Article

Technical Efficiency and Its Determinants of Rice Production in Cambodia

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Abstract: The present study aims to measure the technical efficiency and establish core factors effecting rice production in Cambodia. Four-years dataset generated from the central government document "*Profile on Economics and Social*" of entire 25 provinces between 2012-2015 and the stochastic production frontier model (SFA) was applied. The results indicated that the technical efficiency of Cambodian rice production varied according to the different level of capital investment in agricultural *machineries*, total rice actual *harvested area*, and technically *fertilizers* application within provinces. Furthermore, evidence revealed the overall mean efficiency of rice production is 78.4% implies that there is still room to further improve technical efficiency by given the same level of inputs and technology. More importantly, the findings revealed that *irrigation*, *production technique* and amount of *agricultural supporting staffs* are being as the most important influencing factors of rice production in Cambodia. In conclusion, present study strongly recommends the development of irrigation systems and good water management practices to be considered and bring into more effective actions by the central government as well as related agencies for improving rice production in Cambodia in addition to capital investment and improving technical skills of supporting staffs and rural farmers.

Keywords: technical efficiency; SFA; rice production; Cambodia; agriculture; productivity

JEL Classification: C01 ; C33 ; C51 ; C87 ; E23 ; M11 ; O33

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1. Introduction

Economy of Cambodia is largely dependent on agricultural sector which contributes 27% of national GDP (Gross Domestic Product) in which 65% of the labor force are engaged [1]. Growth in agricultural sector has played a crucial role in the development of Cambodia [2]. Since 2004, garments, construction, agriculture, and tourism have driven Cambodia's growth. Between 2010-2013, GDP climbed more than 7% annually [3], and GDP per capita in purchasing power parity has increased from $2,462 (US Dollar) in 2010 to $3,056 in 2013 [4]. However, although Cambodian's per capita income is rapidly increasing, it still remains low compared to other nations in the region. Most rural households depend on agriculture and its related sub-sectors; and rice, fish, timber, garments and rubber are Cambodia's major export products [3].

Rice production is the central to Cambodian agricultural sector, not only do the majority of Khmer farmers depend both directly and indirectly on the success of the rice crop each year, and as it is the main food staple, rice production is a big factor in the national effort to promote food security. It occupies more than 80% of total cultivated land, and is the most important agricultural export commodity, as well as the main source of crop value added and the major driver of agricultural

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growth [5]. Being one of the most important staple crops for human consumption, rice plays an unprecedented role in combating food insecurity. Further, rice becomes a key economic crop dominated most agricultural economies in the world, particularly in developing countries like Cambodia.

Having similar characteristics to other agricultural crops, nowadays the growth of rice production yield seems to depend on three important aspects: (a) enlarging planting areas, (b) increasing input of material factors, and (c) raising productivity gradually [6]. Due to the limitation of planting area and material input factors, along with the result of rapid population growth from 11.4 million in 1998 to 15.5 million in 2014 [7, 8] and, thus, an increasing demand of land areas and material input factors for non-farm activities, raising productivity of rice production should be the most preferable factor among the three factors previously described.

Khmer farmers have been growing rain-fed rice for at least 2,000 years, possibly longer in the case of upland rice [9]. Today, rice production still serves as the foundation of Cambodian economy. Between 1980-2010, rice production yield has been doubled from 1.21 tons/ha to 2.97 tons/ha [10]. However, productivity of Cambodian rice still has been relatively low compared to other Asian countries, such as Myanmar, Indonesia, Vietnam, Japan, South Korea, and China where rice productivity in 2010 was recorded 4.12 tons/ha, 5.01 tons/ha, 5.32 tons/ha, 6.51 tons/ha, 6.51 tons/ha, and 6.55 tons/ha respectively [11]. Therefore, in order to raise the productivity of rice production in Cambodia, it is important to identify the core factors influencing it.

The main objective of this study was to measure the technical efficiency (hereafter, TE) of rice production in Cambodia. Additionally, the study was also trying to identify core influencing factors of TE in order to explain the possibilities of increasing productivity and profitability of rice by increasing efficiency at provincial level, as well as identify what technical progress policy should be recommended to help decision-makers to increase the rice productivity in Cambodia. The results of this study will be useful for both rice producers and policy makers in government and all other stakeholders along the rice value-chain including development agencies, non-government organizations (NGOs) and many other related parties working towards improving rice production and the agricultural sector at large.

The rest of this article is organized as follows: section 2 presents analytical frameworks and methodology for measuring rice production TE, while in section 3 the data and descriptive statistics of output and input variables is presented. The results are presented, compared, and discussed in section 4. Finally, conclusion remarks are offered in Section 5.

2. Methodology

In the economics literature, productivity refers to the amount of output(s) obtained from given levels of input(s) in an economy or a sector. It is an important topic of study, since productivity is one of the two fundamental sources of larger income streams; the other being savings, which permit more inputs for employment [12]. Coelli, Rao [13] argued that productivity is the ratio of the output(s) that it produces to the input(s) that it uses [Productivity = Output(s) / Input(s)]. In other words, productivity is raised when growth in output(s) outpaces growth of input(s). Productivity growth without an increase in input(s) is the best kind of growth to aim for rather than attaining a certain level of output [14]. Nevertheless, measuring the total input and total output is both conceptually and empirically difficult. Methods to estimate productivity and efficiency that commonly and frequently implement in most of today's empirical works are data envelopment analysis (DEA) and stochastic frontier analysis (SFA), which are non-parametric approach and parametric approach respectively. For instance, studies implemented DEA approach include [15],[16],[17],[18],[19],etc., while studies implemented SFA approach include [20],[21],[22],[23],etc.

Productivity and efficiency studies have taken the attention of most economists and policy makers in recent years, since there is no meaningful welfare improvement and economic development can take place in the absence of productivity growth [10]. Productivity is a basic and intuitive measure of performance. Furthermore, total factor productivity (TFP[1]) is a method of measuring businesses performance. TFP is used both in competitive and regulated industries, such as electricity distribution companies [25] for instance. It is a method of measuring productivity and growth, which is a productivity measurement involving all factors of production. Other traditional measures of productivity, such as labor productivity in a factory, fuel productivity in power stations, and land productivity (yield) in farming, are often called partial measures of productivity. These partial productivity measures can provide a misleading indication of overall productivity when considered in isolation [26].

However, agricultural productivity and efficiency studies as well as rice production efficiency studies in Cambodia seem to be very poor. Most of research works were conducted by the related government agencies, such as National institute of statistics (NIS), Ministry of agriculture, forestry and fishery (MAFF), Cambodia Development Resource Institute (CDRI), Cambodia Agricultural Research and Development Institute (CARDI), etc. Thus, only a few research works were conducted by the scholars. Given the scarcity of literature on efficiency in Cambodia, the present study therefore seeks to augment literature and contribute in many ways to bridge the gap and supplement the shortage.

The objective of this study was achieved through the estimation and analysis of the stochastic production frontier model (hereafter, SFA model), originally proposed by Aigner, Lovell [27], and Meeusen and Van den Broeck [28]. The most commonly used package for estimation of SFA model is FRONTIER 4.1c, see Coelli [29]. The general form of the SFA model:

$$Ln\, y_{it} = Ln\, f(x_{it}, t\,;\, \beta) + v_{it} - u_{it} \tag{1}$$

where *Ln* indicates the natural logarithm function form; y_{it} and x_{it} denote rice production output(s) and input(s) within period *t* respectively; β represent estimated coefficients; v_{it} is statistical random error, assumed to be normal distribution, $v_i \sim N(0, \sigma_v^2)$; u_{it} denotes technical inefficiency, assumed to be truncated normal distribution, $u_i \sim |N(0, \sigma_u^2)|$; v_{it} and u_{it} are assumed to be independent; *i*=1,2,…,*N*; *N* is number of measurement unit (MU_i), i.e. total samples; and *t* is time variable measured as year, *t*=1,2,…,*T*.

The present study utilized the logarithmic form of translog production function, thus equation (1) above can be written as:

$$Ln\, y_{it} = \beta_0 + \textstyle\sum_j \beta_j Lnx_{jit} + \beta_t \mathrm{t} + \frac{1}{2}\sum_j \sum_k \beta_{jk} Lnx_{jit} Lnx_{kit} + \frac{1}{2}\beta_{it} t^2 + \sum_j \beta_{jt} Lnx_{jit} t + v_{it} - u_{it} \tag{2}$$

The technical inefficiency effect can be expressed in following general form:

$$u_{it} = \delta_0 + \textstyle\sum_{k=1}^{n} \delta_k z_{kit} + \omega_{kit} \tag{3}$$

where ω_{kit} is the stochastic noises; z_{kit} denotes exogenous variables that are factors affecting Cambodia's rice production TE; δ_0 and δ_k are estimated coefficients; if δ_k is negative indicates positive relationship between affecting factor variables and TE of rice production, conversely, if δ_k is positive shows negative relationship between TE and affecting factors.

Followed by equation (2) and (3), the parameters estimation of SFA model can be achieved by applying maximum likelihood estimation method, which estimates the likelihood function in terms of two variance parameters, see Coelli [30]:

$$\gamma = \sigma_u^2 / \sigma_s^2 \;;\;\; \sigma_s^2 = \sigma_v^2 + \sigma_u^2 \tag{4}$$

Gamma (γ) takes value between zero and one ($0 \le \gamma \le 1$), reflects validity of the random disturbances (v_i,u_i) proportion. If γ is closer to zero, it indicates that the gap between actual output and the maximum possible output mainly comes from other uncontrolled pure random factors,

[1] Also called multi-factors productivity (MFP) in some lectures, like 24. Zheng, S. and H. Bloch, *Australia's mining productivity decline: implications for MFP measurement.* Journal of Productivity Analysis, 2013. **41**(2): p. 201-212.

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which makes the use of stochastic frontier model meaningless. In contrast, if γ is closer to one, it shows that the gap comes mainly from the effects of one or more exogenous variables z_{ki}, indicates using stochastic frontier production function model is more appropriate.

Rice production TE of every MU_i can be estimated by the ratio of observed output relative to the potential output defined by SFA model, as follow:

$$TE_{it} = y_{it}/f(x_{it}, t) = exp(-u_{it}) \leq 1 \quad (5)$$

TE value is always smaller or equal to one. When TE equal to one, indicates MU_i in the samples is fully technical efficiency. Therefore, the closer of TE value to one indicates the higher TE of rice production.

Technical efficiency change (hereafter, TEC) of every MU_i between period *t* and *t+1* is the ratio of TE in period *t+1* to its TE in period *t*, which can be expressed as the following formula:

$$TEC_i^{t,t+1} = TE_i^{t+1}/TE_i^t \quad (6)$$

3. Data and descriptive statistics

The data used for present study were drawn from the central government document sets "*Profile on Economics and Social*" of entire 25 provinces in Cambodia (24 provinces and 1 capital city, Phnom Penh) from 2012 to 2015 (4-years dataset). These document sets were prepared by Provincial Department of Planning of every province based on computer program namely Commune Database (CDB) that provided derived-data from village and commune data books which are annually documented and kept at commune/sangkat and village chief or village representative who is member of Planning and Budgeting Committee.

Output variable was the total provincial rice production *quantity* which measured in tons. Inputs were total area of rice actually harvested (i.e. *land* variable) measured in hectares, *labor* measured as total people with rice farming as primary occupation, *fertilizer* measured as total families using chemical and organic fertilizers, *pesticide* i.e. total families using poison for insects and grass (both chemical and organic), and capital investment on agricultural *machineries* which measured by total amount of tractors, walking tractors (*koryons*), and rice transplanting machines existing in the provincial territory. **Table 1.** provides summary statistics of the output and inputs by year.

Table 1. Summary statistics of the output and input variables

Variable	2012		2013		2014		2015	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Output								
Rice quantity	290,808	52,994	329,872	60,296	391,150	80,437	315,270	57,785
Inputs								
Land	134,629	23,192	144,944	25,893	212,785	56,497	145,685	26,699
Labor	168,703	27,044	163,805	26,208	160,163	25,683	155,159	24,486
Fertilizer	74,061	13,236	75,027	13,300	160,163	13,436	79,038	13,618
Pesticide	45,116	9,610	47,926	10,021	52,205	10,596	56,117	11,047
Machinery	10,196	1,937	12,213	2,135	14,569	2,394	16,762	2,675

Source: Measured by Ms. Excel 2016. S.E. = Standard Error.

Output *quantity* of rice production in Cambodia was higher in 2015 than in 2012 which increased 8.4% in average from 290 thousand tons (2012) to 315 thousand tons (2015). Total area of rice actually cultivated in average also increased around 8% from 134 thousand hectares in 2012 to 145 thousand hectares in 2015. Total families using chemical and organic fertilizers which is the variable of *fertilizer* input, on the other hand, increased in average by 7%, while *pesticide* and *machinery* input increased greatly between the study period of present study. Total families using poison for insects and grass increased by nearly 25% (3-times larger than *land* and *fertilizer* input), while the total capital investment on agricultural *machineries* between this period increased by a huge percentage of 64.4%,

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indicated the huge improvement of mechanization in Cambodian agriculture, particularly in rice production sector. However, along with the improvement of agricultural mechanization, *labor* input which measured as total people with rice farming as primary occupation tended to decrease a little bit (8%) presented the progression of labor forces transformation out of agriculture to other higher productivity and profitability sectors such as industries and services.

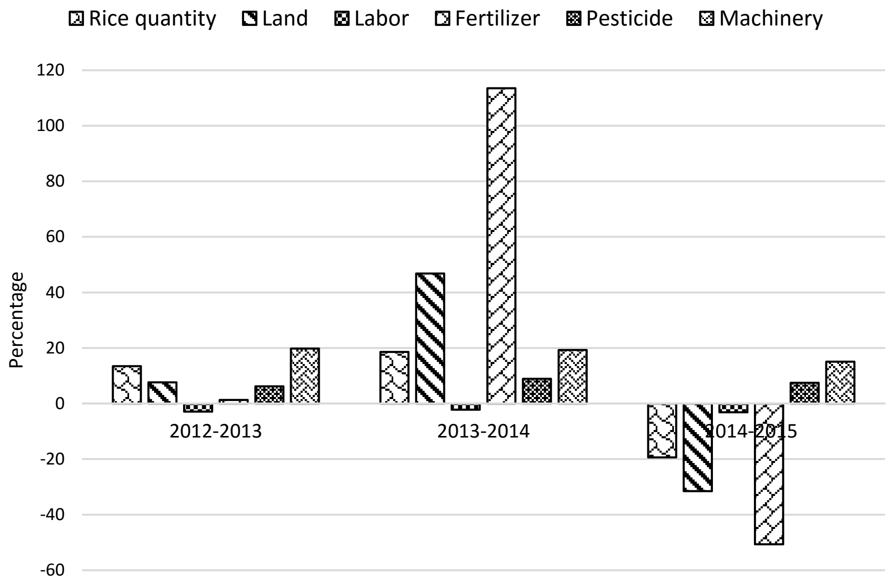

Figure 1. Percentage changes of output and input variables

Figure 1. illustrates the percentage changes of output and input variables between the study period. A closer look to percentage changes within output and input variables from year to year indicated that from 2012 to 2013, there were not significantly changed within both output and input variables. However, there were a massive change in inputs, particularly in *land* and *fertilizer* between 2013-2014 which caused the output (rice *quantity*) to increased greatly. Unfortunately, the natural disasters (drought, flood, and insects) at the end of 2014 and in 2015 had destroyed a huge percentage of rice cultivated *land* in most leading rice production provinces (totally reduced around 30% of 2014 production) and *fertilizer* input was also decreased greatly (50%). Rice production *quantity*, therefore, also decreased by a large percentage of 20%. However, development of capital investment in agricultural *machineries* still continued to increase by 15-20% every year, while implementation of *pesticide* by farmers tended to increased 6-9% annually. *Labor* input, on the other hand, had the decreasing trend from year to year in the percentage of 2-3%.

In the technical inefficiency model (3), there were seven influencing factors of rice production efficiency to be considered in the present study. *Disaster* measured as percentage of rice production land damaged by floods, droughts, and insects to total rice production land actually harvested within the year. *Irrigation* measured as percentage of total provincial paddy land having irrigation system. *Production technique* measured as percentage of families using technical rice intensification. *Distant to information sources* measured as average distance from village center to the center of district/khan (in kilometers). *Agricultural supporting staffs* measured as percentage of total agricultural staffs (both government officers and NGOs staffs) to total farmers existing in the province. *Dry-season production* measure as the total percentage of dry-season paddy land actually harvested to total cultivated land available for dry-season cultivation. And *small-land farmers* measured as percentage of total families having paddy land smaller than one hectare and families having no paddy land. Thus, equation (3) can be written as:

$$u_{it} = \delta_0 + \delta_1 Disaster_{it} + \delta_2 Irri_{it} + \delta_3 Tech_{it} + \delta_4 Distant_{it} + \delta_5 Staff_{it} + \delta_6 Dry_{it} + \delta_7 SmallF_{it} \quad (7)$$

Table 2. presents descriptive statistics of rice production efficiency's influencing factors between 2012-2015. Percentage of rice land area damaged by floods, droughts, and insects was lower in 2015 compared to 2012. Rice land area damaged by disasters in 2012 was nearly 20% in average, while in 2015 disasters destroyed only 5.2% of rice production land in average (decreased by 72.4%). However, this percentage still remains as a large percentage which should be considered by the central government and related agencies. From 2012 to 2015, there were also large percentage changes in rural farmers' *production technique* and amount of *agricultural supporting staffs* existing the province. Percentage of families using technical rice intensification tended to decreased greatly (by 20% within 3 years) and percentage of agricultural supporting staffs decreased 17%, showing the lack of technical supporting techniques as well as technical improvement training for farmers, particularly small-land rural farmers which most of them have rice production as primary occupation, in the purpose of enlarging the national rice production. Although percentage of *small-land farmers* have been reduced within this study period (less than 5%), in 2015 *small-land farmers* in Cambodia still accounted for 40% in average which was still the vast percentage. *Dry-season production* of rice in Cambodia still not fully-efficient yet. In average, only 68% of the total available dry-season rice production area had been actually cultivated within the year of 2012. Additionally, water shortage during the dry season of 2015 had reduced the percentage of dry-season actually cultivated by 5.2% too (reduced to 64%). Therefore, there is still a huge gap for Cambodian famers to improve their dry-season production as well as total production of rice.

Table 2. Descriptive statistics of efficiency influencing factors

Variable	2012		2015	
	Mean	S.E.	Mean	S.E.
Disaster	18.86	12.34	5.20	1.16
Irrigation	21.70	3.49	22.64	3.54
Production technique	3.04	0.48	2.44	0.37
Distant to information sources	14.92	1.53	15.01	1.20
Agricultural supporting staffs	0.11	0.03	0.09	0.02
Dry-season production	68.47	5.72	64.91	6.43
Small-land farmers	41.80	3.17	39.76	3.67

Source: Measured by Ms. Excel 2016. S.E. = Standard Error.

Irrigation plays as a very important role for rice production in Cambodia, particularly in dry-season. Between 2012-2015, irrigation systems were improved gradually by increased the percentage of paddy land having irrigation system from 21.7% in 2012 to 22.6% in 2015 (3.5% increased within 3 years). However, this irrigation rate seems to be very tiny compared to other agricultural nations, especially its neighboring countries like Thailand, and Vietnam, since another nearly 80% of total cultivated land still being performance as the rain-fed agricultural land. These statistics reveled that irrigation systems in Cambodia still remain lack, shortage far behind its potential to improve the national rice production. In many developed countries, irrigation systems were not only used for agriculture, but also being used as natural disasters prevention devices. Global climate change had been affecting Cambodia in the latest decade. Natural disasters like floods and droughts occurred more frequently than previous times. Sometimes, within a year, Cambodian people suffered from flood in wet-season, and then suffered again from droughts in dry-season. These could be the results of irrigation systems shortage, which caused Cambodia to had no ability to deal with such frequently-occurred disasters. What if Cambodia could build irrigation and water storage systems in order to store an over-needed water resources during the wet-season keeping for utilization in agriculture during the dry-season?

4. Results and discussion

4.1. SFA model estimation

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Table 3. listed parameters estimation results by implementing the maximum likelihood estimation method in FRONTIER (version 4.1c) econometrics software of Coelli [29]. The variance ratio parameter of gamma (γ) had a value of 1.00 and significant at 1%, shows that the variation of the composite error term was mainly from the technical efficiency (u_i) almost 100%, and the variation of random error (v_i) less than 1%, indicated the efficiency source of Cambodian rice production within the study period came mainly from the production's technical efficiency.

Table 3. Parameter estimates of SFA model

Variables	Coefficient	Standard Error	t-ratio
Constant	-1.1869 *	0.6189	-1.9178
Ln(land)	0.6796 ***	0.2475	2.7458
Ln(labor)	0.0775	0.3279	0.2364
Ln(fertilizer)	0.9245 **	0.4664	1.9820
Ln(pesticide)	-1.8588 ***	0.3565	-5.2139
Ln(machinery)	1.8642 ***	0.2629	7.0914
t	0.0573	0.0369	1.5529
Land x Labor	0.0420 **	0.0197	2.1339
Land x Fertilizer	-0.0771 *	0.0429	-1.7966
Land x Pesticide	0.1680 ***	0.0309	5.4381
Land x Machinery	-0.1210 ***	0.0241	-5.0263
Labor x Machinery	-0.0585 **	0.0271	-2.1577
t^2	0.0013	0.0068	0.1888
Gamma (γ)	1.0000 ***	0.0001	13,538.2280
Sigma-squared (σ^2)	0.0336 ***	0.0062	5.3882
Log likelihood function			75.7787

Source: Estimated by FRONTIER 4.1c. * indicates significant at 10%, ** significant at 5%, and *** at 1%.

Almost all estimated coefficients have the expected signs. Total actual harvested *land* and agricultural *machineries* involved in rice production were both positively related to TE and significant at 1%, while the number of total families using *fertilizers* (both chemical and organic) in production of rice was also positively related but significant at 5%. These results indicated that enlarging in total actual harvested *land*, more capital investment in agricultural *machineries* and technically improvement of *fertilizers* application by smallholder rice producers (farmers) could cause the result in increasing TE of rice production within the province. Moreover, with the estimated coefficient of 1.86, capital investment in agricultural *machineries* was the main input factor driven more efficiency in Cambodia's provincial rice production compared to *land* and *fertilizer* input factor during the study period. This mean that the provinces with high capital investment (in agricultural *machineries*) tended to have higher rice production TE than the provinces with lower capital investment. Total actual harvested *land* was the second core input factor for increasing TE. The provinces which cultivate more additional lands of rice have the ability to maintain reasonable levels of other necessary inputs in order to cause the TE of rice production to increase faster than the provinces with low rate to rice cultivated land. This result confirmed the results of several previous studies, such as Yu and Diao [5], Smith and Hornbuckle [31] and some studies of Asian Development Bank [2, 32].

Total families using poison for insects and grass (chemical and organic) existing in the province was negatively related to TE and significant at 1%, indicated that provinces with more percentage of poison (*pesticides*) application tended to have lower TE than the provinces with smaller percentage. This could be the result of inefficiency used of poison in rice production by farmers. Be noted that most of smallholder rice producers are the farmers with low education. Moreover, the instruction of product usage for most imported agricultural poison products have not been translated into Khmer language before imported (to Cambodia), which might cause numerous misunderstanding and leaded to incorrected technical used as well as inefficiency used in field practices by farmers.

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However, the study established that there was no significant relationship between TE and the *labor* force involved in rice production.

4.2. Technical efficiency analysis

The study indicated that individual provincial-level TE ranged from a low of 49.8% to a high of 99.7% with a mean technical efficiency of 79.5% in 2012. Rice production TE in 2015, on the other hand, ranged from a low of 36.8% to a high of 99.9% with a lower mean technical efficiency of 74% (7% decreased). However, the findings revealed that the overall mean of rice production TE is estimated as 0.784 which indicated that Cambodian produce 78.4% of rice at best practice at the current level of production inputs and technology. It means that rice output could have been increased further by 21.6% at same levels of inputs if farmers had been full technically efficient. There were only 10 out of 25 provinces have had TE above the TE overall mean, while TE of another 60% of provinces still ranged below the average mean efficiency.

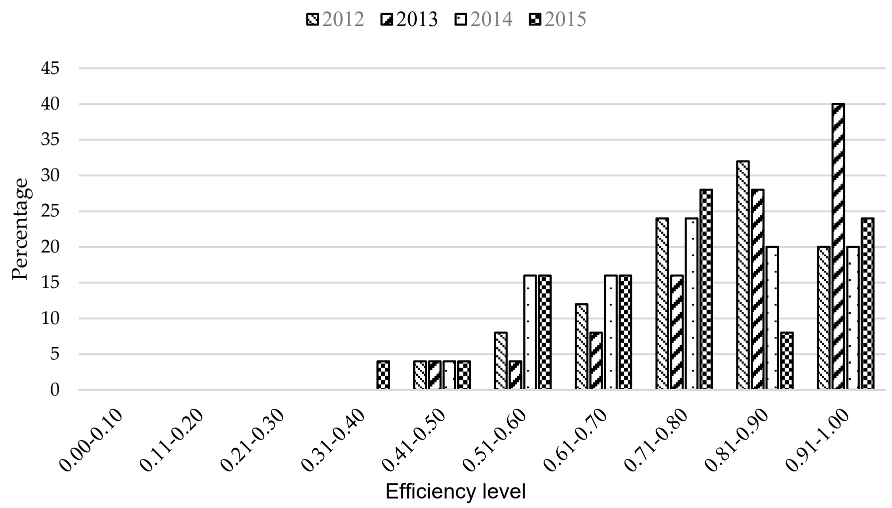

Figure 2. Distribution of Technical Efficiency

Figure 2. illustrates distribution of rice production TE from 2012 to 2015. Rice production in Cambodia performed very well during 2013, which 40% of provinces had technical efficiency score between 0.91-1.00, and another 28% had technical efficiency score between 0.81-0.90. Thus, in 2013 nearly 70% of provinces produce more than 80% of rice at best practice at the current level of their production inputs and technology. However, natural disasters in 2014 and 2015 caused the decreased in technical efficiency score in most Cambodian provinces.

Table 4. shows the rice production TE in different regions of Cambodia. The results revealed that between the study period, *Mekong river plain* which is the second-largest rice production region of Cambodia had highest TE score in both 2012 (0.860) and 2015 (0.878) among all regions, and the only one region have had increasing TE score during the study period (by 2.2%). In 2015, all provinces in this region, except *Svay Rieng* province, had rice production TE more than 91%. *Takeo* province was the most effective province in this region with the highest TE score of 0.999, while *Svay Rieng* province's TE score in 2015 was just 0.599. However, *Tonle sap river plain* which is the largest rice production region of Cambodia (in production area) had TE score of 0.814 in 2012, but decreased (by 5.4%) to 0.770 in 2015. The province with highest TE score in this region in 2015 was *Kampong Chhnang* province (0.914), while *Banteay Meanchey* was the province that had lowest TE score within the region.

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Table 4. Regional level technical efficiency of rice production in Cambodia

Regions	2012		2015		TE Change (%)
	Mean	*S.E.*	*Mean*	*S.E.*	
Capital (Phnom Penh)	0.8333	0.0000	0.6127	0.0000	-26.4760
Tonle sap river plain	0.8138	0.0489	0.7699	0.0371	-5.3984
Mekong river plain	0.8597	0.0709	0.8786	0.0719	2.1988
Mekong river plateau	0.7927	0.0364	0.7028	0.0627	-11.3461
Mountain area	0.6639	0.0899	0.5331	0.0855	-19.6981
Coastal area	0.8061	0.0733	0.7901	0.0808	-1.9813
Cambodia	0.7952	0.0281	0.7400	0.0337	-6.9438

Source: Estimated by FRONTIER 4.1c, and Ms. Excel 2016. S.E. = Standard Error

4.3. *Technical inefficiency model and affecting factors*

Table 5. Rice production technical inefficiency model parameters estimation

Variables	Coefficient	Std. Error	t-ratio
Constant	0.9241 ***	0.1484	6.2261
Disaster	0.0003	0.0005	0.5641
Irrigation	-0.0119 ***	0.0026	-4.5368
Production technique	-0.0841 ***	0.0283	-2.9688
Distant to information sources	-0.0052	0.0060	-0.8703
Agricultural supporting staffs	-0.9530 **	0.4032	-2.3635
Dry-season production	-0.0016	0.0016	-1.0549
Small-land farmers	-0.0007	0.0036	-0.2056

Source: Estimated by FRONTIER 4.1c. * indicates significant at 10%, ** significant at 5%, and *** at 1%.

Table 5. presents the parameters of the rice production technical inefficiency model. In the model specification, it is obvious that *irrigation* and *production technique* both had negative coefficient signs and significant at 1%, while *agricultural supporting staffs* had also negative coefficient signs but significant at 5%, indicated positively related of these three factors to TE of rice production in Cambodia. These results revealed that development of *irrigation* systems and good water management practices, development of rice *production technique* to the rural farmers, and increasing the number of *agricultural supporting staffs* in the provincial territory are the three core factors to cause rice production TE to increase. *Agricultural supporting staffs* and *production technique* played as the first and second core affecting factors. Provinces with more agricultural supporting staffs existing and higher rate of families using technical rice intensification tended to have higher TE score than provinces with less amount to supporting staffs and lower rate of families using technical rice intensification, which indicated the important of new production technique implementation and technical supporting services from agricultural staffs in rice production.

Irrigation systems, on the other hand, served as the third core affecting factor. In Cambodia, *irrigation* is mainly used for dry-season rice and to complete wet season rice if necessary. it is also an essential component to ensure that farmers can crop during the dry season. ADB [2] argued rice production's efficiency in Cambodia is always constrained by low-rates of irrigation, while Smith and Hornbuckle [31] suggested that rice yields could be improved by helping to better regulate water inputs. Khmer farmers are mostly able to cultivate rice only once per year because of inadequate irrigation system and good water management.

As being discussed previously, *irrigation* systems and good water management practices was not only the core factors for improving rice production in Cambodia, but also the main disaster prevention devices for protecting Cambodia from natural *disasters*, such as floods and droughts. Although percentage of rice land area damaged by floods, drought, and insects was not significantly

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affect rice production TE during the study period, frequently-occurred natural disasters still always indirectly affect the rice production from different aspects, for instance, disasters destroyed rice fields caused the result of decreasing in total rice actual harvested *land* which was the second core input factor for increasing TE after capital investment in agricultural *machineries*. *Irrigation* systems, therefore, should be the core factor to be considered and bring into actions by the central government and related agencies. Conversely, the study established that there was no significant relationship between the factors of *distant from information sources*, *dry-season production*, amount of *small-land farmers* and rice production TE.

5. Conclusions

The aim of this paper was to estimate the TE of rice production in Cambodian and determine its main influencing factors by using the SFA model. The present study utilized four-years dataset generated from the central government document "*Profile on Economics and Social*" of all 25 provinces between 2012-2015. The results indicated that the TE of rice production in Cambodia varied according to the different level of capital investment in agricultural *machineries*, total rice actual *harvested area*, and technically *fertilizers* application within provinces. The mean TE of rice production is 0.784 which means that famers in this region produce 78.4% efficiently rice at best practice, at the current level of production inputs and technology. This means that rice output has the potential of being increased further by 21.6% at the same level of inputs if farmers had been technically efficient. However, during the study periods the TE of rice production recorded a 7% decreasing rate. *Takeo* province was the most effective province nationwide, while another 60% of provinces still had TE below the average mean efficiency in 2015.

Three main conclusions emerged from the study's results. First, based on decomposing the technical inefficiency model, enlarging capital investment at provincial level into agricultural *machineries* is the core input factor influencing rice production in Cambodia, while the expansion of total rice land actual *harvested area*, and technically improvement of *fertilizers* application range as the second and third core input factors respectively. These results are not very surprising since they are straightforward techniques for increasing rice productivity in most developing countries in the world. Likewise, these results also confirmed the existing problems in Cambodian rice production sector which were previously addressed by relevant studies like [1],[2],[5],[31] and [32]. It is clearly indicating that although the central government of Cambodia is trying to increase rice production by enlarging the rice production annually, this enlargement still remains far behind its enormous potential to increase rice productivity. Therefore, significant commitments and supported actions are required to address the problem. Second, *production techniques* for rural farmers, technical skills and amount of *agricultural supporting staffs* are being as the most important influencing factors of rice production in Cambodia. Finally, agricultural sector as well as rice production in Cambodia always inevitably linked to development of *irrigation* systems and good water management practices, it is therefore a relevant magnitude to be muscularly considered by policy-makers for developing strategical policies geared towards enhancing rice production. Therefore, the main factors affecting the TE of rice production in Cambodia appear to be: *capital investment*, actual *harvested area*, *irrigation* and good water management, *fertilizers*, *production techniques*, and technical *supporting staffs*.

In conclusion, in addition to capital investment, and improving technical skills for both supporting staffs and rural farmers in order to improve rice productivity in Cambodia, the present study recommends the development of *irrigation systems* and good water management practices should be strongly considered and bring into more effective actions by the central government as well as related agencies for preventing frequently-occurred natural disasters and increasing actual harvested area, particularly in dry-season.

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