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Production efficiency of maize farmers under contract farming in Laos PDR

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Abstract

Maize is the second largest commercial crop in Lao PDR, especially in the northern and southern regions. Traditionally, farmers in Lao PDR produced and distributed products in the market on their own. Recently, however, contract farming has gained in popularity and has become more widely accepted, especially after the country entered international collaborations under the Ayeyawady-ChaoPhraya-Mekong Economic Cooperation Strategy (ACMECS) and the Greater Mekong Sub-region (GMS). This study analyzed the technical efficiency of maize production under the contract farming system. Data were collected from the survey responses of 302 contract farmers in Lao PDR's northern and southern regions and were analyzed using stochastic nonparametric envelopment of data (StoNED). Maize production efficiency estimations were calculated using the Tobit model. The results revealed that the efficiency of contract maize farmers in Lao PDR was on average 0.85 and that the main factors affecting maize production efficiency were the age and education level of the farmer and area of planted land. Age and education level had significantly positive impacts, whereas planted land area had negative impacts.

Introduction

Contract farming is one of the agribusiness investment projects offered by Thailand to neighboring countries, particularly Cambodia, Lao PDR, Myanmar, and Vietnam, under the Ayeyawady-ChaoPhraya-Mekong Economic Cooperation Strategy (ACMECS) and the Greater Mekong Sub-region frameworks. As a result, Thailand and its neighboring countries have collaborated on production under contract since 2004 and under the Free Trade Agreement framework since its introduction in 2010 (Ministry of Foreign Affairs, 2007; The Thailand Research Fund, 2012). Maize is one of the staple crops that has been promoted under the Agreement. Since the Agreement commenced, the maize-planted area within Lao PDR has been constantly expanding. In 2001, the maize-planted area in Lao PDR was recorded at 43,870 ha, which increased to 212,745 ha in 2010, indicating a production rate with a ten-times greater output. In other words, Lao PDR produced 111,869 tonnes of maize in 2001, which rose to 1,020,880 tonnes in 2010 (The Board of Investment of Thailand, 2011). Originally, the majority of Lao PDR's maize-planted area was across the northern part of the country. However, following the promotion of maize production under the contract farming system in the southern provinces of Salavan and Champasak since 2004–2005, the maize-planted area has increased gradually. Farmers continue to encounter issues related to the inability of small traders and contracting partners to undertake the purchase of all the product

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grown. In addition, it was found that Thai-Laos maize contract farming arrangements in northern Lao PDR are different from those in southern Lao PDR. Specifically, the contract system in the north (Bokeo province) does not have a clear written contract. Instead, a representative from Laos PDR (the Head of the maize production group) acts as the coordinator with small-scale farmers while Thai investors invest in the various production factors (seeds, fertilizers, chemicals). In the south (Champasack and Salavan provinces), the contract farming system operates under a clearly written and signed agreement of collaboration between farmers and investors (Kaset Akan Import Export Co., Ltd. and Chanachai Import Export Co., Ltd.). The contract is a fully defined "2 + 3" agreement in which the farmers invest in labor and land while the investors invest in technology (further knowledge regarding production) and production factors, then purchase the farmed products with a guaranteed minimum purchase price.

Though some continue to face marketing issues, participation in the contract farming system has enabled farmers to access more conveniently important inputs, such as seed. This is reflected in the amount of seed used in production, which was a mere 899 tonnes in 2001 but rose significantly to 4,255 tonnes in 2010. This increase reflects the progressive improvement of maize production performance in Lao PDR. Overall, average maize production per hectare increased from 2.55 tonnes in 2001 to 4.80 tonnes in 2010, corresponding to a roughly 88 percent increase. However, at the regional level, many part of the country still face issues related to low production efficiency. For example, in the northern part of Lao PDR, especially in upland areas, maize yields are generally between 1.5 and 2.5 tonnes per hectare, which is lower than national maize yields (Department of Planning, 2010, as cited in; Boundeth, Nanseki, & Takeuchi, 2012). This is because maize production under contract farming is relatively new to farmers in the country. The production system is unlike the traditional approach, which is heavily reliant on labor and environmental conditions. It is important to note that maize production under contract farming requires inputs such as seed, chemical fertilizer, and herbicide, as well as the system that oversees and monitors the production process.

Numerous studies have examined the technical efficiency of maize production in many African countries such as Nigeria (Ibrahim, Shamsudin, Yacob, & Radam, 2014; Oladunni, Aduba, & Onojah, 2013; Raheem, Idris, & Shakita, 2015) and Ghana (Addai, Owusu, & Danso-Abbeam, 2014; Kuwornu, Amoah, & Seini, 2013; Sienso, Asuming-Brempong, & Amegashie, 2014). However, Boundeth et al. (2012) noted that such research on agricultural production efficiency is rather limited in Lao PDR, particularly analysis of the efficiency of maize production, which has never been studied. Therefore, the work of Boundeth et al. (2012), which looked at the technical efficiency of maize production, can be considered the first of its kind. In the same year, Viengpasith, Yabe, and Sato (2012) conducted similar work. Both studies looked at the technical efficiency of maize production in northern Lao PDR using stochastic production frontier analysis (SFA).

The objective of the present study was to analyze the technical efficiency of maize production and the factors affecting this under the contract farming systems in Lao PDR. In this study, the data were analyzed using stochastic nonparametric envelopment of data (StoNED), which was introduced by Kuosmanen (2006). StoNED provides all the benefits of data envelopment analysis (DEA) and SFA without the requirement of a large sample size or the consideration of production-related calculations, while also being able to separate distinct variables. This study is among the first empirical research to investigate maize production efficiency in Lao PDR. The primary aims were to develop a better understanding of the factors affecting output in important production areas, which can be used as guidelines to increase output. These will be critical issues as long as maize remains one of the main commercial crops of Lao PDR.

Methods

Study Area and Data Collection

This study explored the efficiency of maize production in northern (Bokeo province) and southern (Champasak and Salavan provinces) Lao PDR in important maize-planted areas under the contract system. The contract farming system started to gain popularity in Lao PDR in 2004, leading to a continuous increase in maize production yields and maize-planted land area in Bokeo, which peaked at 22.5 million kilograms and 20,700 ha, respectively, in 2008 (Ministry of Agriculture and Forestry, 2010). However, following China's initiative to support banana production under contract farming in Lao PDR, the maize-planted area in Bokeo shrank by more than 260 percent and output began to dwindle. Nevertheless, some farmers have adhered to the traditional production system, which involves the cultivation of paddy rice during the rainy season and the production of alternative crops such as maize to generate additional income during the dry season. It should be noted that areas allocated for banana production cannot be used for rice cultivation, which is the staple crop for households for at least two to three years. Some farmers also chose to grow maize during both the rainy (April to May) and dry (October to November) seasons. Maize production under contract farming in Bokeo is an agreement between Laotian farmers and Thai investors in which the latter provide support in terms of input such as seed, chemical fertilizer, herbicide, and production technology through the Maize Production Group of Lao, whose role is to coordinate with small Laotian producers to undertake delivery to Thai investors of all produce grown, according to the agreement.

Maize can be grown in Champasak and Salavan only during the rainy season and thus production is highly reliant on environmental conditions. Contract farming became more popular in both provinces after Chanachai Import Export Co. Ltd. of Thailand built silos to store agricultural products in 2009 and supported farmers in the "2 + 3" scheme, in which farmers contribute their labor and land while contracting partners provide financial support by leasing inputs, namely plowing costs, seed, and technology, and guaranteeing the purchase of all products grown.

This study used data gathered from a 2013 survey of maize production in the northern (Bokeo province) and southern (Champasack and Salavan provinces) areas of Lao PDR. In the absence of clearly defined statistical data for the number of maize growers in the contracted farming system, the sample size was defined using the Cochran method (Cochran, 1977), where P is equal to 0.27 and Z equals 1.96 (95 percent confidence level), resulting in a sample size of 302 cases. The number of randomly sampled farmers was determined in accordance with the context of each area (Table 1).

Methodology

This study used StoNED to analyze maize production efficiency by estimating conditional expectation (CNLS residual) based on convex nonparametric least square (CNLS) models without determining the production function. Analysis was performed using linear programming with minimized least squares under the limitations of monotonicity and concavity, in which the equation calculates the linear inequalities in the form of quadratic programming (QP). Production frontier function models in the form of QP (Kuosmanen, 2006) were defined by:

$$Min_{\,v,\alpha,\beta} \sum_{i=1}^{302} v_i^2$$

$$\begin{gathered} yield_i = \alpha_i + \beta_{1i} seed_i + \beta_{2i} fer_i + \beta_{3i} herb_i + \beta_{4i} la_i + v_i \\ \alpha_i + \beta_{1i} seed_i + \beta_{2i} fer_i + \beta_{3i} herb_i + \beta_{4i} la_i \le \alpha_h + \beta_{1h} seed_i + \beta_{2h} fer_i + \beta_{3h} herb_i + \beta_{4h} la_i \\ \forall h, i = 1, \ldots, 302; j = 1, \ldots, 4 \ and \ \beta_{ij} \ge 0 \end{gathered} \quad (1)$$

where: α_i, β_{ij} are parameters of input factor j of farm i;

v_i is the residual term;

x_{ji} is input factor j of farm i, which is the efficiency calculation unit;

x_{jh} is input factor j of farm h, which is the production unit with the highest efficiency;

$yield_i$ is the maize yield of individual farmers (kilograms per hectare);

$seed_i$ is the amount of seed sown (kilograms per hectare);

fer_i is the amount of chemical fertilizer applied (kilograms per hectare);

$herb_i$ is the amount of herbicide applied (liters per hectare);

la_i is the labor used (human-hours per hectare).

Subsequently, the CNLS residual (v_i^2) can be used to calculate the estimation of unknown variance (σ_u, σ_v) using the method of moments, which can then be used to determine the variance $\hat{\sigma}_u, \hat{\sigma}_v$. The variance can be used to estimate expected inefficiency (u):

$$E\langle u_i | \varepsilon_i \rangle = \mu_* + \sigma_* \left[\frac{\varnothing\left(\frac{-\mu_*}{\sigma_*}\right)}{1 - \Phi\left(\frac{-\mu_*}{\sigma_*}\right)} \right]$$

where: ε_i shows zero-truncated normal distribution patterns under normal distribution of v and semi-normal distribution of u.

$$\mu_* = \frac{-\varepsilon_i \sigma_u^2}{(\sigma_u^2 + \sigma_v^2)}$$

$$\sigma_*^2 = \frac{\sigma_u^2 \sigma_v^2}{\sigma_u^2 + \sigma_v^2}$$

$\varnothing$ is the standard normal density function.

Φ is the standard normal cumulative distribution function.

The estimation of the condition expected value of inefficiency of individual decision unit i is defined by:

$$\hat{E}\langle u_i | \hat{\varepsilon}_i \rangle = -\frac{\hat{\varepsilon}_i \hat{\sigma}_u^2}{\hat{\sigma}_u^2 + \hat{\sigma}_v^2} + \frac{\hat{\sigma}_u^2 \hat{\sigma}_v^2}{\hat{\sigma}_u^2 + \hat{\sigma}_v^2} \left[\frac{\varnothing\left(\hat{\varepsilon}_i / \hat{\sigma}_v^2\right)}{1 - \Phi\left(\hat{\varepsilon}_i / \hat{\sigma}_v^2\right)} \right]$$

where: $myy = \hat{\sigma}_u \sqrt{\frac{2}{\pi}}$ and $\hat{\varepsilon}_i = \hat{v}_i - myy$

The technical efficiency of production can then be further calculated from the following equation:

$$\lfloor \alpha_i + \beta_{1i} x_{1i} + \beta_{2i} x_{2i} + \beta_{3i} x_{3i} + \beta_{4i} x_{4i} + \ldots + \beta_{ji} x_{ji} + myy - E(u) \rfloor / \lfloor \alpha_i + \beta_{1i} x_{1i} + \beta_{2i} x_{2i} + \beta_{3i} x_{3i} + \beta_{4i} x_{4i} + \ldots + \beta_{ji} x_{ji} + myy \rfloor$$

where α_i, β_{ji} are parameters of input j of farm i and x_{ji} is the input factor j of farm i, which is required to calculate efficiency.

Analysis of the factors affecting production efficiency usede the Tobit model, as this model is the most suitable for cases where the technical efficiency score is between 0 and 1 (Goldberger, 1964, as cited in; Wiboonpong, 2006) and is defined by:

$$y_i^* = Z_i' a + \varepsilon_i$$

Table 1
Sampled maize farmers under contract farming in Lao PDR

Region/Province	Sample number
Northern region (Bokao province)	197
Southern region	105
Champasack province	30
Saravan province	75
Total	302

The efficiency level (y_i^*), where the maximum value is 1 and the lowest is 0, and therefore the estimated efficiency of each unit is between 0 and 1 and can be written as a linear relationship as:

$$TE = a_0 + a_1 SEX + a_2 AGE + a_3 EDU + a_4 LAND + a_5 EXP + a_6 LOCAT + \varepsilon_i \quad (2)$$

where:

TE is the technical efficiency of maize farmers;

a_0 is the constant term;

a_1, a_2, a_3, a_4 is the coefficient term;

SEX represents the dummy variable for sex of the head of the household; which has a value of 1 if the household head is male and 0 otherwise;

AGE represents the age of the farmer (years);

EDU represents the highest level of education completed by members of the household (years);

LAND represents the planted area (hectares);

EXP represents the farmers' maize production experience in contracted farming systems;

LOCAT represents the dummy variable for the area of maize production in the contracted farming system, in which 1 is the northern area (Bokao province) and 0 is the southern area (Champasack and Salavan provinces); and

ε_i represents the composite error term.

The variables included in StoNED comprised seed, chemical fertilizer, herbicide, and labor. These variables are important physical inputs for maize production in the contract farming model. However, herbicide and labor are the two production factors that have very high standard deviations (exceeding twice the mean), which reflects that the contracted farming systems in the two different areas use very different quantities of the production factors in their processes. The model for technical efficiency effects contains the variables associated with human capital, such as sex, amount of schooling, and age of farmers. Several previous studies have used these variables in models of technical efficiency effects in Lao PDR, such as Boundeth et al. (2012) and Viengpasith et al. (2012). Moreover, equations (1) and (2) have been applied to data sets in these studies (Table 2).

Table 2
Summary statistics of key variables for sampled maize farmers under contract farming in Laos PDR

Variable	Mean	Standard Deviation	Maximum	Minimum
Contract farming (302 farmers)				
Yield (kg/ha)	10.35	13.20	120.33	0.80
Seed (kg/ha)	30.64	35.01	239.85	5.00
Fertilizer (kg/ha)	189.32	267.39	1,719.86	0.00
Herbicide (L/ha)	1.45	3.21	16.00	0.00
Labor (human-hours/ha)	108.87	232.04	2,143.08	2.39
Land (ha)	1.67	1.30	10.00	0.13
Age (years)	43.50	12.14	75.00	18.00
Education (years)	5.71	3.62	14.00	0.00
Experience (years)	8.45	5.43	20.00	1.00

Sources: Chaovanapoonphol, Yangluexay, and Arayarangsarid (2012); Somyana, Sura, and Saiwong (2012)

Results and Discussion

Level of Production Efficiency of Maize Production

The efficiency levels of individual farmers were drawn from comparisons against farmers with the highest levels of efficiency for a single input factor. Analysis revealed that maize farmers under contract farming in Laos PDR had an average production efficiency level of 0.85. The highest level was 0.99, corresponding to an average production yield of 60.89 kg per hectare, which is 10.35 kg per hectare higher than average. The lowest level was 0.29, corresponding to an average production yield of 0.80 kg per hectare. Nonetheless, more than 60 percent of farmers had production efficiency levels that were higher than 0.80. The majority of maize contract farmers in Lao PDR have efficiency levels close to 1 because they have access to more production inputs than independent farmers, which reflects the ability of maize contract farmers to adjust their production inputs to improve efficiency. Providing academic support to build understanding of the use of production inputs and the appropriate times and amounts for effective application can enhance maintenance and development of productivity. Consequently, this can result in higher maize production yields using already existing resources, especially in groups with low technical production efficiency (Table 3).

Factors Affecting Maize Production Efficiency

Analysis of factors affecting maize production efficiency in contract farming was conducted using the Tobit model. With the maximum likelihood estimate, the statistical value of the Tobit model for the log likelihood function was 200.600 and the Akaike information criterion (AIC) was −385.200. Factors improving maize production efficiency (positive) were age and the highest education level of the primary caretaker of the household, while the factor reducing maize production efficiency (negative) was planted area for farming. At the same time, experience in maize production under contracted farming systems and planted area (both in the north and the south) did not affect efficiency. This reflected that the maize production experience levels of farmers was irrelevant and that farmers must learn new methods of management and maintenance

Table 3
Frequency and percentages distribution of technical efficiencies of maize farmers under contract farming

Interval	Contract farming	Percentage
≤0.50	8	2.65
0.51−0.60	5	1.66
0.61−0.70	33	10.93
0.71−0.80	54	17.88
0.81−0.90	68	22.52
0.91−1.00	134	44.37
Total	302	100
Maximum	0.99	2.65
Minimum	0.29	0.33
Mean TE	0.85	

Sources: Chaovanapoonphol et al. (2012); Somyana et al. (2012)

when conducting maize production operations in contracted farming systems.

Analysis of marginal effects calculated using average partial effect revealed the results of each factor (Table 4). The average value for the age of the primary household caretaker had a coefficient factor of .0015, which means that an increase in the primary caretaker's age (AGE) by one year would result in a .15 percent increase with a .05 level of significance. This means that an increase in the age of the household primary caretaker reflects lengthy experience in agriculture. This was the same for the primary caretaker's education level (EDU), which had a coefficient level of .0039, indicating that a one-year increase in the primary caretaker's education level would result in a .39 percent improvement in production efficiency with a significance level of .10. This reflected the ability to read, write, and think logically, as contract farming requires understanding and appropriate use of production factors such as fertilizer and pesticides. In addition to individual factors, planted land area (LAND) was also found to have a coefficient value of −.012, indicating that an increase of one hectare of farming land reduced production efficiency by 1.2 percent with a .05 level of significance. While maize contract farming in Lao PDR uses geographically suitable farming areas, production itself is still based mainly on labor. If the planted area is large, management and handling become more difficult. This may then also reduce production efficiency, as shown in Table 4.

Conclusion and Recommendation

The results of the analysis of technical efficiency of maize production revealed that technical efficiency was on average 0.85, and over 60 percent of farmers had high production efficiency scores (0.81−1.00). Further assessment can determine the significance of required production factors and their ability to increase efficiency. The identified factors can then be isolated to help increase yield within the contract farming system. Significant factors with a positive effect on the technical efficiency of maize production were determined as the age and highest level of education completed by the primary caretaker of the household. Planted area had a negative impact, indicating that contract farming was more appropriate for the smallholders than for the large-scale holders. Since production under contracted farming systems require more time to be spent in the production processes, such as fertilization, the larger the area, the more difficult it was to properly manage the process. In addition, the highest level of completed education was significant, while former experience was not significant. In addition, attention should be paid to other issues with a significant impact on maize production, such as providing support for practical maize production management (this should be the responsibility of the company). The use of correct maintenance methods can also improve yield quality and quantity. In the past, companies tended to provide in-depth information during the initial support period, but quickly reduced support in the following years. Providing farmers with consistent and constant support (for various issues) after the initial period will help to generate both increased yield and improved product quality.

Although maize production under contract farming provides farmers with better opportunities to access and utilize greater inputs, which can lead to higher output, the appropriate use of production inputs must be considered if the production of maize continues to expand in Lao PDR. The evaluation of production efficiency levels under contract farming indicates wide variation among contract farmers, implying that although they may have better access to production inputs, their ability to convert input into output remains in question. Investors and related officials can thus provide these farmers with relevant support to encourage higher output. In addition, apart from monetary rewards in the form of financial profits, other non-monetary benefits, as well as issues related to the contract farming system, should be further studied in the future.

Table 4
Factors affecting technical efficiency of maize production

Variable	Tobit model		Marginal effect	
	Coefficient	t Statistic	Coefficient	t Statistic
Constant	.755	20.863***	.674	20.748***
Sex	.0035	.216	.0031	.216
Age	.0017	2.394**	.0015	2.392**
Education	.0043	1.925*	.0039	1.924*
Land	−.013	−2.313**	−.012	−2.312**
Experience	.00065	.329	.00058	.329
Location	.011	.469	.0098	.469
Sigma	.125	24.576***		
Log likelihood function	200.600			
Akaike Information Criterion	−385.200			
Bayes Information Criterion	−355.517			

Sources: Chaovanapoonphol et al. (2012); Somyana et al. (2012)
Notes: ***, **, * denote the size of test $\alpha = .01, .05$ and .1, respectively

Conflict of Interest

There is no conflict of interest.

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