The Study of Technical Efficiency in Tomato Production: The Case Study of Mekong River Bank, Thailand

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Abstract— *This study was proposed to investigate tomato cultivation management, use of input factors and factors affecting the technical efficiency of farmers in contract farming, a case study of Nong Khai and Bueng Kan province. Collecting from 396 household levels in year crop 2016/17, the data were evaluated for technical efficiency by stochastic frontier approach (SFA). Results were found that factors increasingly affecting tomato production included farmland, cultivation period, chemical reagent, tillage, and plots on the bank of Mekong River and trellis construction. The influential factors raising technical efficiency were the utilization of machines for plot preparation and chemical application, while trellis construction and farmland caused reduced technical efficiency. The technical efficiency on average equaled 0.481 which was identified as low-level efficiency. To perform cultivation by the river, it is not only furnishing sustainable and eco-friendly aspect but also providing the major incomes for population inhabiting on the riverside. Therefore, the government is supposed to profoundly consider riverside agriculture, reinforce management and production technology for farmers as well.*

Keywords— **Tomato production, technical inefficiency, Mekong River, riverbank garden, stochastic frontier approach.**

1. INTRODUCTION

Tomato (Lycopersicon esculentum Mill.) is one of the most important vegetables in the World. Since it is an approximately short duration crop and provides a high yield, this crop is a cost-effective vegetable to farmers. Besides, the plantation area is increased and this vegetable is an essential source of nutrients. To smallholders, it is the crucial cash crop [1]. According to an estimated 6.0 million ha, World tomato production in 2016 was nearly 841 million tons of fresh fruit [2]. The tomato cultivation with sustainable and eco-friendly aspects is to grow the vegetables by a large river in the low tide season. This study particularly had investigated tomato cultivation on the bank of Mekong River which provides a plenty of farmland in dry season period [3].

Mekong River Commission [4] had reported the Mekong River is one of the important rivers of the World which is 4,904 kilometers long. Starting from the eastern water shed of the Tibetan plateau, it flows through several areas including China, Laos, Thailand, Myanmar, Cambodia and Vietnam. Therefore, these countries earn many benefits from the river, that is, water energy, water transportation, tourism, biodiversity, aquaculture and irrigation on the agricultural purpose. Each country had to make an agreement to execute water management cooperation in the Greater Mekong Sub-region. There was a great concern about considerable water management due to large dam construction. The effects of climate change and loss of biodiversity are able to affect inhabitant of more than 65 million populations on the bank of Mekong River. However, riverside cultivation is relied on high tide and low tide season farmers are still able to perform agricultural activities in wet and dry season [3]. Erosion of river bank and construction of many large dams play a major part in cultivation by river bank [5].

In Thailand, the main tomato cultivated area is the in the Northern and the Northeast part which particularly, located in the two neighboring provinces, Nong Kai and Bueng Kan. Most farmers widely operate the vegetation farms by the Mekong River. The river sediment is a warehouse of mineral and organic matters allocating both sides of river [6]. Based on the report of Nong Khai Provincial Agricultural Extension Office [7], it was stated that farmers were required to conduct contract farming with the particular industry including Roza Agri-Industrial Co., Ltd., Srichiengmai Industry Co., Ltd. and Thai Soon Foods Co., Ltd. Moreover, the government realized the importance of processed tomato industry in 2012-2016, the tomato cultivation strategies for industrial purpose was reinforced in Nong Kai province [8].

Cultivating tomatoes is counted on crop rotation. Farmers initially cultivate tomato when water tides of Mekong River are lower. The soil on the riverside is enriching with nutrient and there is triviality of ecological disturbance in land exploitation, as well. In addition, it is sustainable agriculture [3]. In dry season, growing tomato sprout is begun in October – November (figure 1) and harvesting in January – March. Most farmers conduct rice cultivation in May-September of wet season (figure 2). Farmers adopt open access where is no greenhouse constructed. Meanwhile, simple trellises with bamboo and rope structure are built. Due to less support in tomato production and drastic disturbance of disease and insect, farmers still need to enhance technical efficiency and plant management systems to raise production yield and effectively use input factor

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(figure 2). Therefore, the evaluation of production efficiency is crucial for developing tomato production.

Fig. 1. Dry season. Source: Mekong watch (2013).

Fig. 2. Wet season. Source: Mekong watch (2013).

There were several reports evaluating technical efficiency of tomato production by stochastic frontier approach (SFA) in many countries including Pakistan [9], Nigeria [10], Turkey [11], Spain [12], and Switzerland [13]. Additionally, Najjuma and Colleagues [14] had analyzed technical efficiency in open-access tomato production. To our best knowledge, there is no study proposing about evaluation of technical efficiency in plant production on the bank of river during low tide.

The principal input factors considering the conventional variable factors of production included land, labor, fertilizer, chemical agents, cultivating period and non-conventional factor which expectedly affected to yield production [15]. Generally, farmers performed ploughing (or digging) in order to modify the soil structure. While some of them preferred performing tillage or growing tomato on raised beds and ridges for the purpose of providing better drainage. Constructing trellis for tomato with bamboo poles, wood stakes, or other tough material was not only supporting the plant structures but also maintained the fruit and foliage above the ground. Besides, staking enhanced fruit yield and size, minimized fruit rot, and be convenient for spraying and harvesting [1].

Plantation area beside Mae Kong River possesses enrichment from river sediment. [16] Most farmers used machine in tomato production for soil preparation and chemical spraying. In 2017, Qiao [16] had studied about raising agricultural wages and utilizing machine in China. He reported that replacement of intensive labor by agricultural mechanization had impacted on grain production and negatively affected cotton production during 2000-2014, but some farmers preferred employing man labor. Individual characteristics, in particular, age and educations possibly affect technical efficiency. To reveal the differences in the inefficiency effects among the farmers, the influential managements of tomato production including trellis and machine utilization were investigated.

2. MATERIALS AND METHODS

We had investigated estimation of the tomato production frontiers using parametric approach, Stochastic Frontier Approach [17] [18]. The model followed by [19] was then employed to determine the factors relating with technical efficiency. The method is able to analyse cross-section data and panel data. Error term is separated into 2 parts comprising noise and technical inefficiency and the equation form is presented as:

$$y_i = f(x_i, \beta_i)\exp(v_i - u_i) \quad (1)$$

where y_i is the output at i = 1,...N , β_i is unknown parameter, x_i is production factor, v_i is noise which can be either positive or negative, have normal distribution, be independent from u_i While, u_i is technical inefficiency. Technical efficiency model was presented by [20] as following equation.

$$u_i = z_i \delta_i + w_i \quad (2)$$

where δ_i is unestimated coefficients, w_i is error term, z_i is vector of explanatory variables associated with technical inefficiency effects. The estimation of SFA is aimed to investigate the inefficiency effect. To evaluate the output-oriented measure of technical inefficacy, the ratio of observed output to stochastic frontier is calculated concertedly according to the expression below [20].

$$TE_i = \frac{y_i}{\exp(x_i \beta_i + v_i)} = \frac{\exp(x_i \beta_i + v_i - u_i)}{\exp(x_i \beta_i + v_i)} = \exp(-u_i) \quad (3)$$

3. DATA AND VARIABLES

This study used primary data collecting in household level from the interview of 369 farmers with questionnaires in Nongkai and Bueng Kan provinces, crop year 2016/17. The values of explanatory variables in the translog stochastic frontier model were mean-corrected to zero. The quantity of tomato production equation was relied on conventional variable including farmland (in hectare), cultivating time (in month), labor (in manday) and value of chemical agents (in baht). On the other hand, non-conventional variable demonstrated qualitative variables in terms of dummy variables including tillage, plots on the bank of Mekong River, trellis and machine.

Table 1. Summary of the observed sample statistics

Variable	Unit	Mean	Minimum	Maximum	Average per ha
production function					
Tomato product (output)	kilogram	12,910.0	216.0	84,000.0	6,455
Farmland	hectare	0.5	0.05	8.0	-
Labor	manday	18.9	1.5	110.0	32.0
Cultivating time	month	5.5	2.0	9.0	-
Chemical reagent value	baht	556.7	0.0	10,000.0	1666.7
Tilling	dummy	0.80			
Plots on the bank of Mekong River	dummy	0.79			
Trellis construction	dummy	0.54			
Machine utilization	dummy	0.80			
Efficiency model					
Age	year	51.0	16.0	96.0	-
Education	year	7.8	0.0	18.0	-
Farmland	hectare	0.5	0.05	8.0	-
Trellis construction	dummy	0.54			
Machine utilization	dummy	0.80			

Note: * were dummy variable
Source: Survey

Table 2 Hypothesis testing

Hypotheses	$L(H_0)$	$L(H_1)$	df	LRtest	at the level of 0.01 statistical significance	Result
Production function H_0: Cobb-Douglas H_1: Translog	-470.5	-462.0	16	16.92	23.5	**Accept** H_0
Existence of technical efficiency $H_0: \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$ $H_1: \gamma \neq \delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq 0$	-514.3	-470.5	10	87.6	22.5	**Reject** H_0

Source: Estimation

4. HYPOTHESIS TEST

This study used Likelihood-Ratio Statistic (LR Test) to investigate the hypothesis. The test was conducted as following 1) Defining the appropriate production function between Cobb-Douglas and Translog 2) Testing for the existence of the inefficiency in production function, according to the formula below:

$$LRtest = -2[L(H_0) - L(H_1)] \quad (4)$$

where LRtest is Likelihood-Ratio statistic, $L(H_0)$ is value of log likelihood under the null hypothesis and $L(H_1)$ is value of log likelihood under the alternative hypothesis

1) The result of production functions between Cobb-Douglas model and Translog. Given that $L(H_0)$ is likelihood function of Cobb-Douglas and $L(H_1)$ is likelihood function of Translog, then LR Test equaled 16.92. When comparing chi-square at 99% confidential range, the statistic value was equivalent as 23.54. Therefore, the results of hypothesis test had accepted H_0 and rejected H_1. In consequence, Cobb-Douglas model is the most suitable function in estimating SFA. (Table 2).

2) The results of existence of the inefficiency in production function. Given that $L(H_0)$ is value of likelihood function of Ordinary Least Square (OLS) and $L(H_1)$ is value of likelihood function of Maximum likelihood Estimation (MLE), then LR Test, equaled 78.66. When comparing to critical region from Kodde and Palm at confidence level 99%, the statistic value equaled 22.52 (greater than critical region). Therefore, the results of hypothesis test showed rejecting H_0 and accepting H_1. Consequently, there was no inefficiency in production function (Table 2).

5. RESULTS AND DISCUSSION

5.1 Stochastic production frontier estimates

According to the estimation of coefficient in tomato production stochastic frontier, it was found that Cobb-Douglas was the most appropriate estimating function. Most of input factors positively influenced quantity of tomato product except machine utilization. Factors that was statically significant at level of 0.01 comprised farmland and cultivating time. As tomato plantation was inevitably counted on farmland, the coefficient equaled 0.734. On the subject of cultivating time, the longer period made farmer enable to harvest frequently [1] and the coefficient of this factor was 0.384. Factors being statically significant at the level of 0.05 composed of chemical reagent and trellis construction. Chemical reagent demonstrated level of protection from pest and disease and the coefficient was 0.020. Given that the other factors were constant, increasing 3 factors i.e. farmland size, cultivating time and chemical reagent only 1% could enhance the amount of tomato product 74.3%, 38.4% and 2%, respectively. Dummy variable in production function possessing statistical significance at 0.0 was tillage. This activity helped promoting drainage and root system of tomato leading to the higher quantity of product [1]. The variables that possessed statistical significance at level of 0.05 were plots on the bank of Mekong River and trellis construction. The enrich nutrient from river sediment caused greater amount of tomato product [3], [5]. Trellis construction provided tomato plants to expand their branches freely; in consequence, tomato products were increased [1].

Table 3. Coefficient of the particular variables from estimation of production frontier

Variables	Coefficient	standard -error	t-ratio
Constant	0.659	0.175	3.769***
Farmland	0.734	0.071	10.307***
Fertilizer	0.026	0.042	0.619
Labor	0.024	0.063	0.379
Cultivating time	0.384	0.155	2.474***
Chemical reagent	0.020	0.012	1.685**
Tillage	0.253	0.085	2.978***
Plots on the bank of Mekong River	0.157	0.086	1.837**
Trellis construction	0.215	0.094	2.299**
Machine	-0.110	0.144	-0.763

Source: Estimation

Note: ***statistically significant at level of 0.01

** statistically significant at level of 0.05

5.2 Inefficiency effects

According to the estimation of technical efficiency model of household level, the result revealed that the factors positively influencing technical efficiency comprised machine utilization in manufacturing process. On the other hand, farmland and trellis construction represented the factors that decreased the technical efficiency.

The variable supplementing technical efficiency of tomato cultivation was utilizing machine. It was able to prepare plots and spray chemical reagent better than labor. There was associated with study of Lei et al., (2016) [21], which analyzed technical efficiency of grape farm in China. The research was proposed that using machine in grape farm management enabled to improve technical efficiency.

The factor negatively influencing technical efficiency was farmland. Since, the tomato cultivation used intensive labor and being sensitive to disease and insect, farmers with small size farmland were able to deal with the tasks. Moreover, they had developed cultivating technology for large size tomato farm by means of greenhouse. There were 2 studies of Donkoh and coworkers [22] and Najjuma [14] which evaluated technical efficiency of tomato cultivation in Nigeria and Kenya, the results were reported that size of tomato farms inversely affected to the technical efficiency.

The technical efficiency was decreased in trellis construction. Owing to stem extension in tomato, farmers had to take more responsibility to perform farm management. According to the study of Mustapha [23] which investigated rubber plantation in Malaysia, the result showed that increasing of rubber tree per ha had effected on reduced technical efficiency with labor-intensive agriculture, the increase of plants made managing factors more difficult.

The overall mean of technical efficiency of tomato cultivation equaled 0.481. Sigma square (δ^2) was not equivalent to 0 means the technical efficiency is statistically significant with normal distribution. While, gamma (γ) equaled 0.96 that is ratio of the technical efficiency was higher than noise and it was able to interpret statistical significance [20].

Table 4. Maximum-likelihood estimates for first-order parameters of the Cobb-Douglas production frontier

Variables	Coefficient	standard-error	t-ratio
Constant	-1.025	1.665	-0.616
Age	0.012	0.019	0.646
Education	-0.039	0.063	-0.623
Farmland	0.148	0.045	3.316***
Trellis construction	1.165	0.479	2.433***
Machine	-2.091	0.686	-3.047***
sigma-squared (δ^2)	2.922	0.996	2.933
gamma (γ)	0.965	0.013	73.197

Source: Estimation

Note: ***statistically significant at level of 0.01
** statistically significant at level of 0.05
*statistically significant at level of 0.1

According to the density from estimation of technical efficiency as shown in Figure 1, there was insignificant difference of the distribution of technical efficiency with average as 0.48 and median as 0.505. These results were less than technical efficiency from the study of Najuma and coworkers [14], although it was relatively corresponding to the study of Kramol and coworks [24] which conducted the research about vegetable production in Thailand. Overall, farmers possessed rather low technical efficiency revealing that there was high opportunity to develop management of tomato production.

6. CONCLUSIONS AND DISCUSSIONS

From the result of technical efficiency analysis for tomato cultivation in Nong Kai province using SFA, it was found that the factors enhancing tomato production included farmland, cultivating period, chemical reagent value, tillage, plots on the bank of Mekong River and trellis construction. As a consequence of open-field tomato growing in these particular areas, therefore it was rather difficult to cope with inputs or other associated factors i.e. pest, diseases, temperature, etc., therefore average technical efficiency was shown as 0.481 indicating low-level of productivity.

Since, tomato requires daily care, for this reason, the cultivated area should not be to larger than 0.5 hectares for each farm. We also suggest that all farms are supposed to construct trellis to increase tomato production, despite time-consuming job and labors management. Although increasing chemical utilization had reinforced productivity, it also caused higher production costs and affected farmer's health [15]. Accordingly, farmers should use any chemical derived from natural substances or biocontrol instead of chemical utilization [25-26]. Furthermore, the related organization should provide helpful advice and conduct technical efficiency assessment occasionally to maintain long-term effectiveness.

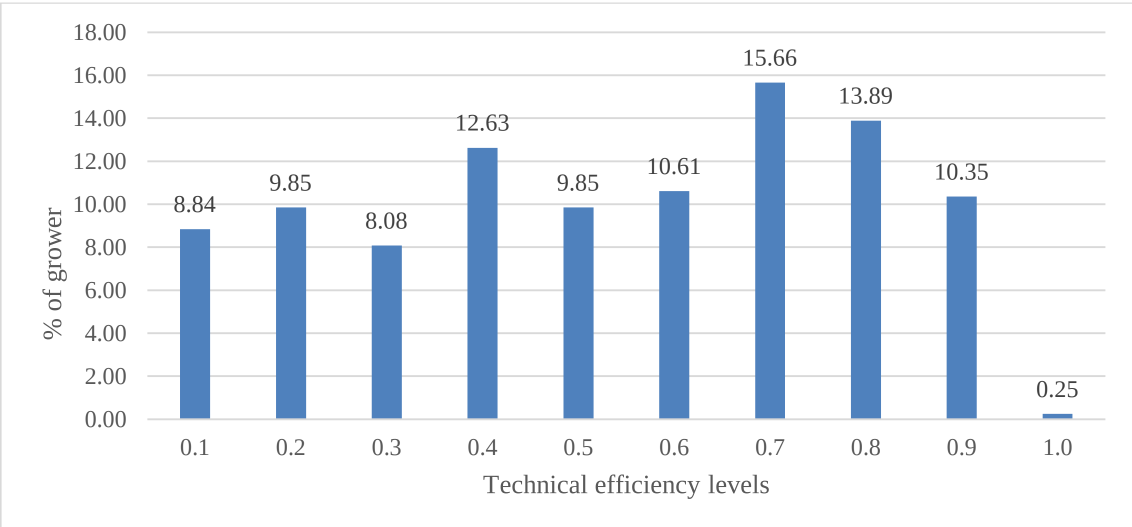

Fig. 3. The density from estimation of technical efficiency
Source: Estimation

Tomato cultivation on the bank of the Mekong River is a beneficial approach to earn a great number of incomes. There are several large firms supporting products in terms of contact farming. Moreover, farmers gain bountifulness from river sediment and this approach causes a minor impact on the ecosystem. Therefore, the government should reinforce management and technology that provides a profitable aspect to the riverside vegetable farming in a particular season.

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