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Productivity and Technical Inefficiency of Paddy Rice Production in Laos: A Case Study of Farm Household Survey

Vanxay Sayavong

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National Economic Research Institute (NERI), Vientiane Capital, Lao PDR
Email: sai_vanxay48@yahoo.com

Abstract

This study applies stochastic production frontier and inefficiency models to examine paddy rice production as well as factors hindering its inefficiency. This research uses a cross section data of 343 farm households in different locations from the survey. Production factors such as farmland, labor, capital, inputs and other spending are analyzed in the production model while the specific factors such as water availability, quality of soil, seeds per hectare, fertilizers per hectare, size of a plot, education and extension services related to technical inefficiency are examined in the inefficiency model. The findings show that about 70 percent of paddy rice production's potential has been realized and the production inefficiency can primarily be attributed to the membership of rice association, training, soil quality and the use of inputs in proportion per hectare. The result identifies knowledge transfer on new technologies and skills to farmers via rice association and training is the most effective way to improve/reduce the efficiency/inefficiency whereas public extension service needs more attentions. Also, investing in water control systems such as a large scale of canals and drainage is necessary.

Key words: Laos, stochastic production frontier, inefficiency and paddy rice

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1. Introduction

Rice is an important agricultural product as a main staple food for Lao people for many years and contributes to economic growth steadily in terms of Gross Domestic Product (GDP). Following the Lao Expenditure Consumption Survey 2008 (LECS IV), rice accounted for 83 percent as an average of total dietary energy consumption and the rice consumption per capita is 162.6 kilogram per year. The Lao Agriculture Census survey in 2010/11 also shows that 724,000 households or 71 percent of total households engage in paddy rice plantation. Throughout the country, paddy planted land covers over half of total agricultural land significantly. This demonstrates that paddy rice production is crucial to the livelihood of Lao people especially those who live in rural areas. Table 1 presents top 10 agricultural productions in 2012. Since the agricultural production means sources of income, it highlights the majority of production both in terms of value and share is predominated by paddy rice production. The second main agriculture is vegetables sharing of 10 percent and other crops such as bananas, cassava, maize, coffees and meats (40 percent). In terms of value added in GDP, FAO (2011) indicates 20 percent of nationwide GDP and 50 percent of agricultural GDP consisted of rice production. As a result, paddy rice is seen as a crucial crop that play an important role to national economic growth and the livelihood of people especially in rural areas. Also, paddy rice seems to show a contribution to the export sector. Based on Bouahom and Douangsavanh (2013), Laos exported rice of 2,204 tons officially in 2010-11 and the 100,000 tons unofficially per year along the border with Thailand and Vietnam. Yet, Laos is expected to export rice around 450,000-500,000 tons in 2015 as estimated by the World Bank (2014, p.25). Recently, an amount of 8,000 tons was exported to China in 2015 and expected to scale up to more than 10,000 tons per year[1].

TABLE 1

Top 10 Farming Commodities (Production Value) in 2012

No.	Commodity	Value (1000 USD)	Share (%)
1	Rice, paddy	865,350	50.6
2	Vegetables	171,497	10.0
3	Bananas	102,823	6.0
4	Cassava	99,740	5.8
5	Maize	98,677	5.8
6	Coffee, green	93,824	5.5
7	Meat indigenous, pig	88,814	5.2
8	Meat indigenous, cattle	71,238	4.2
9	Tobacco, unmanufactured	64,666	3.8
10	Meat indigenous, buffalo	52,704	3.1
	Total	1,709,333	100

Source: FAOSTAT, FAO of the UN, Accessed on February 4, 2015.
http://faostat.fao.org/site/612/default.aspx#ancor

Basically, there are three types of paddy rice plantation in Laos which are (1) paddy rice fed-lowland in the wet season, (2) upland paddy rice in the wet season and (3) paddy rice lowland in the dry season. Paddy rice lowland plantation and upland paddy rice in the wet season begins from May to November while paddy rice lowland in the dry season starts from

[1] http://www.chinadaily.com.cn/business/2015-12/15/content_22717796.htm

December to April. Paddy rice lowland in the wet season is the largest in terms of land and yield. For instance, 728 thousand hectares of farmland is for paddy rice lowland, 118 thousand hectares is for paddy rice upland and 92 thousand hectares is for paddy rice lowland in the dry season in 2013. The difference between paddy rice lowland in the wet and dry season is only when the paddy rice lowland in the dry season is realized mainly on the irrigation access and different calendar. The upland paddy rice is attached with the slash and burn practice on upland areas or mountainous areas which is determined by the rainfall in the wet season. Central region has the largest farmland and is also the biggest producer of paddy rice which shares more than a half of total in terms of farmland and yield. Glutinous or sticky rice is the main paddy in Laos, according to MAS (2014) and Latvilayvong, et. al (2010).

Although the productivity of paddy rice (output per ha) has increased steadily as an average of three percent over in the last two decades due to the expansion of irrigation system, rice seeds, market and machinery, it is still lower than neighboring countries such as China, Indonesia, Korea, Philippines and Vietnam. Still cited as several constraints on the growth of paddy rice are poor agricultural infrastructure such as irrigation and logistics system, weak agro-food processing industry and marketing system, weak research and development (R&D) and extension services (Im 2014). All of these constraints prevent farmers producing the output at optimal frontier. Although previous research were carried out, they suffer some limitations such as a small sample size, un-diversification (do not capture the different practices of paddy rice farms in different locations), and have poor discussion on the results.

Hence, this study attempts to find ways to escalate the productivity of paddy rice in Laos through improving the production efficiency and filling the gap of previous studies with a larger sample size in different locations. To do this, two research questions are identified as: (1) What is the potential paddy rice yield and level of its technical efficiency and to what extent and (2) How to improve the production efficiency grounded on the results from the technical inefficiency model? The stochastic production frontier and technical inefficiency models are the main methodology for analysis. Paddy glutinous rice lowland in the wet season is considered as a case study for the purpose of this study since the paddy rice lowland and glutinous rice in the wet are the majority. The expected outcome of this research would be able to provide policymakers a constructive and specific recommendation and in turn for policymakers to help farmers reach their frontier given an amount of inputs through efficiency improvement.

This paper proceeds as follows. The background and identified problems are presented in the first section. Visiting previous literature is highlighted in section 2 while paddy production and methodology are described in sections 3 and 4. Section 5 reports the statistics summary and discussion. Econometric result and discussion are highlighted in section 6. The last section is the conclusion.

2. Literature Review

Although wide interest in research on technical inefficiency in paddy rice can be found, few studies in the case of Laos appear. Inthavong (2005) studied the rice production efficiency in a village of Home in Vientiane Capital, Laos. He used the stochastic frontier model with a sample of 112 households for paddy rice in the wet season and 82 households for paddy rice in the dry season in 2003. Socioeconomic factors are analyzed whether there is anyone that would influence the technical efficiency of individual rice farmers. Firstly, he indicates that the level of technical efficiency was 72 percent and 100 percent (full efficiency) for paddy rice in the wet season and the dry season. Secondly, the determinants on production efficiency in the wet season are claimed as the area of paddy farm, fertilizer use, and numbers of labor, the use of a modern variety, sandy soil and contract with a professional agricultural advisor. Similarly, the determinants for paddy rice in the dry season are only the area of farmland and fertilizer. The independent variables for paddy frontier production and efficiency model in the wet season involve the area of rice farms in hectares, fertilizer in kilogram per hectare, hired and family labor in hours per hectare, seed varieties (modern and traditional seed) as dummy variables and soil types (sandy and heavy) as dummy variables.

The study by Phetsamone (2012) is another one that also applied the stochastic frontier model to investigate the technical efficiency of paddy rice production in Laos. The finding reveals that only a half level of efficiency is identified. He suggests agricultural extension services[2], education and improved rice seed variety are key factors that could reduce the technical inefficiency or increase the efficiency of rice production. The author asserts that the extension services and education help farmers gain better knowledge on agriculture, skills of dealing with any difficulties and better farm planning. This study extends the findings of the previous work by including extension services, education and other costs such as machinery as other factors on technical efficiency. Data of a small sample (112 farmers) in Bolikhanh district, Bolikhamxai province as a case study is collected.

Likewise, several research studies were carried out in neighboring countries on rice production efficiency. One of them is the study by Kai and Tabe (2011) in a case of Vietnam. The technical efficiency of rice production is measured and the determinants for the efficiency are identified for farmers. Household living standard survey 2005-06 is used and stochastic frontier analysis is employed. The result reveals that 81.6 percent of technical efficiency was realized and the main driving forces on the efficiency are the intensive labor in rice cultivation, irrigation and education. Farmers who have secondary school level or above are more productive than farmers without education or with primary school level. The variables for frontier model include seed expenditure, cost of pesticide, quantity of fertilizers in kilogram, machinery services, hired labor, family labor, rice land area in hectares, small tool and energy, and other rice expenditure. Variables for the technical inefficiency model are the socioeconomic characteristics of farmers such as ethnics, member, age, experience, gender, education, irrigation and others.

Similarly, Heriqbaldi et. al (2015) estimates technical efficiency in rice production and assesses the effect of farm-specific socioeconomic factors on technical efficiency. Survey data from 15 provinces in Indonesia is used. The authors find that factors like land size, income and source of funding are the determinants on technical efficiency. Age is also asserted as important since younger farmers tend to be more efficient on farming. The authors discuss that, if the use of inputs does not increase when the cultivated land increases, efficiency would decline as a result of the diminishing return to land. This evidence is also seen in the case of Thailand. Srisompun and Isvilanonda (2012) indicated that the cost of rice production increased to about 85.67 percent from the last few decades in Thailand. It is because return to scale has decreased, highlighting the inefficient use of inputs. The technical efficiency was revealed to be 88.32 percent in 1987/88 then dropped to 72.63 percent in 2007/08. The study suggests that crop diversification, supervised credit on fertilizers and seeds to farmers would improve production efficiency at the farm level.

[2] The extension services is defined as building a farmer's capacity to be able to apply technologies suitable to their farm and making available resources through transferring agricultural techniques and technologies based on research and other crosscutting information sources; in addition, providing consultation and technical services to solve a farmer's problems.

Furthermore, Rido (2014) uses the Cambodia Socioeconomic Survey (CSES) 2009 to examine the technical efficiency of paddy rice in the case of Cambodia. The author argues that an appropriate number of laborers cultivating in a plot of land can increase production cost efficiency. In contrast, if too many laborers are employed to cultivate a small plot of land, efficiency will drop.

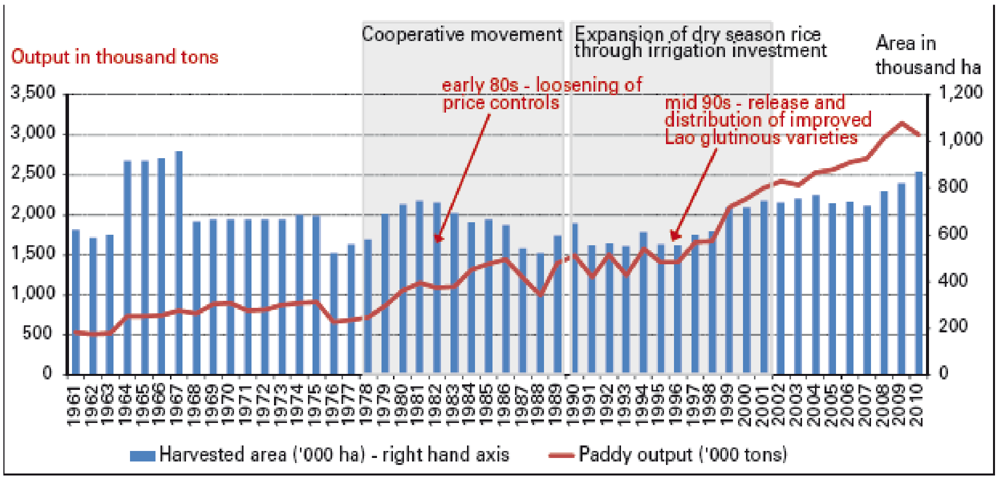
3. Paddy Rice Production

Laos was a net importer since the 1970s before becoming rice self-sufficient since 1990. Paddy rice plantation is greatly vulnerable to natural disasters. For instance, extreme climate events such as severe droughts occurred in 1977 and floods in the following years. To ensure food security and stimulate economic growth as stated in national development policies and strategies, increasing paddy rice production is a top priority of the Lao government. Consequently, a number of reforms and policies such as the introduction of cooperative organization during 1978-1988 known as a collective system, provision of tax incentive and preferable credit access, the introduction of the first improved seed varieties in 1970s and loosening the control price in early 1980s were introduced and enforced. However, due to a lack of incentive for farmers to invest on paddy rice farming, the collective system collapsed eventually in 1988 and the market oriented system was gradually put in place.

Throughout the whole period, the trend of rice production had been in an upward trend while planted areas fluctuated in some periods due to natural disasters. Generally, there was a demonstrable increase of productivity in paddy rice production. Such an increase of production is explained by the evolution of the rice production reforms shown in Figure 1.

FIGURE 1

Historical Evolution of Rice Production and Harvested Area



Source: FAOSTAT data from www.fao.org as of August 2012.

Source: IRRI and etc., 2014, p.30

Figure 1 shows paddy rice production, planted areas and policy reforms since 1961. It illustrates that before the reforms in 1977, paddy production seems to be constant with around 700 thousand tons in the planted areas of around 700 thousand hectares. However, since the beginning of policy reforms, paddy rice production had surged to more than double, from 700 thousand tons up to 3.3 million tons in 2010. In particular, a huge increase was mainly driven by the expansion of irrigation systems and the scaling up of the use of improved Lao glutinous seeds since1990s. At the same time, the use of fertilizers by farmers is in the upward trend.

The expansion of irrigation systems, which were mainly funded by Lao government particularly in 1990s with around 8,000 irrigation pumps, has increased the output of dry season paddy rice through enlarging land cultivation from 12 thousand hectares (2.98 percent of total farmland) in 1990 up to 92 thousand hectares (11.91 percent of total farmland) in 2013, according to Lao Statistic Bureau. Not only does the availability of irrigation systems enable farmers access to water to feed paddy rice fields but could also do the same for other short duration crops such as corn, cassava, cucumber, watermelon and others. However, the development of irrigation scheme is still in a small scale or dominated by the village-scale while a large scale of irrigation is limited (MAF 2014, p.49). MAF shows that the standard irrigation consists of 22 percent where the remains are considered as traditional irrigations such as permanent and temporary weirs, reservoirs, pump schemes, private pump installations, gates and dykes, and gabions. Nevertheless, the development of irrigation system in Laos is lagging behind its neighboring countries such as Cambodia. In addition, it is recognized that the investment on irrigation systems for paddy rice is costly since paddy rice requires much more water than other crops (Fukai and Mitchell, 2014).

The expansion of improved rice seeds is also claimed as a reason of increasing productivity. In 2011, the improved rice seeds are planted in growing areas accounting for as high as 46 percent of total paddy rice growing area. Since the improved rice seeds provide higher yields per hectare relative to traditional rice seeds, the extension of planted areas with such improved seeds would be able to raise the total output substantially. Similarly, farm mechanism has also changed to machinery and modern equipment such as two-wheeled tractor, generator, water-pump, and rice thresher leading to an increase of paddy rice productivity as well. MAF (2014, p.52-53) reports that the use of two-wheeled tractors by farmers had increased from 20 percent in 1999 to 61 percent of farm households in 2011, reducing the use of drought animals (buffalos). The advantage of two-wheeled tractors is in reducing soil erosion and nutrient loss. They are also better adapted to small size plots of paddy rice fields. Although considerable interventions by the government has been done such as the expansion of irrigation systems, invention of improved rice seeds and extension services over the last two decades, Im (2014) still concludes that the agricultural infrastructure such as irrigation and logistics system are regarded as poor.

TABLE 2

Regional Rice Production in 2013 by Selected Countries

Country	Area Harvested (ha)	Output (ton)	Output per Hectare (ton)
Australia	113,638	1,161,115	10.22
China, mainland	30,311,750	203,612,200	6.72
Indonesia	13,835,252	71,279,709	5.15
Cambodia	3,100,000	9,390,000	3.03
Republic of Korea	832,625	5,631,689	6.76
Laos	880,000	3,415,000	3.88
Malaysia	688,207	2,626,881	3.82
Philippines	4,746,082	18,439,406	3.89
Thailand	12,373,163	36,062,600	2.91
Viet Nam	7,902,808	44,039,291	5.57

Source: FAOSTAT Date: Fri May 01 10:19:57 CEST 2015

Comparing the position of Laos in the region, Table 2 shows rice output per hectare by country in 2013. It reports that rice output per ha in Laos is lower than several countries in the region such as Australia, China, Indonesia, South Korea, Philippines and Vietnam. For example, the output per hectare in Laos takes only 37.9 percent of Australia, 57.7 percent of China, 75.3 percent of Indonesia, 57.3 percent of South Korea and 69.6 percent of Vietnam. However, Laos has a slightly higher productivity than Cambodia, Malaysia and Thailand. The low productivity of rice in Laos is mainly due to poor infrastructure such as irrigation systems and poor machineries. However, since Laos is bordered with two largest of paddy rice producers such as Thailand and Vietnam, it is possible for Laos to improve the productivity by importing the technologies and investment from neighboring countries.

4. Methodology

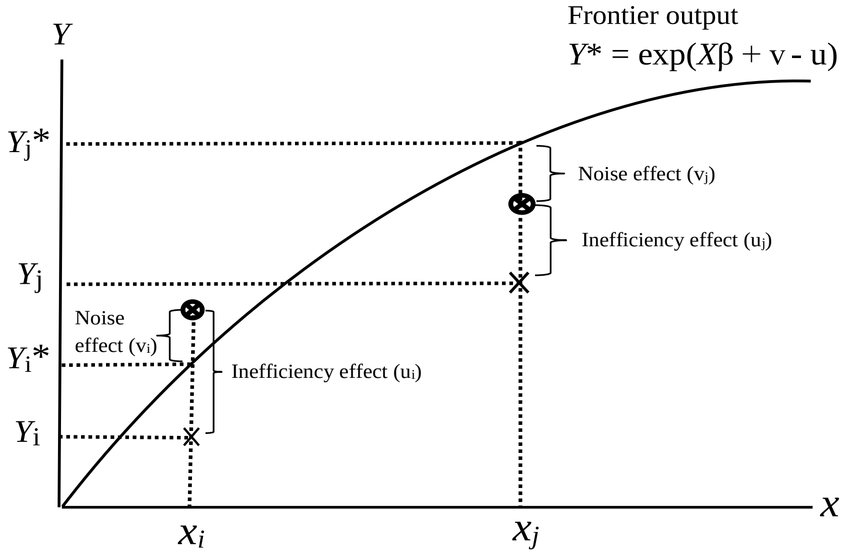
4.1. Theoretical Concept

Two approaches are widely applied to estimate the production frontier and measuring the efficiency, which are namely Data Envelopment Analysis (DEA) and Stochastic Frontiers Analysis (SFA). While DEA uses the linear programming, the stochastic frontier is dependent on the econometric methodology (Coelli, T. *et. al*, 2003). In this study, the stochastic frontier method is applied. Before approaching the details on specification of econometric model, the theoretical concept is presented.

According to Farrell (1975), the efficiency of firm's production consists of two components (1) technical efficiency and (2) allocative efficiency. The technical efficiency refers to the ability of a firm to gain the optimal (maximal) output given a set of inputs whereas the allocative efficiency demonstrates the ability of a firm to use inputs in the optimal proportions given their respective prices. On the other hand, Lee and McKibbin (2014) indicates that there are three sources of raising productivity as follows (1) increasing in the quality of inputs, (2) improving in the way the inputs are used , and (3) improving in the way inputs are allocated across the economy.

FIGURE 2

The Stochastic Frontier Function



Source: edited from Coelli *et al.* (2005, p, 244)

Figure 2 demonstrates the concept of production frontier where the horizon *axis-x* represents the inputs; the vertical *axis-y* is denoted as output and where *i* and *j* refer to the observed farm household *i* and farm household *j* in this study respectively. The production function of equation (1) is assumed as diminishing return to scale. Household *i*, as the same as household *j*, uses inputs (x) to produce outputs (y*) at the frontier level as in the equation as follows:

$$Y_i^* = f(X_i, \beta)\, e^{vi - ui} \qquad (1)$$

Where, *i* is the number of farm households (i = 1, 2, ……, n), Y_i^* is the optimal paddy yield, X_i is a (1xk) vector of inputs such as capital, labour, seed and fertilizer and β is a (kx1) vector of parameters to be estimated. Note that there is no subscription of time (*t*) because this study uses the cross-sectional data. However, with the existing of the technical inefficiency and given the amount of inputs, farm household could produce the output only at *Y* (Figure 1). The error term v_i is assumed to be independently and identically distributed as N ~ $(0, \sigma^2_v)$ and captures random variation in output due to factors beyond the control of farmers such as luck, natural disaster such as flooding or drought, and measurement errors. The error term u_i captures farms-specific technical inefficiency in production, specified by

$$u_i = z_i \delta + w_i \qquad (2)$$

Where, z_i is a (1xm) vector of explanatory variables, δ is a (mx1) vector of unknown coefficients and w_i is a random variable. u_i is obtained by a non-negative truncation of N ~ $(z_i\delta, \sigma^2_u)$ or N~ (μ, σ^2_u). It is recognized that the farm inefficiency of u_i can be assumed to have an exponential and a half-normal distribution. However, Gutierrez et al. (2001) highlight that because the null hypothesis test of standard errors (σ_u^2) under the exponential and half normal distribution lies on the boundary of the parameter space of the standard error (σ_u^2), the standard likelihood-ratio test is likely not to be valid resulting in no farm efficiency. Accordingly, a non-negative truncation distribution is preferable. Input variables can be included in both equation (1) and (2) as long as technical inefficiency effects are stochastic (Battese and Coelli 1995). When $u_i \geq 0$ in equation (1), it is conditional to ensure all observations fall under the stochastic production frontier.

According to Battese and Corrra (1977) and Battese and Coelli (1993), variance terms are parameterized by replacing σ^2_v and σ^2_u with $\sigma^2 = \sigma^2_v + \sigma^2_u$ and $\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$. As a result, the technical efficiency (TE_i) of i^{th} farm household can be defined as

$$TE_i = E(Y_i / u_i, X_i) / E(Y_i / u_i = 0, X_i) = e^{-ui} = \exp(-z_i \delta - w_i) \qquad (3)$$

The measure of technical efficiency (TE_i) is given by equation (3) based on the values of $v_i - u_i$ evaluated at the maximum likelihood estimates of the parameters in the model, where the expected maximum value of Y_i is conditional to $u_i = 0$ (Battese and Coelli 1988). Thus, TE_i must have a value between zero and one.

4.2. Economic Specification

To examine the efficiency of paddy rice farm, stochastic production frontier and inefficiency model are applied. Both models are simultaneously estimated in one step and facilitated by a software program of FRONTIER 4.1 with the maximum likelihood estimation. The theoretical concept of stochastic production frontier and inefficiency model is already explained in previous section. Equation (4) specifies the details for the production frontier function. It shows that total output of paddy rice is the function of capital (K_i), labor (LAB_i), farmland (LAN_i), inputs (FER_i, $SEED_i$), and other costs ($OTHER_i$) such as payments for fuel, irrigation fee and land tax. Location, natural disaster, infrastructure and project development which are regarded as factors beyond the control of farmers are also included in the production model to capture the differences between locations. For instance, the different infrastructure is expected to capture the cost of transportation including time consumed between regions. Also, the location effect is anticipated to capture other unobservable factors such as different temperatures between regions. Both production frontier and inefficiency models are assumed to be Cobb-Douglas function and the most relevant variables are selected since the sample size is small.

- *Stochastic Production Frontier Model*

$$lnY_i = \beta_0 + \beta_1 lnK_i + \beta_2 lnLAB_i + \beta_3 lnLAN_i + \beta_4 lnFER_i + \beta_5 lnSEED_i + \beta_6 lnTHER_i + \beta_7 DISASTER_i + \beta_8 LOCATION_i + \beta_9 INFRAST_i + \beta_{10} PROJECT_i - u_i + v_i \qquad (4)$$

Where,

- Y_i is total output in kilograms for farm household *i*
- K_i is capital such as tractor, knife, axe and harvesting machines in local currency (LAK) for farm household *i*
- LAB_i is total labor use in numbers for farm household *i*
- LAN_i is total area of planted land in hectares for farm household *i*
- FER_i is total amount of fertilizer usage in kilograms for farm household *i*
- $SEED_i$ is total amount of seed usage in kilograms for farm household *i*
- $OTHER_i$ is total other spending such as payments for fuel, irrigation fee, land tax and land preparation service in local currency (LAK) for farm household *i*
- $DISASTER_i$ is a dummy variable for a natural disaster of floods. The dummy variable is 1 if the farms of household *i* is flooded and 0 if farms aren't.
- $LOCATION_i$ is a dummy variable for survey locations. The dummy variable is 1 if the location is Vientiane capital and 0 if locations are others.
- $INFRAST_i$ is a dummy variable for infrastructure. The dummy variable is 1 if farm household *i* access the main road and 0 if they don't.
- $PROJECT_i$ is a dummy variable for project developments. The dummy variable is 1 if farm household *i* is treated by development projects and 0 if they aren't.
- u_i is the a non-negative random
- v_i is a random with well behavior

- *Inefficiency Model*

While the error term u_i captures farm-specific technical inefficiency, equation (5) identifies the possible specific variables expected to have some influences on the inefficiency or efficiency of the production. It should be noted that only the specific variables under the control of farmers and other factors such as training and advisory that affect directly the production efficiency of farmers are considered in the inefficiency model (equation 5). External factors like location and infrastructure which are beyond the ability of farmers to control are not taken into account; rather, they are considered in the production model (equation 4). The specific variables of $QLAND_i$, $WATER_i$, $USEED_i$, $UFER_i$ and $PLOTS_i$ are classified in the component of technical efficiency since they demonstrate to the ability of a farm household to gain the optimal (maximal) output by improving the use of inputs efficiently such as the plots of farmland ($PLOTS_i$) and the quality of soil ($QLAND_i$) and water management ($WATER_i$) given a fixed amount of inputs (size of farmland and amount of water). Another example is the use of seeds per ha ($USEED_i$) and fertilizers per ha ($UFER_i$) to increase the efficiency of production (the yield and output) given their respective prices. Lastly, ED_i, $VISIT_i$, $CERT_i$, $MEMBER_i$, $CONT_i$ refers to other factors that might influence the technical efficiency directly through the channels of knowledge transfer and capacity building for farmers. For example, as a membership of rice association, the expertise of farmers can be strengthened through knowledge transfer or lesson learned among group members and prioritized for formal training, visit tour and other assistance such as subsidies from governments and non-government organizations (NGOs).

$$lnu_i = \delta_0 + \delta_1 lnED_i + \delta_2 lnPLOTS_i + \delta_3 lnUSEED_i + \delta_4 lnWATER_i + \delta_5 lnQLAND_i + \delta_6 lnUFER_i + \delta_7 VISIT_i + \delta_8 CERT_i + \delta_9 MEMBER_i + \delta_{10} CONT_i + \epsilon_i \qquad (5)$$

Where,

- ED_i is education in schooling years of household' head i
- $PLOTS_i$ is the size of a plot in square meter for farm household i
- $USEED_i$ is the seed usage in kilograms per hectare for farm household i
- $WATER_i$ is the variability of water measured by the height in centimeters for farm household i
- $QLAND_i$ is a dummy variable for the quality of land for a farm household i. The dummy variable is 1 if the quality of farmland is good or very good and 0 if it isn't.
- $UFER_i$ is the fertilizer usage in kilograms per hectare for farm household i
- $VISIT_i$ is a dummy variable for a visit by agricultural officers for farm household i. The dummy variable is 1 if farm household i was visited by agricultural officers and 0 if they aren't.
- $CERT_i$ is a dummy variable for training with a certificate. The dummy variable is 1 if farm household i was trained and received a certificate and 0 if they aren't.
- $MEMBER_i$ is a dummy variable for membership of rice association. The dummy variable is 1 if farm household i is a member of rice association and 0 if they aren't.
- $CONT_i$ is a dummy variable for contract farming. The dummy variable is 1 if farm household i makes a contract farming with private companies such as mills and 0 if they don't.
- ϵ_{it} is the error term with a well behavior

4.3. Data Source

This study applies a cross section data from farm household survey conducted in central and south region of Laos as they are the main rice producers. As a result, Vientiane Capital, Khammuane, Savannakhet and Champasack provinces are selected as the representatives in the Central and South region (Figure 3) since they are the top largest producers sharing more than half of total output in 2014[3]. The districts of Hadsaifong, Nasaitong and Pakngeum[4] were selected as the targeted locations in Vientiane capital. In Khammuane province, Nongbok district[5] in Khammuane province was selected. Saybouly district[6] was targeted for the survey in Savannakhet. Lastly, the districts of Phonetong, Champasack and Sanasomboun[7] were picked up respectively for the survey in Champasack province. About 343 paddy farm households were randomly selected in the targeted areas as a sample and the survey was carried out after the harvest in the middle of December 2015.

Questionnaire is the main use for the survey while the interview schedule is supplementary. Farm households were asked to give a bundle of information on farm activities in details such as the size of farmland, output, the use of seed, plot, quality of land, labour use, wage, capital spending and extension services such as the visits by agricultural officers and the provision of training by public agencies such as Japan International Cooperation Agency (JICA).

FIGURE 3

Vientiane Capital, Kammuane, Savannakhet and Champasack Province in the Map of Laos

Source: https://www.google.la/search

[3] According to the Department of Agriculture, Ministry of Agriculture and Forestry (MAF) sourced by Lao Statistics Bureau (2015, pp. 68-70)

[4] The survey was mainly carried out in two villages in each district and around 18 households are randomly selected for each village. They are Ban Nongngau and Pattana in Hadsayfong district. Ban Padthana and Kongngau in Nasaytong district. Ban Thakok and Khounlau in Pakngeum district. The terms of "Ban" mean village.

[5] There are four villages in Nongbok district which are Ban Nongpham, Phonepheang, Nanoy and DongKong.

[6] Three villages were selected in Saybouly district which are Ban Vernneua, Tonhane and Kajou.

[7] In Phonetong district, Ban Phonetong and Tea are selected for the survey. In Champasack district, the targeted Bans are Nongnokkhien and Kateub. Lastly, two bans are selected in Sanasomboun district. They are Ban Souvanhnakhily and Ban Nakharm.

5. Survey Statistics Summary

Generally, the survey reports that the average size of households members in all locations is five persons per household with the standard deviation of 1.89. The household size for working age (between 6-60 years old) is 4.5 persons per household. Household size for working age in Kuammuance province is slightly higher than other locations whereas the smallest household size is in Vientiane capital. This statistics could illustrate the availability of labor for paddy rice plantation in different locations. However, since there are some members of the household migrating to work at other regions and neighboring countries, the size of household is likely to be underestimated. More importantly, most of farm households heads have education (6 years of schooling) below high school level. In addition, the sample are all the majority ethnic groups believing in Buddhism. Approximately 90 percent of the sample live in rural areas without main road access where the main occupation is farming. Only a small proportion of the sample engages as farm laborers, government officials, traders, and workers in manufacturing factories.

Table 3 reports the summary of paddy rice production from survey including areas of farmland in hectares. Generally, it indicates that there is a variation of paddy rice farm areas in different locations. It can be seen that paddy rice farmland per farm household is relatively small or around 2 ha as an average compared to the national level (2.4 ha[8]). Of which, paddy farmland per household (2.3 ha) in the survey location in Champasack province is respectively higher than other locations whereas farmland per household in Vientiane capital is the least (1.5 ha). More importantly, not all farmlands are utilized, reflecting that there are some spaces for farmers to increase the yield. Likewise, about 20 percent of farmlands are irrigated. Because paddy rice in the wet season is very much dependent on the availability of rainfall, irrigation access, especially relatively large canals and drainage would be helpful to adjust the water in paddy fields when the rainfall is low or excessive. Accordingly, it discloses that the yield of farmers who have access to irrigation systems is 3,147 kg per ha which is higher than those without irrigation access (2,652 kg per ha).

TABLE 3

Summary Statistics of Paddy Rice Production per Farm Household

List	Vientiane Capital	Khammuance	Savannakhet	Champasack	Total
• Total farmland (ha)	1.5 (0.3274)	2.5 (0.1881)	1.8 (0.1561)	2.3 (0.1248)	2.0 (0.1148)
• Irrigated area (ha)	0.73 (0.0785)	0.027 (0.0270)	0.64 (0.1379)	0.25 (0.0534)	0.4 (0.0399)
• Planted areas (ha)	1.1 (0.0845)	2.4 (0.1693)	1.6 (0.1171)	2.2 (0.1130)	1.8 (0.0665)
• Plots per ha (number)	23 (6.7624)	32 (1.8255)	19 (1.4227)	44 (9.2338)	31 (3.6839)
• Size of a plot (square meter)	1,025 (101.5617)	690 (130.5615)	999 (153.5588)	575 (63.3942)	799 (53.1231)
• Output per ha (kg)	3,145 (178.3563)	2,485 (114.7438)	2,897 (179.5651)	2,735 (121.0899)	2,825 (76.4219)

Note: The number in parentheses refers to the standard error.
Source: Author’s calculation

[8] Based on the Lao Census of Agriculture 2010/11

The survey also shows a number of plots per hectare by farm household. It presents that there are 31 plots per ha as on average and a size of a plot is 799 sq m or 20 m x 40 m. The number of plots per ha demonstrates the size of the plots in farmland. For instance, a small number of plots per ha indicates a larger size of a plot. According to the interview with a farmer at Dongkoung village in Khammuance province, a bigger size plot gives a large output of paddy per ha compared to a smaller one by as much as 10 percent. This is because between small plots per hectare are cleared to become bigger size plots. Such bigger size plots can expand the output per ha as a consequence. In addition, the enlarged size plots per ha shows an advantage for land preparation. Farmers in Vientiane capital and Savannakhet province apply larger size of plots per ha compared to farmers in other locations.

The productivity is also shown which is essentially reflecting efficiency differences among the farmers in different locations in producing paddy rice given inputs such as land, labor, varieties, and fertilizers. Note that the term productivity refers to output per hectare. Overall, the productivity is 2,779 kg or 2.7 tons per ha in survey locations which is much lower than the national level (4.0 tons). However, productivity in Vientiane capital performs better than other locations. For instance, the productivity in Vientiane capital is 3,145 kg per ha whereas it is less than 3,000 kg per ha in other locations. Such different productivity levels might be due to various factors such as quality of land, water availability, the effective use of seeds and fertilizer, size of plots and labor use.

TABLE 4

Scoring the Quality of Farmland by Farmers in Different Locations

Quality of Land	Vientiane Capital	Khammuance	Savannakhet	Champasack	Total
Very good	7%	0%	0%	1%	2%
Good	36%	20%	25%	32%	29%
Medium	48%	65%	63%	58%	57%
Bad	5%	8%	7%	7%	7%
Very bad	0%	0%	0%	0%	4%
Total	100%	100%	100%	100%	100%

Source: Author’s calculation

Given scores on the quality of land by farmers in different locations presented in Table 4 reveals that a number of farmers in Vientiane capital and Champasack province hold rich soil of farmland as relatively higher than in other locations. For instance, around 32-42 percent of the sample in Vientiane capital and Champasack province report that their farmlands are regarded as good and very good. Only 20-25 percent of the sample in two other locations claim their farmlands as good and very good. Furthermore, half of total farmland is declared as sandy soil.

TABLE 5

Water Availability Measured by Height in Centimeters (cm)

Life-circle of Paddy Rice	Vientiane Capital	Khammuance	Savannakhet	Champasack	Total
• Seedling emergence Stage	10.6 (0.8452)	12.9 (1.1300)	10.2 (0.9536)	6.9 (0.6160)	9.7 (0.4418)
• Initial stage	15.3 (1.1719)	14.0 (0.9093)	12.0 (1.4085)	8.5 (0.6328)	12.2 (0.5206)
• Flowering stage	19.6 (1.3580)	15.3 (0.7291)	15.1 (1.1044)	10.2 (0.6371)	14.8 (0.5401)

• Grain setting stage	20.4 (2.1115)	15.0 (0.8157)	12.4 (1.0052)	10.1 (0.6378)	14.5 (0.7138)
• Ripening stage	17.7 (1.8645)	12.0 (0.8931)	11.4 (0.9273)	7.3 (0.6102)	11.9 (0.6639)
• Harvesting stage	4.2 (1.0827)	7.8 (2.1187)	3.3 (1.6666)	0.6 (0.2895)	2.2 (0.4241)

Note: The number in parentheses refers to the standard error.
Source: Author's calculation

In a similar manner, water availability in the paddy fields is also crucial since paddy rice consumes considerably large amounts of water and which is dependent on the rainfall. Fortunately, the survey gives the information on water availability (water height in cm) and whether water availability in their paddy fields is insufficient or excessive. It turns out that a majority of sample (70 percent) states that water availability in paddy fields is sufficient. Only 30 percent asserts that water is short or excessive. Table 5 demonstrates the different levels of water in cm in different locations for different life-circle f paddy rice. It suggests that the water level is varied in different locations due to amount of rainfall. In brief, water in paddy fields is 14.6 cm in Vientiane Capital and is likely higher than other locations such as Savannakhet province (7.3 cm). It is unconcluded whether water availability in Vientiane capital. or Savannakhet province is considered as insufficient or excessive. However, water availability is for sure as one of the important factors for paddy rice in the wet season. Paddy rice could die in the life-circle of maturity, according to the interview with a farmer at Phonetong village in Champasack province, if water in the fields is either flooding or low for one or two weeks. He mentions that the yield is 3.5 tons per hectare when the water is sufficient or under control but the yield would be 2.8 tons and 2.5 tons per hectare in case of insufficient and excessive water, respectively. Because the rainfall is uncertain water availability in the fields is also uncertain, and water management and control is crucial not only for the yield but also for the use of inputs such as fertilizers. Farmers claim that they cannot always apply the correct proportion of fertilizers in kg per ha and according to soil quality. The uncertainty of rainfall may make fertilizer input useless if their farms experience flooding or drought.

TABLE 6

Input Use per Farm Household

Input	Vientiane Capital	Khammuance	Savannakhet	Champasack	Total
• Seeds (kg/ha)	158 (20.8631)	73 (4.2195)	164 (32.6915)	125 (7.5488)	130 (8.6445)
• Chemical fertilizer (kg/ha)	199 (17.6770)	123 (10.5248)	118 (18.0253)	118 (9.0539)	142 (7.2136)
• Organic fertilizer (kg/ha)	115 (63.6420)	528 (93.3153)	316 (76.2993)	194 (65.6163)	275 (37.6860)
• Pesticides (kg/ha)	0 (0.0000)	0 (0.0000)	0 (0.0000)	0 (0.0000)	0 (0.0000)
• Herbicides (liters/ha)	8.6 (1.5592)	0 (0.0000)	2.7 (0.8695)	0.2 (0.0923)	3 (0.5078)
• Fuel (liters/ha)	41 (4.7948)	30 (1.6701)	32 (2.5714)	30 (2.4879)	33 (1.7107)

Note: The number in parentheses refers to the standard error.
Source: Author's calculation

TABLE 7

Actual Cost Items per ha by Value in Local Currency (LAK)

Items	Vientiane Capital	Khammuance	Savannakhet	Champasack	Total
• Irrigation/water use	274,332		282,098	452,071	302,576
fee (LAK/ha)	(31,869)	0	(55,695)	(78,926)	(27,217)
• Loan interest	1,288,538	200,963	83,333	747,346	742,883
(LAK/ha)	(460,412)	(45,334)	(0.0000)	(188,436)	(129,392)
• Rental land	1,249,118			1,036,400	1,167,785
(LAK/ha)	(254,680)	0	0	(145,189)	(165,935)
	113,923	45,750	47,889	73,764	74,210
• Tax land (LAK/ha)	(15,835)	(2,931)	(4,674)	(8,533)	(5,046)
• Wage of hired	781,078	425,597	772,477	432,857	587,221
labor (LAK/ha)	(1,280,960)	(988,758)	(948,393)	(931,811)	(1,066,919)
• Other services	1,005,186	396,223	651,686	568,094	669,789
(LAK/ha)	(94,890)	(49,092)	(67,012)	(110,538)	(5,524.611)

Note: The number in parentheses refers to the standard error. The value of 0 means there is no farmers are irrigation membership or rent farmland. So there is no payment for fees.
Source: Author's calculation

The use of other inputs such as rice varieties, fertilizers, pesticides, fuel and other costs vary in different locations as presented in Table 6. Overall, there is around 86 percent of the sample using chemical fertilizers and less than 40 percent using organic fertilizers. Only eight percent of the sample applies herbicides and no one use pesticides. In terms of the amount, farmers use an amount of seeds of 130 kg per ha per farm household on average, 142 kg of chemical fertilizer per ha, 275 kilograms of manure per ha, three liters of herbicides per ha and 33 liters of fuel per ha. The use of seeds and chemical fertilizers per ha is higher in Vientiane capital than other locations. Farmers in Khammuance and Savannakhet province tend to use a combination of organic and chemical fertilizers more than in other locations. In addition, the improved varieties are widely used. Nonetheless, this shows that the use of inputs by farmers is different among locations suggesting that there might be some unappropriated use of inputs by farmers in some locations leading to lower output per ha. Fortunately, no farmers report that their farms were threatened by disease.

TABLE 8

Production Cost per Farm Household by Value (Local Currency-LAK) and Share (%)

Items	Payout Cost (LAK)	Share	Total Cost (LAK)	Share
Seeds	0	0%	48,362*	5%
Chemical fertilizer	613,726	13%	13,726	5%
Pesticides	611	0%	611	0%
Herbicides	32,331	1%	32,331	0%
Fuel	374,317	8%	74,317	3%
Irrigation/water use fee	302,576	7%	02,576	2%
Loan interest rate	742,883	16%	742,883	6%
Rental land	1,167,785	26%	1,167,785	9%
Tax land	74,210	2%	74,210	1%
Wage of hired labor	587,221	13%	587,221	5%
Wage of family's labor	0	0%	7,704,961*	60%
Other services	669,789	15%	669,789	5%
Total	4,565,449	100%	12,918,771	100%

Note: * refers to the estimated cost based on the market price. Total Cost including unpaid cost
Source: Author's calculation

Other costs are also reported such as irrigation fee, loan interest, rental land, land tax, wage of hired labor and other services in Table 7. Taking all variable costs into account, the structure of production cost for both payout cost and total cost per household per ha can be estimated and shown in Table 8. Payout cost means farmers pay for the production cost in cash. Total cost includes the payout cost and unpaid cost such as the use of household labor and varieties. For the payout cost, it is seen that major costs of the plantation are chemical fertilizer, loan interest, rental, payment for hired labor and other services which account for more than 80 percent of total payout cost. In contrast, payments on herbicides, fuel, tax on land and other fees are less than 20 percent. Although the price of fuel has declined recently, this might not help lower cost because of its share is small. At the same time, the price of fertilizer and hiring labors are costly. Hence, farmers are probably relieved if the use of chemical fertilizers and labor use can be substituted by machinery and organic fertilizers from livestock. The information from the survey reveals that less than 10 percent of the sample uses machinery such as harvesting, threshing machine and big tractors. Also, less than 40 percent of the sample use manures as an organic fertilizer. The use of machines is possible to reduce the cost of hiring laborers, in particular for weeding and harvesting while the use of organic fertilizers would incur savings from purchasing expensive chemical fertilizers. When including the unpaid cost, which are the use of seeds and household labor, the structure of production cost is substantially different. Accordingly, the estimated wage for household employment share the largest with over 60 percent of total cost, followed by rental land and interest rate at nine and six percent, respectively. However, it should be noted that not all samples made rental payment for the farmland, borrowed funds or paid for irrigation fee. The survey shows that less than 10 percent of sample paid rent for farmlands, 21.8 percent of sample are members of an irrigation association and made such payment. Only 7.8 percent of sample borrowed funds from banks and microfinance agencies, respectively.

TABLE 9

Labor Use in Different Stages of Plantation per Hectare

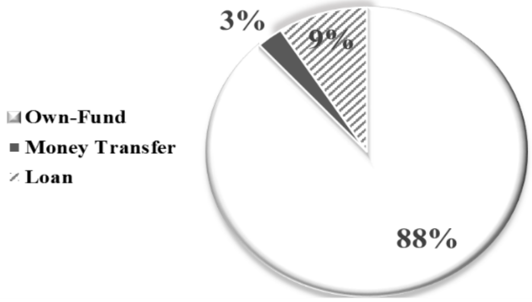
List	Hired Worker (Person)	Total Labour (Person)	Total Days (Total)
Land preparation	0	3	4
Seeding	2	6	16
Maintenance	0	2	50
Harvesting	3	8	14
Total	5	19	84

Source: Author’s calculation

While the use of labor by farming household is illustrated in Table 9, the source of fund is summarized in Figure 5. It reveals that a total of 19 laborers are employed for the whole circle of plantation which takes about 84 days or three months approximately. Of which, five laborers are hired for weeding and harvesting on average. The wage of hired labor is around LAK 50,000-80,000 or USD 6-10 per person per day. Finally, a major fund for paddy rice plantation is their own-fund sharing, which is 88 percent of total fund while money transfer and loans from banks and village fund are the minority.

FIGURE 5

Source of Fund by Share (%)



Source: Author's calculation

It is interesting to know that a fraction of sample could access extension services at some point. For instance, only 14 percent of sample was trained formally with certificates on new technological agriculture and skills such as how to produce organic fertilizers, the use of organic pesticides, seed varieties, irrigation management, livestock and maintenance. The trainings were held by public and non-government organizations such as local agricultural office, provincial department of agriculture and Japan International Cooperation Agency (JICA). In 2015, only 32 percent of sample (109 out of 343 households) was visited by agricultural officers. The purpose of visits is to introduce mainly the use of inputs such as organic fertilizers instead of using chemical fertilizers, the use of pesticides, and seed varieties. Only nine percent of sample is a member of a rice association. The main benefits of being a member of a rice association are knowledge transfer or lessons learned on new technology among group members and prioritized for training, visit tours and other assistance such as subsidies from governments and non-government organizations (NGOs). These suggest that there are still a large proportion of farmers without access to extension services. In a similar way, a small proportion (two percent) undertook contract farming with private companies such as mills.

6. Econometric Result and Discussion

This section presents the result of the hypothesis specified in econometric specification model (equation 4 and 5). The purpose is to identify the key factors for paddy rice production and technical inefficiency based on the farm household survey to provide policy recommendation to increase farmers' production efficiency. The factors such as infrastructure, location and project development are also included in the model to capture the differences between households that might influence paddy rice production directly or indirectly. The econometric results for two models are summarized in Table 10. At first, the value of Gamma (γ) associated with the variance in the stochastic frontier is 0.96 which is highly significant at 1 percent level implying that 96 percent of the difference between observed output and maximum production frontier is due to the difference in farmers' level of technical inefficiency rather than random variability. The value of Gamma (γ) lies between 0 to 1 and the closure of such value to 1 means the frontier model is appropriated. Secondly, the value of LR test for the one-sided error is 97.604713 which is higher than the value of Chi-square ($\chi 2$) distribution (29.588) at 1 percent level proves the existence of inefficiency while rejecting the null hypothesis of no existence of inefficiency.

Results for the stochastic production frontier show mainly expected signs of coefficients. Farmland (LAN), labor (LAB), capital (K), seed (SEED) and natural disasters (DISASTER) are highly significant for paddy rice production whereas other inputs such as fertilizers (FER), geography (LOCATION), infrastructure (INFRAST), project development (PROJECT), and other spending (OTHER) such as land tax, fuel, irrigation fees are insignificant. The coefficients on farmland (LAN), labor (LAB), capital (K), seed (SEED) and natural disasters (DISASTER) are 0.58, 0.14, 0.074, 0.13 and -0.71, respectively. It is demonstrated that, for instance, an increase of farmland areas by 1 percent will raise the total output by 0.58 percent assuming other things are constant. Also, an increase of labor use, capital spending and seeds will improve total output by 0.14 percent, 0.074 percent and 0.13 percent, respectively, given that other things are constant. This suggests that an area of farmland, labor use, seed and capital are the main factors for total output production in the wet season while a natural disaster of floods reduces the output.

The variable of other costs that show as insignificant suggests that an increase of these spending will not really increase total output of the production. Instead, the production would expand when farmland or seeds are extended or increased in size and amount. Lastly, farmers who have their farms flooded would obtain the output lower than farmers who have not flooded by 71 percent.

TABLE 10

Estimates for Parameters of Stochastic Production Frontier and Technical Inefficiency

Model	Parameter	Coefficient	Standard-error	t-ratio
Stochastic Production Frontier Model				
CONS	β_0	2.1332***	0.3231	6.6021
LAN	β_1	0.5841***	0.0464	12.5678
LAB	β_2	0.1476***	0.0423	3.4882
K	β_3	0.0742***	0.0169	4.3857
SEED	β_4	0.1344**	0.0423	3.1757
FER	β_5	-0.0131	0.0104	-1.2592
OTHER	β_6	0.0008	0.0073	0.1136
DISASTER	β_7	-0.7175***	0.1236	-5.8042
LOCATION	β_8	0.0895	0.0605	1.4778
INFRAST	β_9	0.0370	0.0740	0.5006
PROJECT	β_{10}	0.0303	0.0986	0.3078
Technical Inefficiency Model				
CONS	δ_0	2.7665**	1.0160	2.7229
EDU	δ_1	-0.1869	0.1353	-1.3811
PLOTS	δ_2	-0.8617***	0.2267	-3.8009
USEED	δ_3	-0.4948**	0.1836	-2.6947
WATER	δ_4	0.2821	0.1613	1.7490
QLAND	δ_5	-0.5952**	0.2147	-2.7714
UFER	δ_6	-0.2184***	0.0616	-3.5466
VISIT	δ_7	0.3925	0.2519	1.5582

CERT	δ_8	-0.8324*	0.3729	-2.2322
MEMBER	δ_9	-5.6005**	2.0293	-2.7597
CONT	δ_{10}	0.7897	0.9815	0.8046
Sigma-squared		1.4408***	0.3434	4.1948
Gamma (γ)		0.9644***	0.0113	85.2903
Log Likelihood Function		-192.5429		
LR test of the one-sided error		120.0005		
Mean Efficiency (percent)		69.7		
Number of Observation		343		

Note: ***, **, and * denote significance at the 1 percent, 5 percent and 10 percent level, respectively.
Source: Author's estimation

The results from the inefficiency model showcase key factors significantly on the production inefficiency reported as well in Table 10. Size of a plot (PLOT), an amount of seeds per hectare (USEED), quality of land (QLAND), an amount of fertilizers per hectare (UFER), training with a certificate (CERT), and membership of rice association (MEMBER) are significant. Their coefficients are (-) 0.86, (-) 0.49, 0.16, (-) 0.59, (-) 0.21, (-) 0.83 and (-) 45.6, respectively. The negative coefficient means reducing/improving the production inefficiency/efficiency. However, the variables of the visit by agricultural officers (VISIT) and contract farming (CONT) are not significant. The discussion of each variable is as follows:

Firstly, farmers who becomes a member of a rice association (MEMBER) are more efficient than non-members. The benefits of knowledge sharing and transfer among members are the main reasons. Since the success or best practice or poor practice of a particular member can be easily observed by other members in the paddy fields, it is convincible when a skill of best practice is passed to other members. Then knowledge transfer can be made through the conversation among members at the formal or informal meeting organized by the association. Because of knowledge sharing, farmers who belong to the association are more skilful than who are not. Secondly, training with a certain certificate (CERT) is also important for farmers to absorb new technologies or appropriated practice on paddy rice plantation through such training. Farmers can apply the lessons from training in the areas of land preparation, use of fertilizers (both organic and chemical), seeds, pesticide and herbicide in the correct way. Therefore, farmers who were trained are more efficient than farmers are not. Taking together, this should suggest that the expansion of rice association and certified training are the most effective ways to improve farmers' skills raising the efficiency of their farming since their coefficients are relatively large.

Thirdly, it is clearly seen that the quality of land (QLAND) is highly significant. Rich nutrient soil can minimize production inefficiency and boost productivity compared to poor soil. This result supports the statement by Lee and McKibbin (2014) that an increase in soil quality is among three sources of raising productivity. The other two are: improving the way inputs are used (technical change); and improving the way inputs are allocated across the economy.

As farmers in different locations use a proportion of inputs per hectare differently, the output should be different among farmers. The production inefficiency can be reduced as a result of appropriate use of inputs such as seeds and fertilizers in an optimal proportion respective to the size of farmland. Efficiency can be improved by almost one percent by adjusting the proportion of seeds and fertilizers to farmland size (per ha). The survey shows that proportions of seeds and chemical fertilizers per ha applied by farmers are 130 kg per ha and 142 kg per ha. Meanwhile the appropriated proportions, suggested by an experienced farmer, should be around 100 kg per ha and 250 kg per ha, respectively. This indicates that there is room to reduce the inefficiency by adjusting the amount of seeds and fertilizers per ha. Also, increasing the size of the plot (PLOTS) by 1 percent can reduce the inefficiency by 0.8 percent. According to the interview, a bigger size of a plot gives both larger productivity and total output of paddy compared to a smaller one by 10 percent. It is because the medium between small plots per hectare are cleared, allowing the size of plots to become bigger and expanding the productivity and total output as a consequence.

The role of education (ED) is unlikely to play a part of helping farmers to learn new technologies compared to other instruments such as membership in a rice association and training. The result indicates that education is not an important factor for farmers to improve production efficiency since farmers are generally uneducated. Yet, the variable of water availability (WATER) shows a disappointing result although the sign of coefficient is positive as expected. Water availability is an important matter on production efficiency even as farmers are unable to control water in paddy fields during excessive rains but the econometric result proves that this is not the case of concern since its impact is not significant statistically. However, water availability seems to have an indirect effect on efficiency with regards to use of inputs such as fertilizers. Farmers cannot apply fertilizers appropriately to match with the type of their farmland because fertilizers could be washed away by the water. Hence, water availability is considered to play an important part on production efficiency for paddy rice in the wet season.

The reasons why other variables such as the visit by agricultural officers (VISIT) and contract farming (CONT) are insignificant seems to be that the visits by agricultural officers (VISIT) are not helpful. Such visits are mainly to convince farmers to use organic fertilizers instead of chemical ones. Although organic fertilizers can recover and maintain the quality of soils and give better productivity, the effect takes more time or at least two to three years, according to the interview. Inputs such as animal manure for making organic fertilizers are scarce since animals, like cattle, have declined in number over time. Farmers seem to be more satisfied using chemical fertilizers that give quicker results. Therefore, in their view, chemical fertilizers are preferable. Contract farming (CONT) is not supportive as well. When farmers undergo contract farming, only inputs such as seeds and fertilizers are provided by private companies; there is no accompanying training. Therefore, the effect of contract farming on production efficiency is invalid and significantly proved by the econometric result.

Based on the econometric regression, the technical efficiency for farmers is estimated at 69.7 percent of the frontier which is close to the efficiency level estimated by Inthavong (2005) at 72 percent but is higher than the estimate of Phetsamone (2012) at 50 percent. The mean of the optimal frontier in terms of output per hectare or the productivity is around 4,032 kg while the mean actual is 2,825 kg. As a consequence, the difference between the optimal and the actual is 1,207 kg due to technical inefficiency.

7. Conclusion

Since Laos is an agricultural economy, the majority of population living in rural areas is dependent on agricultural activities as the main source of income. Within agriculture, paddy rice share predominantly and play an essential role for rural people's consumption and income. Paddy rice plantation in Laos is classified into three types which are (1) paddy rice fed-lowland in the wet season, (2) upland paddy in the wet season and (3) paddy rice lowland in the dry season. Paddy rice fed-lowland is the main productivity source in terms of areas and outputs. Since the productivity of paddy rice in Laos is relatively low relatively to other countries in the region, this research seeks ways to escalate the productivity of paddy rice in the wet season by improving production efficiency. To do this, Cobb-Douglas stochastic production frontier and inefficiency models are used. The models are delivered by FRONTIER 4.1. The data of 343 farm households is collected in rural areas in different locations in Laos, namely, Vientiane capital, Khammuance province, Savannakhet province and Champasack province.

Statistics from the survey shows that the productivity level is different among farmers in different locations, reflecting the difference in efficiency in producing paddy rice. The production inefficiency is predominantly explained by the use of different inputs such as water, farmland areas, soil, seeds, fertilizers and other spending. This implies that there might be some unappropriated use of inputs by farmers in some locations leading to lower productivity. Generally, the survey reveals that farmers use an amount of seeds for 130 kg per ha per farm household on average, 142 kg of chemical fertilizer per ha, 275 kg of manure per ha, three liters of herbicides per ha and 33 liters of fuel per ha. While around 30 percent of the sample claims the water in their fields is short or excessive, about 20-40 percent states that the soil of their farmland is rich in nutrients only. The econometric results indicate that farmland area, capital, seed and labor use are the key determinants for paddy rice production. This suggests that increasing the output can be done by accelerating an amount of these inputs, especially the size of farmland. Also, key determinants on production inefficiency can be identified. The study reveals that knowledge transfer on new technologies and skills through rice associations and training are the most influential determinants on production inefficiency while quality of land, size of a plot, seeds per ha and fertilizers per ha are also important. Public extension and contract farming are not really helpful for farmers to increase their production efficiency.

For policy recommendation, the priorities need to be identified. Firstly, knowledge transfer on new technologies, skills and lessons learned to farmers should be strengthened through the expansion of rice associations and training. Knowledge transfer will allow farmers to utilize inputs more efficiently and appropriately such as seeds, fertilizers per ha, and size of a plot which are central elements to reduce the inefficiency. Land reform should be warranted to secure the confidence of farmers when they invest more on their farmland, especially in increasing plot size since plot size matters to increase efficiency. Secondly, improving the quality of land should be considered as production efficiency increases by improving nutrients of the soil. To this end, the use of organic fertilizers is encouraged. This can be done by promoting raising of livestock and stimulating an organic fertilizer industry. Thirdly, the service of public extension should be strengthened to assist, facilitate and supervise farmers to increase efficiency, including organizing, training and expanding rice associations. Fourthly, as the output and the use of inputs (fertilizers) are limited by water availability, attention needs to be paid on water control systems in paddy fields. This can be done by investing on large scale irrigations such as canals and drainage to make sure that irrigation will allow farmers to manage the water in their farms both in the case of floods and drought.

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