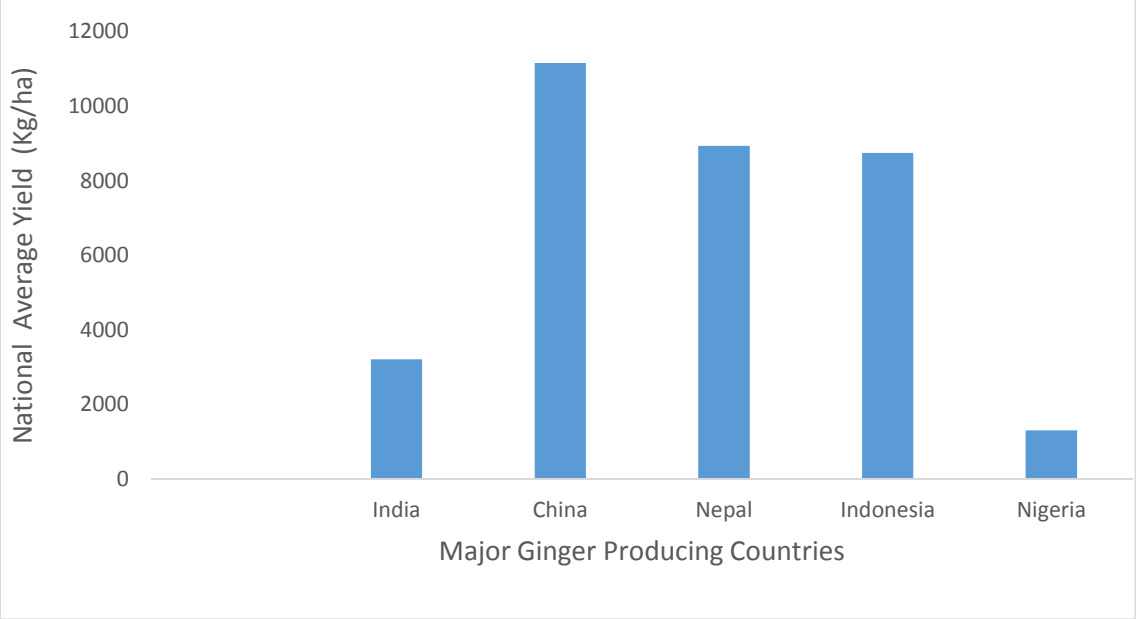


Figure 1: National average Yield (Kg/ha) of Ginger among the Leading Producing Countries of the World
Source: FAO (2017)

However, in terms of land area devoted to the production of ginger, Figure 2 shows that Nigeria is ranked first with 145,000 hectares, followed by India with 133,000 hectares. China, Nepal and Indonesia have 39,800 hectares, 24,200 hectares and 10,200 hectares, respectively.

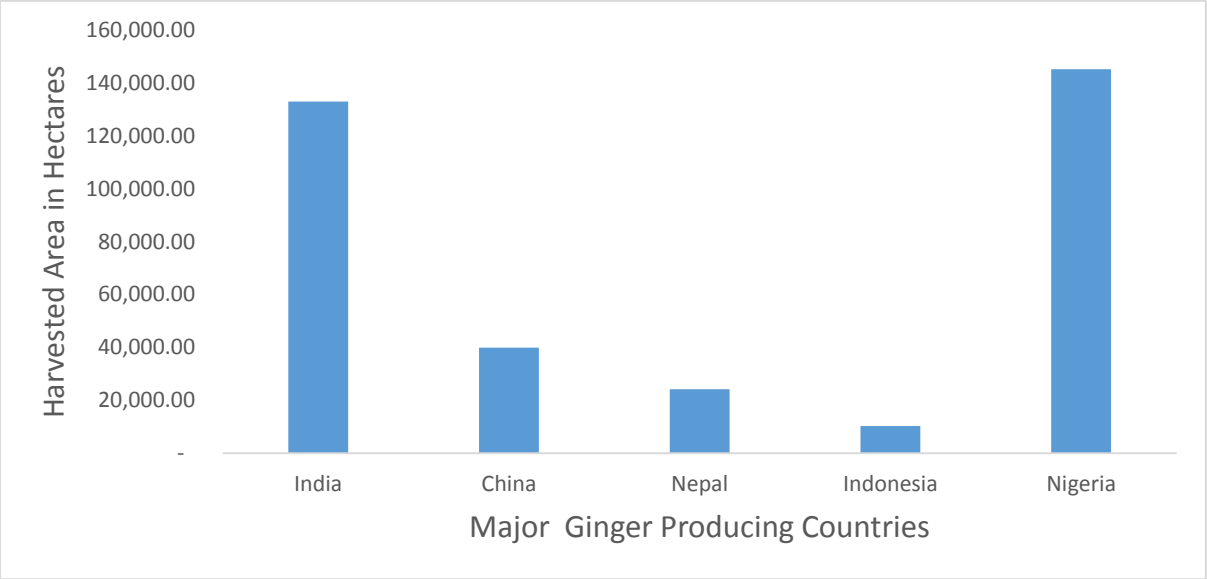


Figure 2: Harvested Land Area (hectares) among the Leading Ginger Producing Countries of the World
Source: FAO (2017)

Many factors could be responsible for low productivity of ginger in Nigeria. Poor combination and utilization of physical resources in the production of ginger could be a major factor responsible for poor yield. Improving the performance of ginger farm for greater productivity relies on both efficiency and effectiveness in resource utilization and management. Farm's efficiency in physical resources or inputs utilization is determined through technical efficiency measurement. Technical efficiency reflects the ability of the farm to obtain the maximal output or yield from the given set of inputs. The common approaches to the measurement of technical efficiency are the parametric approach- Stochastic Frontier Analysis (SFA), created by Aigner *et al*. (1977), and non-parametric approach- Data Envelopment Analysis (DEA), developed by Charnes *et al.* (1978). Previous research works in relation to ascertain the efficiency of ginger farms largely used SFA approach namely Mailumo *et al.* (2014); Folorunso and Adenuga (2013) and Ayodele and Sambo (2014). However, other studies used DEA to measure technical efficiency in crop farms (Tipi *et al.*, 2009; Kocisova, 2015).

Stochastic Frontier Analysis and Data Envelopment Analysis differ in the assumption underlining their application, but the two methods remained popular in estimation of technical efficiency in crop farms. For instance, DEA approach does not require the SFA's assumptions of functional form specification and distributional of the inefficiency term. So, the question arises as whether the technical efficiency estimates from both methods are similar or not. Hence, in the present study, effort is made to compare technical efficiency estimates and its determinants from both estimation methods in order to establish similarity or not in their results; and to provide comprehensive knowledge of extent of technical efficiency and its factors necessary for informed decision towards enhancing productivity of ginger farms for greater production in the study area.

METHODOLOGY

The study was conducted in Samaru Zone of Kaduna state Agricultural Development Project (KADP), which is located in the Southern part of Kaduna State. The climate is predominantly tropical with two distinct seasons (dry and wet seasons). The Zone is predominantly agricultural with over 75 percent of the active population engaged in farming as their primary occupation. Ginger is the major cash crop grown in the region with Kachia, Jaba, Kagarko, Jema'a and Zangon Kataf Local Government Areas as the major areas of production in the State. The target population for this study is ginger farmers in Southern zone of Kaduna Agricultural Development Project (KADP). A multi stage sampling technique was used to collect the sample of ginger farming households: the first stage involved a purposive selection of two Local Government Areas (LGAs) namely: Jaba and Kachia. The selection of the duo was due to relatively high concentration and intensity of ginger production. The second stage involved a purposive selection of three villages from each of the LGAs. This amount to 6 villages selected namely: Nok, Kuryas,Fai, Jaban kogo, Yarbung 1 and Sabon Sarki. In the third stage, a list of ginger farming households from each village was used as sample frame, from which a sample of ginger farmers were proportionately drawn as shown in Table 1. Finally, 205 ginger farmers were randomly selected for the study.

Table 1: Distribution of Ginger Farming Households in the Sampled Villages

LGAs	Villages	Sample frame	Proportionate Selection (%)	Random Selection
Kachia	Jaban kogo	180	14	25
	Yarbung 1	210	16	34
	Sabon sarki	240	19	46
Jaba	Nok	200	16	32
	Kuryas	219	18	39
	Fai	190	15	29
Total	6	1239		205

Source: KADP (2017)

Primary data were collected through structured questionnaire administered on ginger farmers. Data collected included socioeconomic characteristics of the ginger farmers: age, educational status, farming experience, household size, farm size etc. Data on ginger output and farming inputs, namely: fertilizer, seed, agrochemical and labour were also collected.

Analyses of the data were done using Descriptive Statistics, Data Envelopment Analysis (DEA), Tobit Regression and Stochastic Frontier Analysis (SFA).

(i) Data Envelopment Analysis (DEA): Following Coelli *et al*. (2002) and applied by Alboghdady (2014), assumed that there are data on a single output (Y=1, ginger) for each of N farms (N=1,2,…,205) and K inputs (K=1,2,…,5) denoting farm size (Ha), seed (Kg), fertilizer (Kg), agrochemical (Litres) and labour (Man-day). For ith farm, inputs and output data were represented by the column vectors k_i and y_i. The data for all N farms are represented by $K \times N$

input matrix, k, and Y ×N output matrix, y. Hence, the Constant Return to Scale (CRS) input oriented DEA model for the ith farm is specified as follows:

$Min_{\varphi i,i}\varphi_i$,

Subject to $Y\lambda - yi \geq 0$

$k_i\varphi_i - K\lambda \geq 0$, $\lambda > 0$ ……1

Where,

Where φ is a scalar and λ is a N ×1 vector of constant. The linear programming problem for constant return to scale (CRS) can be easily modified to obtain variable return to scale (VRS) by adding the convexity constraint: $N1'\lambda = 1$ so as to minimize the following equation:

$Min_{\varphi i,i}\varphi_i$,

Subject to $\lambda - yi \geq 0$,

$k_i\varphi_i - K\lambda \geq 0$…….. (2)

$N1'\lambda = 1$ $\lambda > 0$, where $N1$ is a N ×1 vectors of ones. In this study, constant return to scale (CRS) DEA model was applied.

According to Coelli *et al*. (2005), the input technical efficiency score gets a value $0 \leq \varphi \leq 1$. If the φ is equal to one, the farm is on frontier and then technically efficient.

(ii) Tobit regression: According to Alboghdady (2014) and Tipi *et al.* (2009), Tobit regression analysis is commonly used to determine the impact of certain desirable factors on the production efficiency scores generated through DEA. Tobit model, which is also known as censored regression model, is designed to estimate linear relationships between variables when there is left and/or right-censoring in the dependent variables. A two limits (left and right censored) Tobit model as suggested by Maddala (1986) was applied to this study because efficiency scores are bounded between zero and one. However, estimation with an ordinary least squares (OLS) regression of DEA scores would lead to a biased parameter estimate since OLS assumes a normal and homoscedastic distribution of the disturbance and the dependent variable (Maddala 1986).

Following Alboghdady (2014) approach, the Tobit model is expressed as follows:

$y_i^* = \Psi_0 + \sum_{i=1}^{k} \Psi_{1i} X_{ik} + \xi_i$, $\xi_i \sim IN(0,\sigma^2)$……3

Where,

y_i^* = latent variable representing the efficiency score for the ith farm;

Ψ_0 and Ψ_i = parameters to be estimated;

X_{ik}= hypothesized determinants of efficiency scores or latent variable, namely: age (year), household size (number), level of education (year) and ginger farming experience (year). The latent variable (y_i^*) is generated from the observed variable y_i through DEA estimation, which range from zero to one

(iii) The stochastic Frontier Model: It is a parametric function with a multiplicative disturbance terms is specified as follows:

$Y = f(K\beta)\ expE$ ……(4)

Where; Y= output of ith farm,

K = vector for input quantity in ith farm,

β = vector of parameter,

E = stochastic disturbance term consisting of two independent random variables, Where E = v-u symmetric component, v, accounts for factors outside the farmer's control. It is assumed to be independently and identically distributed as $N\sim (o, \sigma_v^2)$. A one side component, $U \leq 0$ reflects the technical inefficiency with half normal distribution. The stochastic production frontier model

simultaneously estimates production function and individual efficiency of the ith farmer, as well as determinants of technical inefficiency (Baltese and Coelli, 1995). The stochastic frontier production model is specified as follows;

$Y_i=\beta_0+\sum_{i=1}^{n}\beta_{1iK_{in}}+v_i-u_i$ ..... (5)

Where, Yi= ginger output ith farm

K_{in} = vector for inputs as earlier mentioned

β_0- β_i = parameters to be estimated

It is assumed that inefficiency effects are independently distributed with constant mean and variance

Where; U is specified as:

$U_i=\delta_o+\sum_{i=1}^{n}\delta_{1iZ_{in}}+\mu$ ..... (6)

Where,

U_i= Technical inefficiency of the ith farmer,

$Z_{in}=X_{ik}$=determinants of efficiency scores as mentioned above.

δ_o- δ_i= parameters to be estimated

RESULTS AND DISCUSSION

The descriptive statistics of all the variables deployed for analyses are presented in Table 2. The output of ginger varied widely from the minimum of 1620 kg to maximum of 57000 Kg. The mean value for the output in the study was 19684 Kg. High value of the standard deviation from mean of the output is a confirmation of wide variability of the ginger output among the farmers. Farm size allocated to the cultivation of ginger is largely small; as the mean of farm size was about 1 hectare with low value of standard deviation (0.8). The ginger seed used also has wide variability among famers with the minimum value of 300Kg and maximum of 12600 Kg. The mean value of ginger seed was 3876 Kg, with high value of standard deviation implying wide variability from the mean. The mean of fertilizer and other agrochemical utilized in the area were 646 Kg and 7 litres respectively. Table 2 also shows the statistics of the ginger farmers' demography. The mean of age, household size, level of education and farming experience were 39 years, 6 persons, 9 years and about 16 years, respectively.

The efficiency scores generated through DEA and SFA are presented in Figure 3 and Table 3. Table 3 shows that mean of efficiency scores generated from DEA model was 0.70, which is less than 0.88 generated through SFA model. The difference in the two means is statistically significant at 1% (Table 3). This implies that technical efficiency estimates from the two approaches are significantly different. Table 3 also shows that the value of standard deviation of the efficiency distribution is higher (0.14) in DEA model than SFA (0.11). This result implies that efficiency scores generated through SFA show better convergence to the mean than that derived from DEA. Frequency distribution of efficiency scores as indicated by Figure 3 shows that 20% of ginger farmers were operating below efficiency level of 0.85 by SFA measurement as against 86% by DEA approach. By DEA measurement, 60% of the farmers were performing at efficiency level higher than 0.66 as against 98% for SFA.

However, the means of the efficiency scores distribution from both models suggest that the ginger farmers are not technical efficient, as they operate at suboptimal level or below frontier. This result is supported by previous studies of Ayodele and Sambo (2014) and Mailumo *et al.* (2014), who recorded 0.82 and 0.74, respectively as the mean of efficiency of ginger farms in the study area.

Table 2: Descriptive Statistics of Variables used in the Models

Variable	Unit	Minimum	Maximum	Mean	Std. Deviation
output	Kilogram	1620.00	57000.00	19684.0976	13336.63313
Farm Size	Hectare	.10	4.00	1.1107	.78887
Seed	Kilogram	300.00	12600.00	3876.2927	2729.78020
Fertilizer	Kilogram	50.00	4500.00	646.2195	605.76356
Agrochemical	Litre	0.50	25.00	7.1024	5.26427
Labour	Man-hour	15.00	644.00	181.00	130.000
Age	Year	25.00	61.00	39.4341	8.29078
Household Size	Number	1.00	12.00	5.9863	2.22616
Educational Level	Year	1.00	16.00	9.2976	5.60499
Farming Experience	Year	1.00	40.00	15.5805	8.51294

Source: Estimated data collected through Field survey (2017)

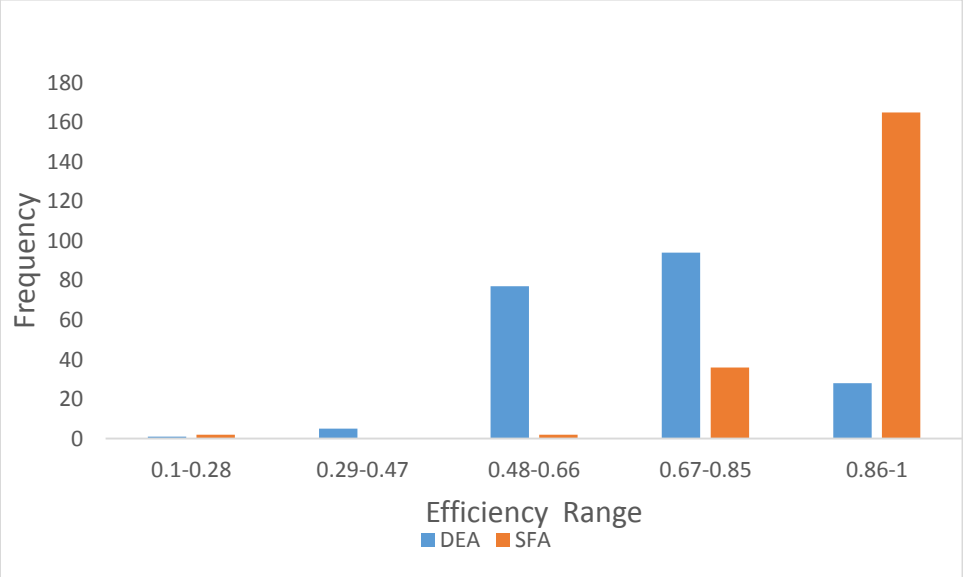


Figure 3: Frequency Distribution of efficiency scores between DEA and SFA
Source: Estimated data collected through Field survey (2017)

Table 3: Descriptive Statistics of Efficiency Scores between DEA and SFA

Statistics	DEA	SFA	T-ratio
Mean	0.704815	0.882707	14***
Maximum	1.000000	0.977000	
Minimum	0.100000	0.073000	
Std. Dev.	0.137022	0.108174	
Observations	205	205	

Source: Estimated data collected through Field survey (2017)

The estimate of socioeconomic determinants of inefficiency effect was achieved using two limited Tobit regression analysis (whose dependent variable was originally generated as DEA efficiency scores) and Cobb-Douglas functional forms of stochastic frontier analysis. The Stata version 11 edition was used to estimate Tobit regression model, while Frontier version 4.1 by Coelli (1996) was used to estimate Cobb-Douglas functional form. Both methods of estimation utilized Maximum Likelihood Function. The estimated coefficients are presented in Table 4. The negative coefficient implies an efficiency increase, whereas a positive coefficient means an efficiency decrease. The sigma-squired (δ^2), which measure the model goodness of fit was significant for both SFA and Tobit regression models (Table 4). The estimated value of gamma-parameter (γ) associated with SFA model was 0.96. This implies that 96% of variation in ginger output was due to inefficiency effect. This further underscore the need to examine and compare the factor of inefficiency effects of the ginger farms using the two methods.

Table 4 also shows simultaneously estimated coefficients of stochastic production function, which is impossible with DEA being a non-parametric model. The coefficients of all the variables were significantly influencing the ginger output. This implies that a percentage increase in the variables would result in proportionate increase in the output of ginger farms. Table 4 further revealed that the two estimation methods (SFA and DEA-based Tobit regression) regarding results of determinants of efficiency were not similar. Based on SFA method, household size, level of education and farming experience were responsible for enhancing the efficiency of ginger farms in the study area as they were statistically significant at 1%. But, coefficients of age carry positive sign and significant. This implies that age of the ginger farmers increases their inefficiency. Comparatively, none of these variables influenced the farmers' efficiency under Tobit regression (Table 4). In support of the SFA estimates, previous findings by Ayodele and Sambo (2014) confirmed that education of the ginger farmers in the area enhance their efficiency significantly but disagreed on the ground of household size. However, household size as a variable for enhancing efficiency of ginger farms was confirmed by Folorunso and Adenuga (2013). Age as an inefficiency enhancer of the ginger farmers tallied with the finding of Ayodele and Sambo (2014). Coefficient of farming experience, which suggests efficiency enhancer of ginger farm, is confirmed by the finding of Ayodele and Sambo (2014).

Table 4: Determinants of Technical Efficiency Estimated through the Two Methods

	Tobit Regression based on Output from Data Envelopment Analysis				Stochastic Frontier Analysis			
Variable	**Para-meter**	**Coeff.**	**Std Err**	**T-ratio**	**Para-meter**	**Coeff.**	**Std Err**	**T-ration**
Intercept					β_0	8.143	0.496	16.40***
Farm size					β_1	0.673	0.068	9.81***
Seed					β_2	0.112	0.067	1.67*
Fertilizer					β_3	0.054	0.021	2.52**
Agrochemical					β_4	0.065	0.029	2.26**
Labour					β_5	0.092	0.031	2.95***
Intercept	Ψ_0	0.235	0.062	3.81**	δ_0	-7.980	1.982	-4.03***
Age	Ψ_1	0.002	0.002	1.15^{NS}	δ_1	2.950	0.654	4.51***
HH Size	Ψ_2	-0.002	0.005	-0.28^{NS}	δ_2	-0.865	0.211	-4.10***
Education	Ψ_3	-0.002	0.002	-1.04^{NS}	δ_3	-0.213	0.059	-3.61***
Farming Exp.	Ψ_4	0.001	0.002	0.50^{Ns}	δ_4	-0.922	0.160	-5.74***
	δ	0.143	0.007	20.43***	δ^2	0.236	0.032	7.33***
	LR	5.26			γ	0.956	0.011	89.39***

Source: Estimated data collected through Field survey (2017)

CONCLUSION AND RECOMMENDATION

The means of the efficiency scores from both models namely DEA (0.70) and SFA (0.88) were significantly different. But, estimates from both methods suggest that the ginger farmers were operating at suboptimal level or below frontier in the study area. Also, efficiency scores generated through SFA show better convergence to mean than that of DEA. Still, the results of determinants of efficiency from two estimation methods (SFA and DEA-based Tobit regression) were dissimilar. While SFA method shows that household size, level of education and farming experience were responsible for enhancing the efficiency of ginger farms in the study area, none of these variables influenced the farmers' efficiency under Tobit regression. The results of production function generated only through SFA, shows that the coefficients of all the variables (farm size 0.671; seed 0.112; fertilizer 0.054; agrochemical 0.065; and, labour 0.092) were significantly influencing the ginger output in the area.

Given the study results, it is recommended that selection of efficiency estimation method between SFA and DEA by the researcher should be based on study objective rather than consideration on the premise of alternative opportunity; since efficiency scores estimated from two methods differ significantly. Also, the mean of efficiency scores generated by the two methods confirmed suboptimal level of inputs utilization by the ginger farmers. Hence, greater output level or potential output can be achieved, given the current production technology, by educating ginger farmers on how to ensure that production inputs are combined and managed efficiently.

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