Technical Efficiency of Edible Mushroom production farms in Thai Nguyen province, Vietnam

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Abstract _ Edible mushroom plays an important role in the diet of human as well as an economic field because of its efficiency. The aim of this paper was to measure technical efficiency of edible mushroom production by using Data Envelopment Analysis and Tobit regression model. The results showed that the average of technical efficiency level were 0.567, 0.834 with input-oriented CCR-DEA and BCC-DEA, respectively. In addition, the findings indicated that factors had positive influences on technical efficiency which include age, education and family size. The results suggested that improving educational level of manager's farms will help them to update and approach new technology in production leading to enhance the efficiency of mushroom production in Thai Nguyen province.

Index Terms _ Technical efficiency, Data Envelopment Analysis, Tobit regression model, CCR-DEA, BCC-DEA

1 Introduction

Edible mushroom is known as a product using extensively in the diet of human around the world because of their nutritional and medicinal value. Mushrooms are used widely not only as food but also in the area of medicine for human healthy. According to Rathore et al. [20] mushroom has 12000 species in natural environment in which edible mushroom account for 2000 species and nearly 200 species are used for pharmaceutical sector. Moreover, edible mushroom is also considered as a sources of protein-rich food, vitamin, acid folic and minerals like potassium, calcium, phosphorus and magnesium [3], [20].

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Besides, edible mushroom cultivation also helps to use efficiently agricultural wastes because the raw materials to produce mushroom almost originated from agriculture and forestry sector such as paddy straw, sawdust, wood, and other cost.

In recent years, edible mushroom production is growing increasingly in many regions in the world because of well-adaptability climatic conditions; short growing times; very low cost for production, and easy production technologies [21].

Therefore, the development of edible mushroom cultivation will contribute to create the job, income as well as reduce the poverty rate in the rural area.

In Vietnam, since 2012, edible mushroom has been considered as a prioritized commodity for investment and development because of its economic efficiency.

Thai Nguyen is a mountainous province, located in the North of Vietnam with the natural area is 354,655, 25 ha [11]. In recent years, Thai Nguyen province issued many policies to support and encourage farms in developing edible mushrooms production. Hence, the number of mushroom producing farms are increasing significantly. However, edible mushroom production households in Thai Nguyen province are facing many difficulties such as small scale production, lack of linkage in production, low price, unstable output market, lack of applying hi-technology in production. Therefore, the study on analysis technical efficiency in edible mushroom production is necessary in Thai Nguyen province.

Moreover, according to Farrell [10], technical efficiency refers to the ability of farm to obtain maximal output from a given set of inputs. There are two main methods to measure technical efficiency of farms or firms which include parametric (Stochastic Frontier Analysis) and non-parametric methods (DEA-Data Envelopment Analysis). DEA method is considered as a widely technique in measuring the efficiency of multiple decision-making units (DMUs). Therefore, this study focused on DEA techniques to analyze the technical efficiency of edible mushroom farms in Thai Nguyen. In recent years, many authors used DEA methods to estimate technical efficiency in agricultural sector due to its advantages compare to parametric frontier methods [13]. Mardani and Salarpour [17] applied DEA technique for measuring technical efficiency of potato producers in 23 Iranian provinces. The research based six input variables (human labor, land, diesel and machinery, irrigation water cost, fertilizer cost and pesticide cost). The results indicated that the average technical and scale efficiency of potato producers are quite high with 90% and 97%, respectively. The findings of research suggested that inefficient provinces were improved by reducing their overall cost for potato production. Au (2016) [1] used output-oriented DEA methods to analyze technical efficiency of oyster mushroom production in Quang Tri province of Vietnam. The findings revealed that mushroom farms should expand their current level of output from 9 to 17% to be efficient because technical inefficiency of farms was mainly due to scale inefficiency. In addition, determining factors influencing inefficiency plays an important role in suggesting solutions for policymakers. There are many ways to identify factors, in which Tobit regression model was chosen commonly by studies. Tobit regression is used to explain the likelihood of changes in inefficiencies by farm-specific factors [14].

Liu et al. [16] employed the DEA-Tobit model to analyze eco-efficiency level of tourism in Chinese coast cities. The results of the study showed that economic and ecological indicators have significantly positive influences on eco-efficiency score, while the number of visitors and the use of pollutants have a negative impact. DEA and Tobit model applied by Sağlam (2017) [22] to evaluate efficiency of 39 state's wind power in the United States. In this research, the author indicated the difference in efficiency levels between early installed wind power and currently installed others. The new wind powers showed is more efficient than other installed previous. Using Tobit model to identify factors influencing the technical efficiency of sorghum production in Kenya was investigated by Chepng'etich et al. (2015) [7]. The study showed that socio-economics factors like educational level, experience, and farmers' associations affected significantly to technical efficiency of sorghum farmers.

This study aim to estimate technical efficiency of edible mushroom farms and to determine the factors influencing inefficiency farms. Therefore, the above literature reviews have shown that to obtain the objectives of this study, input-oriented DEA method and Tobit regression model should be applied.

2 Materials and Methods

2.1 Data collection

The study was conducted in Thai Nguyen province which located in the Northern mountainous region of Vietnam. Data were collected from 50 edible mushroom farms by using a face-to-face interview. The formal survey was conducted by structured questionnaires in which include information relating to yield of edible mushroom and input variables such as land, seed, sawdust, wood, powdered lime, labor, electricity and other cost. Besides, socio-economic information of farms was also gathered such as age, educational level, the experience of farm manager in mushroom production.

2.2 Data envelopment analysis method

Data envelopment analysis (DEA) is a non-parametric tool using to measure the efficiency in various research fields [18]. It is also applied in the estimation of production functions and developed by Charnes et al. (1978) [6]. According to Khoshroo et al. (2013) and Raheli et al. (2017)

[13,19], the DEA is known as a mathematical programming approach for comparing the inputs and outputs of a homogeneous number of producers which were called decision-making units (DMUs). These DMUs use multiple inputs to produce multiple outputs. In this study, DMUs refer to each edible mushroom farm.

In DEA approach, there are two main models that include input-oriented and output-oriented [4]. Input-oriented model means that an inefficient farm can be become efficient by reducing the number of inputs used without a decreasing in output [8], [19]. While, maximizing in output production with input levels constant called output-oriented approach [4], [8], [19]. Using input or output orientation depends on the characteristics of each study. In present study, the input-oriented model is more suitable to estimate technical efficiency of farms (farms used multiple inputs, while only one output is produced).

*** CCR model in DEA**

Following Charnes-Cooper-Rhodes (CCR), the efficiency is considered as the ratio of its weighted outputs to its weighted inputs (Mardani & Salarpour, 2015) [17]. According to Raheli et al [19], technical efficiency of DMUs can be expressed by the ratio of sum of the weighted outputs to sum of the weighted inputs as the equation (1) below:

$$TE_k = \frac{\sum_{r=1}^{s} u_r\, y_{rk}}{\sum_{i=1}^{m} v_i\, x_{ik}} \qquad (1)$$

Where, TEk is technical efficiency of farm k using m inputs to produce s outputs; yrk is the quantity of output r produced by farm k; xik is the quantity of input i consumed by farm k; ur is the weighted of output r (r = 1,…, s); vi is the weighted of input i (i = 1,…,m). Charnes et al. (1978) [6] developed equation (2) into a linear programming model as follow:

$$\text{Maximize} \quad \theta o = \sum_{r=1}^{s} u_r\, y_{ro} \qquad (2)$$

$$\text{Subject to} \quad \sum_{i=1}^{m} v_i\, x_{io} = 1$$

$$\sum_{r=1}^{s} u_r\, y_{rk} - \sum_{i=1}^{m} v_i\, x_{ik} \le 0, \forall k,$$

$$u_r \ge 0, v_i \ge 0 \qquad \forall r, i$$

Where θ is the technical efficiency of DMUo and k represents kth DMUs (k=1,…,n). Therefore, Eq. (2) is known as the original CCR DEA model.

In this research, the input-oriented CCR model is applied. It is developed by Charnes et al. (1978) [6] and a linear programming can be expressed as equation (3) follow:

$$\text{Min } \theta - \varepsilon \left(\sum_{i=1}^{m} si- + \sum_{r=1}^{s} sr+\right)$$

$$\text{S.t. } \sum_{k=1}^{n} xik\lambda k + si- = \theta xio, \quad i = 1,2,\dots m; \qquad (3)$$

$$\sum_{k=1}^{n} yrk\lambda k - sr+ = yro, \quad r = 1,2,\dots,s;$$

$$\lambda k \ge 0,\ si- \ge 0,\ sr+ \ge 0\ \forall i, r, k,\ k = 1,\dots,n$$

Where si- and sr+ are slack variables. ε is a positive and called non-Archimedean element defined to be smaller than any positive real number and it is used to prevent the weights from being zero [9], [25].

*** Input-oriented BCC model**

The input-oriented BCC model is developed by Banker et al. (1984) [2]. It can be described as equation (4) below:

$$\text{Min } \theta - \varepsilon \left(\sum_{i=1}^{m} si- + \sum_{r=1}^{s} sr+\right)$$

$$\text{S.t. } \sum_{k=1}^{n} xik\lambda k + si- = \theta xio, \quad i = 1,2,\dots,m; \qquad (4)$$

$$\sum_{k=1}^{n} yrk\lambda k - sr+ = yro, \quad r = 1,2,\dots,s;$$

$$\sum_{i=1}^{m} \lambda k = 1;$$

$$\lambda k \ge 0,\ si- \ge 0,\ sr+ \ge 0\ \forall i, r, k$$

$$k = 1,\dots,n$$

Where ε is the same as that in CCR model; si- and sr+ are slack variables; $\lambda k \ge 0$ is dual variables; the value of $\sum_{i=1}^{m} \lambda k = 1$ is the variable returns to scale.

2.3 Tobit regression model

The Tobit regression model is a statistical model proposed to describe the relationship between a non-negative dependent variable and an independent variable (Tobin, 1958). The Tobit model can be expressed as equation (5), (6), (7) follow:

$$Y^* = \beta Zi + \varepsilon i, \; i = 1,2,\dots\dots N \qquad (5)$$

$$Yi = Yi^* \text{ if } Yi^* > 0 \qquad (6)$$

$$Yi = 0 \text{ if } Yi^* \le 0 \qquad (7)$$

Where, Yi is the dependent variable, Yi* is latent variable, β is a vector of estimable parameters, Zi is a vector of independent variables related to farm characteristics which include age of manager (Z1), educational level (Z2), experience of household head (Z3), family size (Z4) and the number of main labor (Z5), εi is a normally and independently distributed error term with zero mean and constant variance σ2, and N is the number of farms [16].

2.4 Data analysis

The study used DEA-Solver LV8 and Eviews version 9 software to analyze the data. Base on DEA model to measure efficiency, the choice variables play an important role. The variables were chosen including one output variable that is the total yield of edible mushroom (Y), and eleven input variables such as cultivated area (X1), seed (X2), powdered lime (X3), sawdust (X4), rubber band (X5), cotton button (X6), wood (X7), straw (X8), nylon bag (X9), electricity (X10) and labor (X11). Moreover, socio-economic indicators like age of manager, educational level, experiences, family size and main labor of farms used to analyze factors influencing inefficiency on edible mushroom production in Thai Nguyen. The summary of variables presented in the Table 1.

TABLE 1. DESCRIPTIVE STATISTICS OF VARIABLES FOR EDIBLE MUSHROOM FARMS

Variables	Unit	Mean	Std. Deviation	Min	Max
Output variable					
Total output (Y)	Kg/farm	4606.90	2572.785	750	15000
Input variables					
Cultivated area (X_1)	m2	462.40	710.411	100	4600
Seed (X_2)	Kg/farm	639.93	557.758	30	3000
Powdered lime (X_3)	Kg/farm	2430.70	10664.631	50	75000
Sawdust (X_4)	Kg/farm	11.20	12.689	0	80
Rubber band (X_5)	Kg/farm	19.79	35.700	3	220
Cotton button (X_6)	Kg/farm	82.74	69.879	15	360
Wood (X_7)	m3	11.90	10.062	4	55
Straw (X_8)	Tons/farm	5.46	8.782	0	50
Nylon bag (X_9)	Kg/farm	155.09	167.317	28	1080
Electricity (X_{10})	1000VND/farm*	1268.80	980.055	100	4000
Labor (X_{11})	Man-days	357.28	492.230	50	3000
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

* 1USD = 22,795VND (Updated 1/6/2018)

The results indicated that there was a large difference in yield of edible mushroom farms. It ranged from 750 kg/farm to 15000kg/farm, with an average yield of 4,606.90 kg per farm. On the inputs side, the average amount of powdered lime using to produce mushroom was the highest (2,430.70kg/farm) and the figure was followed by electrical cost with 1,268.80 VND per farm. Besides, the cost for the labor of edible mushroom farm was quite high, with 357.28 man-days per farm. The results also showed that the average of managers' age was 48.06 years, educational level was 7.30 years, and farms worked in edible mushroom production around 3.46 years. In Thai Nguyen, almost edible mushroom farms need labor in harvesting and processing. Therefore, the factors related to family size and main labor have an important role in the edible mushroom production of farm. The average of family size was 3.58 people and this figure for main labor was 2.48 people.

3 Results and Discussion

3.1 Technical efficiency of edible mushroom farms

This study based on input-oriented CCR and BCC to measure the technical efficiency of mushroom farms. The results were illustrated in the Table 2:

Table 2: Results of technical efficiency of edible mushroom farms in Thai Nguyen province based on CCR and BCC model

TE levels	CCR-DEA		BCC-DEA	
	No. of farms	Percent (%)	No. of farms	Percent (%)
Less than 0.50	23	46	8	16
0.50-0.59	7	14	3	6
0.60-0.69	8	16	5	10
0.70-0.79	1	2	1	2
0.80-0.89	0	0	1	2
0.90 and above	11	22	32	64
Mean	0.5671		0.834	
Min	1		1	
Max	0.1193		0.2222	
St. Dev	0.2763		0.245	

There was the difference in efficiency levels of farms between CCR and BCC model. The number of efficient farms based on BCC-DEA model was higher than CCR model. According to the results of CCR model, 11 edible mushroom farms were efficient, with technical efficiency score from 0.90 to 1. It meant that there were 39 inefficient farms. Moreover, the average of TE score was quite low (with 0.5671). The findings suggested that under constant return to scale those farms could potential to reduce the current of all inputs by 43.29% with the same output level. Based on input-oriented BCC model, the number of efficient farms was 32, account 64% of total farms. The mean of TE score was 0.834, which was about 0.267 higher than CCR model. The results showed that the edible mushroom farms in Thai Nguyen province could decrease 16.6% inputs without compromising the current output level.

3.2. Factors influence the efficiency of edible mushroom farms in Thai Nguyen province

In order to determine factors affecting inefficiency to farms, Tobit regression model was used. It was applied to show the relationship between dependent variables (TE score based CCR and BCC-DEA model) and independent variables like age of manager, educational level, experience of household head, family size and the number of main labor. The results of Tobit regression was illustrated in Table 3. All socio-economic variables had effects on the technical efficiency of farms. The positive sign on age, education and family size displayed that these factors had an effect on technical inefficiency. This meant that old manager obtained fewer technical efficient level than of young manager. The relationship between age of household head and farm efficiency also was stated by Bozoğlu and Ceyhan (2007), and (Linh, 2016; Saiyut et al., 2018) [5], [15], [23]. However, in our result, the statistic of p-value showed that this factor was unable to explain the effect of age on technical efficiency score because of no significant statistics at 10%.

Table 3: Factors affecting technical efficiency of edible mushroom farms

Variable	Coefficient	Std. Error	z-Statistic	Prob.
Age_Z1	0.0074	0.0054	1.3721	0.1700
Education_Z2	0.0085	0.0192	0.4453	0.6561
Experience_Z3	-0.0368	0.0274	-1.3446	0.1787
Family size_Z4	0.0571	0.0347	1.6434	0.1003
Main labor_Z5	-0.0806	0.0498	-1.6158	0.1061
Constant	0.6552	0.3736	1.7537	0.0795

The education variable had positive impact on technical efficiency of farms. This indicated that manager with higher education lead to obtain higher technical efficiency, but the p-value (p-value = 0.6561) showed that this factor was unable to explain the effect of education level on technical efficiency score because of no significant statistics at 10%. In addition, labor was considered as an important factor affecting to efficient levels of farm and it is illustrated by family size and the number of main labor. It is clearly shown from Table 3 that family size had a positive effect on the technical efficiency of farms. It means that farms with big family size are expected to reduce labor cost and obtain higher efficiency level than others.

In contrast, the negative coefficient signified the effect of decreasing technical efficiency of farms. The results also illustrated that the experience of farm manager had negative effect on technical inefficiency. This result was also investigated in the study of Linh (2016) [15]. However, the experience was showed to have significant positive effects on technical efficiency of household tea in Thai Nguyen province [12]. Besides, factor related to the number of main labor of farm also had negative impact on input-oriented technical inefficiency.

4 Conclusion

Edible mushroom production plays vital role in creating job as well as income for rural people in Thai Nguyen province. In this study, we employed input-oriented DEA method and Tobit regression model to estimate technical efficiency and to determine factors affecting inefficiency on edible mushroom farms. The findings indicated that the mean technical efficiency score was 0.567 with CCR-DEA model, which was about 0.267 less than BCC approach. The factors related to age, education and family size had positive impact to technical efficiency of edible mushroom. The results suggested that improving educational level of manager's farms will help them to update and approach new technology in production leading to enhance the efficiency of mushroom production in Thai Nguyen province.

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