International Journal of Botany Studies
ISSN: 2455-541X; Impact Factor: RJIF 5.12
Received: 21-06-2019; Accepted: 23-07-2019
www.botanyjournals.com
Volume 4; Issue 5; September 2019; Page No. 123-127

Evaluation of Technical Efficiency and its determinants of edible mushroom production in Thainguyen province, Vietnam

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Abstract
The purpose of this study is to investigate the technical efficiency of edible mushroom production and to identify the factors influencing efficiency of edible mushroom farms in Thainguyen province, by using stochastic frontier analysis approach. The results indicated that the mean score of technical efficiency was 0.72, ranging from 0.12 to 1. Besides, the findings also revealed that factors had a significant impact on technical inefficiency including age, educational, family-scale, the number of main labor and household group. Hence, the government should give policies focused on the training activities and facilitate technology transfer for farmers to improve the technical efficiency of mushroom production.

Keywords: mushroom farms, technical efficiency, stochastic frontier analysis

1. Introduction

The cultivation of edible mushroom plays an important role in using agricultural residues as well as improving livelihood for rural people. In the world, the edible mushroom is used widely by their nutritional and medicinal value. In recent years, researchers showed that mushroom has 12,000 species in the natural environment in which edible mushroom account for 2,000 species and nearly 200 species are used for the pharmaceutical sector. Moreover, the edible mushroom is also known as a source of rich in protein food, vitamin (B1, B2, B12, C, D, and E), minerals and poor in fat [1-4]. According to Zhang *et al.* [5] the protein content was found around 26.3% to 36.7%. Therefore, mushroom is considered to be healthy food and suitable for all age groups. It is the reason why the demand of mushroom is more and more increasing in the world.

In Vietnam, the development of edible mushroom production has been considered as a prioritized commodity for investment and development because it does not only helps produce clean food, creates jobs, reduces poverty but also helps reduce environmental pollution. Thainguyen is a province in the Northern mountainous region of Vietnam with a population of 1,268,300 [6] and many cultural and industrial centers. Hence, the goal of development mushroom production in Thainguyen province plays an important role in meeting domestic demands, creating income for farmers, contributing to environmental protection and diversification livelihood for the rural area. However, edible mushroom production farms in Thainguyen province is recently facing many problems such as small scale production, low price, unstable output market, poor technologies in processing and preservation.

Recently, using stochastic frontier analysis (SFA) to analyze the technical efficiency in agricultural production applied by many researchers, e.g., Kea *et al*. [7] applied SFA model to analyze technical efficiency (TE) of household's rice production in Cambodian. The research indicated the average TE was 0.34 and the empirical results suggested that the rice output has the potential of being increased in the future by 66% without adding inputs if farmers had been technically efficient. Dlamini *et al.* [8] used stochastic frontier production function to estimate the technical efficiency of mushroom farmers in Swaziland. The findings showed that the mean of technical efficiency of mushroom farmers was quite high with 95% and the results revealed that farmers can increase the quantity of mushroom by improving technology in production.

In SFA model, the Cobb-Douglas and translog production function are the two most popular function forms using in many empirical researches [9]. Saiyut *et al.* [10] applied SFA approach to estimate the age structure effect of agricultural labor on technical efficiency in Thailand agriculture. SFA method was used by Chiona *et al.* [11] to evaluate the technical efficiency of smallholder maize farms in Zambia. The author stated that maize farmers can increase technical efficiency from the present level of inputs by improving access to credit and extension services.

The current study aims is to estimate technical efficiency and to determine the main factors influencing the efficiency of mushroom farms in Thainguyen province, Vietnam, and in hope to increase income, improve livelihood and reduce the poverty rate of the local community. According to the authors' knowledge, using SFA to estimate the technical efficiency of edible mushroom production have not explored in Vietnam. Hence, this study provides for this gap in the literature.

2. Methodology

2.1. Research Methodology

The concept of technical efficiency which was first proposed by Farrell [12] showed that the technical efficiency refers to the ability of firm to obtain maximal output from a given set of inputs. In agricultural economics sector, SFA is widely used to measure the efficiency of farms because of the inherent nature of uncertainty related to agricultural production. SFA is a method of frontier estimation that used to assume a functional form for the relationship between inputs and output [13]. Therefore, this study focused on SFA approach to estimate the technical efficiency of edible mushroom farms in Thainguyen. The stochastic frontier production function is expressed in Equation (1):

$$y_i = x_i\beta + v_i - u_i \qquad i = 1, 2, \ldots n \qquad (1)$$

Where, y_i is the output of farm, x_i represents the vector of inputs used in the production, and β is the vector of unknown parameters, v_i accounts for measurement error and other random factors that farmers cannot control such as weather, strike, and luck,…and u_i is non-negative random variables, related to technical inefficiency in production of farms. The v_i is independent and identically distributed to normal random variables with mean zero and constant variance as N (0, σ_v^2). The u_i is assumed to be independently distributed as truncations at zero distributions or half-normal random variables [13, 14].

The Cobb-Douglas functional form can be specified as Equation (2) follow:

$$Lny_i = \beta_0 + \sum_{i=1}^{n} \beta_i Lnx_{ij} + v_i - u_i \qquad (2)$$

Where, y_i denotes the output for the i-th farm, x_{ij} is a vector of value of input j for the i-th farm, β_0 and β_i are vectors of unknown parameters, v_i is random error assumed to be independent and identically distributed, and u_i is non-negative random variables assumed to be independent and identically distributed exponential or half-normal random variables [14].

The translog production frontier can be expressed by Equation (3):

$$Lny_i = \beta_0 + \sum_{j=1}^{7} \beta_j Lnx_{ij} + \sum_{j \le k, k=1}^{7} \beta_{jk} Lnx_{ij} Lnx_{ik} + v_i - u_i \qquad (3)$$

Where, Ln is natural logarithm, y_i represents the output value of mushroom farms, x_{ij} is a vector of value of input j for the i-th farms. The farms used 7 inputs in production (x_1 is the area cultivated (m^2); x_2 is the amount of seed (kg); x_3 is the amount of sawdust (tons); x_4 is the amount of wood (m^3); x_5 represents the quantity of nylon bag (kg); x_6 is the total cost of electricity (1000.VN Dong); and x_7 is the amount of labor (man-day).

Furthermore, to determine of factors affecting technical efficiency of edible mushroom farms, in this study, we used the inefficiency effect model. The model for estimating technical inefficiency denoted by equation (4) as follow:

$$U_i = \delta_0 + \sum_{m=1}^{6} \delta_m Z_m \qquad (4)$$

Where, U_i represents the level of technical inefficiency farms; Z_m denotes the explanatory variables in the inefficiency effect model which include age of household head (Z_1); educational level of household head (Z_2); Experiences of household head in year (Z_3); Family size (Z_4); the number of main labor of households (Z_5) and the type of household group (Z_6).

2.2. Data collection

The survey of the study was conducted in Thainguyen province. Data were collected from 50 edible mushroom farms using face-to-face interviews during the crop year of 2017/2018. The formal survey was conducted by structured questionnaires in which include variables related to edible mushroom output and input used on production, i.e., land, seed, sawdust, wood, powdered lime, labor, electricity, and other costs. Besides, general information of farms was also collected such as age, educational level, the experience of household head, the number of main labor, household type and family size.

To analyze technical efficiency and determine factors affecting inefficiency mushroom farms, this study used output and 7 input variables and 6 socio-economic variables. Table 1 showed the descriptive statistics of variables. In the sample, on average, the yield of mushroom was 4,606.90 kilograms and ranged from 750 kg/farm to 15,000kg/farm. On the inputs side, there was a large difference between farms in using inputs. The cost of electricity was the highest, with 1,268.80 (1000 VN Dong) per farm. However, the electric cost depended on farm size and production scale. Therefore, there was a high variation in the cost of electricity with a range from 100 (1000 VN Dong) to 4,000 (1000 VN Dong).

Table 1: Descriptive statistics of variables for edible mushroom farms

Variables	Unit	Mean	Std. Deviation	Minimum	Maximum
Output variable					
Total output (Y)	Kg/farm	4,606.90	2,572.785	750	15,000
Input variables					
Cultivated area (X_1)	m^2	462.40	710.411	100	4,600
Seed (X_2)	Kg/farm	639.93	557.758	30	3,000
Sawdust (X_3)	Kg/farm	11.20	12.689	0	80
Wood (X_4)	m^3	11.90	10.062	4	55
Nylon bag (X_5)	Kg/farm	155.09	167.317	28	1,080
Electricity (X_6)	1000VND/farm*	1,268.80	980.055	100	4,000
Labor (X_7)	Man-days	357.28	492.230	50	3,000
Socio-economics variables					
Age of manager (Z_1)	Years	48.06	7.192	30	62
Educational level (Z_2)	Years	7.30	1.972	4	12
Experiences (Z_3)	Years	3.46	1.417	1	7

Family size (Z_4)	People	3.58	1.430	2	6
Main labor (Z_5)	People	2.48	0.735	1	4
Household group (Z6)	-	2.60	0.948	1	4

***** 1USD = 23,255VND (Updated 24th 7, 2018)

Besides, on the average, each of farm applied 639.93 kilograms of seeds, 11.20 kilograms of sawdust, 11.90 m^3 of wood, 155.09 kilograms of Nylon bag and 357.28 man-days including hired and family labor. For the rest of socio-economics variables, on average, farmers had 48.06 years old, 7.3 years of educational, 3.46 years of working in edible mushroom production (Table 1). Moreover, the mean family size was 3.58 people and this figure for main labor was 2.48 people.

3. Results and Discussion

The data were analyzed by using the computer program, Frontier version 4.1, proposed by Coelli [14].

The maximum-likelihood estimates (MLE) of parameters in the Cobb-Douglas and translog models were calculated by using FRONTIER 4.1 software and the likelihood ratio was used for testing the null hypothesis. The likelihood ratio was estimated as the Equation (5) as follow:

$$LR = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \quad (5)$$

Where, H_0 was the null hypothesis and assumed by the value of log-likelihood for Cobb-Douglas, H_1 represented the alternative hypothesis and assumed by the value of log-likelihood for the translog model [13]. From equation (5), the result of likelihood ratio test was calculated as LR = -2 (-13.90-14.75) = 57.3. This value exceeded the critical value of Chi-squared distribution for the degree of freedom equal to 28 (41.34) with significant at 5% level. Therefore, the null hypothesis was strongly rejected, implying that the translog frontier production function was an appropriate model for the data of this study compared with the Cobb-Douglas model.

The distribution of the edible mushroom farms based on technical efficiency scores are described in Table 2. The results of the study showed that the technical efficiency scores of farms ranged from 0.12 to 1. The findings illustrated that 23 out of 50 farms recorded technical efficiency score below 0.7, whilst 27 observations registered technical efficiency scores from 0.71 to 1.

Moreover, the average technical efficiency of mushroom farms in Thainguyen province was estimated to be 0.72. In other word, mushroom farms in Thainguyen province produced 72% of the potential frontier output, implying that edible mushroom farms could expand its output by 28%, without changing the input used. Furthermore, this study based on the gamma value of translog model to choose OLS or MLE to explain the data. If $\gamma = 0$, the technical inefficiency was not presented. It meant that OLS was an adequate representation of data. In contrast, if γ was close to unity, it indicated that the frontier model was appropriate [7, 9, 15]. As the results of translog production function model, with $\gamma = 0.999$, the technical efficiency of mushroom farms were represented by MLE results.

The results of the translog production function are presented in Table 3. The estimated coefficients for the logarithm of all input variables in the production model were significantly different from zero. The findings illustrated that the estimated coefficient for the area (Lnx_1), seed (Lnx_2), electric cost (Lnx_6) and labor cost (Lnx_7) were positive. The elasticity for the area (or farm size) was the highest (9.937) with significant at 1% level. This figure was followed by electric, labor and seed cost at 5.579, 4.073 and 3.101, respectively (Table 3). Besides, these results also indicated that the productivity of mushroom farms could be increased by improving the use of land, seed, electricity, and labor cost. On the other hand, an increase in using wood, nylon bag, and sawdust would lead to reducing the mushroom output of farms. Moreover, the gamma (γ) value was equal to 0.999, implying that 99.9 % of the deviation in mushroom production was due to the technical inefficiency of farms.

Table 2: Technical efficiency scores of edible mushroom farms in Thainguyen Province

Technical efficiency scores	**Number of farms**	**Percentage of distribution (%)**
Less than 0.50	14	28.0
0.50 - 0.59	4	8.0
0.60-0.69	5	10.0
0.70-0.79	3	6.0
0.80-0.89	5	10.0
0.90 and above	19	38.0
Total	50	100.0
Mean	0.72	-
Minimum	0.12	-
Maximum	1.00	-

Table 3: Parameter estimates of translog production function

Variables	**Parameters**	**Coefficients**	**t-ratio**
Lnx_1 - Area	β_1	9.937	11.690***
Lnx_2 -Seed	β_2	3.101	3.319**
Lnx_3- Sawdust	β_3	-0.296	-0.320
Lnx_4- Wood	β_4	-22.658	-22.639***
Lnx_5- Nylon bag	β_5	-1.879	-2.034*
Lnx_6 - Electric cost	β_6	5.579	6.019***
Lnx_7- Labor cost	β_7	4.073	4.570***
$1/2(Lnx_1)^2$	β_8	1.085	1.060
$1/2(Lnx_2)^2$	β_9	0.290	1.110
$1/2(Lnx_3)^2$	β_{10}	0.211	6.080***
$1/2(Lnx_4)^2$	β_{11}	-4.540	-6.080***
$1/2(Lnx_5)^2$	β_{12}	-8.584	-9.393***
$1/2(Lnx_6)^2$	β_{13}	-2.300	-5.810***

$1/2(Lnx_7)^2$	β_{14}	-2.161	-4.577***
Lnx_1*Lnx_2	β_{15}	-1.510	-5.813***
Lnx_1*Lnx_3	β_{16}	-1.517	-7.604***
Lnx_1*Lnx_4	β_{17}	5.013	9.904***
Lnx_1*Lnx_5	β_{18}	-2.731	-3.540**
Lnx_1*Lnx_6	β_{19}	-0.883	-2.083*
Lnx_1*Lnx_7	β_{20}	0.581	1.386
Lnx_2*Lnx_3	β_{21}	-0.119	-0.813
Lnx_2*Lnx_4	β_{22}	0.853	2.026*
Lnx_2*Lnx_5	β_{23}	-0.787	-1.402
Lnx_2*Lnx_6	β_{24}	0.365	1.789*
Lnx_2*Lnx_7	β_{25}	0.554	1.660
Lnx_3*Lnx_4	β_{26}	-1.615	-3.550**
Lnx_3*Lnx_5	β_{27}	1.380	2.178**
Lnx_3*Lnx_6	β_{28}	0.528	1.740
Lnx_3*Lnx_7	β_{29}	0.646	0.240
Lnx_4*Lnx_5	β_{30}	4.397	6.224***
Lnx_4*Lnx_6	β_{31}	-1.647	-4.192***
Lnx_4*Lnx_7	β_{32}	-1.364	-3.214**
Lnx_5*Lnx_6	β_{33}	5.069	3.643**
Lnx_5*Lnx_7	β_{34}	0.287	0.364
Lnx_6*Lnx_7	β_{35}	-1.534	-5.479***
Constant	β_0	-28.024	-27.964***
Sigma squared	σ^2	0.056	4.437***
Gamma	γ	0.999	127.219***

Notes: ***,**,* indicate significant at 1%, 5% and 10% level, respectively

Besides, this study used the generalized likelihood ratio (LR) for testing the null hypothesis. From Equation (5), the result of LR test was equal to 57.65. This value exceeded the critical value of Chi-squared distribution for the degree of freedom equal to 7 (14.07). Therefore, the null hypothesis, which stated that there are no inefficiency effects in the model, was strongly rejected. It meant that inefficiency effects existed in the model. The estimated coefficients of explanatory variables are represented in Table 4. The results indicated that all socio-economic variables had significant effects on the technical inefficiency of mushroom farms. The positive sign on age displayed that farms with old manager achieved lower technical efficiency level than that of young counterparts. The relationship between age of farmers and technical efficiency level also stated in studies of Dlamini *et al*. [8]; Linh [16]; Saiyut *et al*. [10]. The positive sign of family size on the technical inefficiency model denoted that the higher the number of family members, the fewer technical efficiency score [7, 11, 17].

Table 4: Determinants of technical inefficiency model by Tranglog

Variables	Coefficients	t-ratio
Constant	2.105	2.317*
Age of household head	0.025	1.901*
Educational level	-0.229	-3.861***
Experience of household head	-0.010	-0.136
Family size	0.147	2.108*
Main labor	-0.245	-1.739**
Type of household	-0.585	-5.477***

Notes: ***, **,* indicate significant at 1%, 5% and 10% level, respectively

Moreover, the negative coefficient of educational level illustrated that the farm's manager with higher education lead to obtain higher technical efficiency at 1% significant level. This result was consistent with the studies of Linh [16], Bozoğlu and Ceyhan [18].

In addition, the findings also revealed that type of household factor had the highest coefficient compared with other factors, meaning that technical efficiency scores of farms were the most influenced by factors determining the type of household. At 1 % significant level, the farms with higher income tended to get higher technical efficiency level because they can enhance their production by an increase in investment in improving technology as well as expanding farm scale.

4. Conclusions

The development of mushroom production was known as an important strategy to improve livelihood for rural people in Thainguyen province. This study applied SFA approach to analyze technical efficiency and to determine factors affecting inefficiency on mushroom farms in Thainguyen province of Vietnam. The findings indicated that average technical efficiency score was 0.72 and it ranged from 0.12 to 1.

All most explanatory variables had significant effects on technical inefficiency of farms. Age and family size had a positive effect on technical inefficiency, while the negative sign was shown on educational level, main labor of household and type of household group. The results highlight the improvement of training actives and enhancing the income of households will contribute to increasing the technical efficiency of farms.

The empirical findings of this research suggested that Thainguyen province should give the policy related to training and investment actives to help farms to apply high technology in production efficiently leading to enhancing the efficiency level of mushroom farms in Thainguyen province.

5. Acknowledgments

We would like to say many thanks to Thainguyen Department of Agriculture and Rural Development and Department of Tropical Agriculture and International

Cooperation, National Pingtung University of Science and Technology (NPUST) for supporting to conduct this study. Finally, we are grateful to the reviewers for their valuable comments and suggestions on our manuscript.

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