Technical Efficiency Analysis
of Small-Scale Cassava Farming in Lao PDR

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ABSTRACT

This study investigates returns of scale, estimates technical efficiency, and identifies the determinant factors of the efficiency of small-scale cassava farming in Vientiane and Savannakhet provinces, Lao PDR. Cross-sectional data on inputs, output, and farming characteristics from 193 cassava farmers were collected for this study. The maximum likelihood method is employed to estimate parameters, elasticity, and inefficiency scores using the stochastic frontier production function model. This study found that the elasticity of the mean value of cassava output is estimated to be an increasing function of farm size, labor cost, and seed cost in Vientiane and Savannakhet. Increasing returns to scale was found for smallholder cassava farming in Savannakhet. The estimated mean score of technical efficiency are 72 percent and 75 percent for Vientiane and Savannakhet, respectively. The determinants of technical efficiency in Vientiane showed that planting cassava with good land preparation, suitable time period for plantation, and young farmers play a key role in the improvement of technical efficiency for cassava farming.

INTRODUCTION

The government of the Lao People's Democratic Republic (Lao PDR) attempts to achieve the first Millennium Development Goal (MDG1) by ensuring food security and improving the livelihoods of rural community through commercialization and modernization of agricultural production (Ministry of Agriculture and Forestry [MAF] 2010). Programs for the promotion of commercial crop production in order to raise farmers' incomes with the expectation of better livelihoods and sustainable farming have been introduced. Therefore, a number of favored cash crops have been introduced to Lao farmers, including maize, cassava, rubber, Job's tears, banana, and sugarcane. Among these, cassava farms have recently expanded in Lao PDR, due to the high demand for raw cassava for bio-ethanol fuel production in China, Thailand, and Vietnam as well as domestic demand for flour production.

Cassava farms are needed not only for food crops but more importantly as a major source of income for rural households. Between 2005 and 2012 there were 12 private domestic and 11 foreign companies registered to operate cassava plantations within the country with a total registered capital investment of USD 64.76 million covering a concession land area of 11,428 hectares (ha) (MAF 2013). In 2010/11, the area planted by individual growers was about 18,900 ha (MAF 2014). Subsequently, cassava farm areas have expanded more than six-fold from 6,765 ha in 2005 to 43,975 ha in 2012 (MAF 2015). Cassava is fast becoming a key commercial crop that is expected to generate higher farming incomes.

Over the past five years, average cassava farm sizes and productivity have also grown markedly in Laos. Cassava farm sizes increased from 0.1 ha in 1998/99 to about 0.4 ha in 2010/11 (MAF 2014), while their productivity increased from 17.47 tons per hectare (tons/ha) in 1998

to 25.08 tons/ha in 2010 (MAF 2015). In the long-term, if farm sizes continue to expand in this manner, it may led people to believe that large farms are more efficient than small ones. Individual small-scale cassava farmers who are key players in the agriculture sector would be left behind and will eventually be replaced by large-scale cassava corporations (Kislev and Peterson 1991). It is also generally recognized that small-scale farmers are poor with low productivity in their agricultural production (Ajibefun 2002; Akpan, Inimfon, and Udoka 2012). Improving productivity and efficiency is a key to increasing farmers' income and improving livelihoods which could move them out of poverty (Ajibefun 2000).

In general, the problems affecting small-scale cassava farmers in Lao PDR are not different from those for other crops. First, most small-scale farmers lack information on and technologies of production; they use simple techniques and often have improper land preparation; have little knowledge about planting materials and minimal cassava farming experience. Second, small-scale rural farmers do not have access to financial support with which to procure proper inputs and production equipment. Lastly, farm size is limited, thus, the harvested cassava yield do not reach the ideal optimum output. Therefore, in order to maintain high production in the face of limited land size holdings, there is a particular need to improve the efficiency of small-scale cassava farms.

For small-scale farmers to achieve optimum output and production efficiency, limited resources have to be optimally and efficiently utilized. The ability of cassava farmers to adopt new technology and achieve sustainable production depends on their level of production efficiency, mostly determined by variable input factors. Farm-specific variables, such as characteristics of the farmers and their farm management systems, experience of farmers, and distance from market can

influence farm efficiency (Battese and Coelli 1995; Brock 1994). In order to increase the level of productive efficiency, farmers need to expand their farm plots, learn more about new innovations, and maintain soil fertility, which is affected by land use and forest cover change. This is especially true for rural farmers in forest frontier areas. The challenge to improving the level of productive efficiency,[1] therefore, is to increase the technical efficiency of cassava farms.

This study aims to examine the factors that influence the technical efficiency of small-scale cassava farms, which would imply that there is a high return to product input factors for cassava farms in Vientiane and Savannakhet provinces, where there is a significant increase in the number of cassava farms. According to Desli, Ray, and Kumbhakar (2003), two otherwise identical firms will never produce the same output, and costs and profits are not the same. The difference in output, cost, and profit can be explained in terms of efficiency and unforeseen exogenous shocks.

The specific objectives of this study are to investigate whether there is evidence of increasing or diminishing returns to scale for cassava farms under the given outputs and inputs; to estimate cassava farm-level technical efficiency; and to ascertain the determinant factors influencing efficiency levels of cassava farms in the two areas. In addition, the following assumption and null hypotheses were tested: stochastic frontier production function is in Cobb-Douglas form, technical inefficiency is absent from the Cobb-Douglas production function model, technical inefficiency effects are absent, and farmer-specific determinant factors have no effect on technical inefficiency. Furthermore, the null hypothesis on constant

returns to scale is also tested for the Cobb-Douglas stochastic frontier production function.

There is little research on technical efficiency analysis for commercial crop plantations in Lao PDR although some studies have been carried out to assess the technical efficiency analysis of maize farmers in Hauixay District, Bokeo Province (Southavilay, Teruaki, and Shigeyoshi 2012) and smallholder maize farmers in Paklay District, Sayaboury Province (Vanisaveth, Yabe, and Sato 2012). The research on cassava farms, however, is scant. Therefore, this study on technical efficiency analysis for small-scale cassava farms in Vientiane and Savannakhet can be considered as pioneering research. The findings from this study will directly feed into various ongoing research to support policy development for agricultural practices, especially for cassava farming in Lao PDR.

METHODS

Study Area and Data Collection

The study areas for cassava farming are Muen District, Vientiane Province and Phin District, Savannakhet Province (hereafter the study sites will be referred to as Vientiane and Savannakhet, respectively).

Vientiane Province, located in the northwest part of the country, is the largest in terms of land area at 22,554 square kilometers (km²) with 13 districts and a total population of about 506,881 people (Ministry of Planning and Investment [MPI] 2013). The total agricultural land area is 103,960 ha covering about 4.6 percent of the total provincial land area. The main crop plantations are rice, maize, cassava, small orange, sesame, Job's tears, black bean, yellow

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1 The concept of productive efficiency is composed of technical, allocative, and economic efficiencies (Farrell 1957). This section is lifted heavily from Daite, Ramirez, and Staal (2013).

bean, pineapple, cucumber, watermelon, and sweet tamarind. The province is the third largest in terms of area planted to cassava compared to other provinces across the country (MAF 2011). Cassava areas in the province rapidly increased from 1,425 ha in 2010 to 3,130 ha in 2011 covering about 3.03 percent of the total agricultural area of Vientiane Province (Table 1).

Savannakhet Province, located in the central part of Laos, is known as the land of fertility because of its suitability for agriculture. In terms of land area, Savannakhet is the second largest with a total land area of 21,774 km^2 (Table 1). It has the highest population of about 937,907 people (MPI 2013). In terms of agricultural development, Savannakhet plays an important role as there is a wide plain area where total agricultural land is 245,365 ha covering 11.26 percent of total provincial land area (MPI 2014). The main crops in the province are rice, cucumber, bean, and various vegetables, while the industrial crop plantations include sugarcane in Xaybury District, cassava in Phin District, and banana in Xepon District

(MAF 2013). Of these, cassava farms have been continually expanding. In 2012, the cassava planting area in Savannakhet reached 3,772 ha which could produce 80,865 tons. Most of this cassava production is supplied to processing factories to produce cassava flour and about 1,976 tons are exported to Vietnam (MAF 2013).

Field surveys were conducted to gather both primary and secondary data in Vientiane and Savannakhet. The structured questionnaires were used for face-to-face interviews with key informants for primary data from 109 randomly selected cassava farmers in Vientiane province and 84 cassava farmers in Savannakhet province during the crop season of 2012. In order to empirically investigate and analyze the technical efficiency of cassava farming, the output (cassava yield) and inputs (farm size, labor used, and cost of planting materials) were carefully collected. In addition, data on socioeconomic characteristics of farmers including age, cassava farming experience, education, and cassava planting practices were also collected. Secondary data on related studies

Table 1. A comparison of provincial information, 2012

Description	Vientiane Province		Savannakhet Province	
	Area (ha)	**Product (ton)**	**Area (ha)**	**Product (ton)**
Population (persons)	506,881		937,907	
Total land area	2,255,400		2,177,400	
Agricultural plantation	103,967		245,365	
Paddy rice	53,017	230,430	173,117	614,600
Season rice	6,612	28,850	31,286	138,915
Upland rice	7,073	11,570	1,417	2,139
Vegetable	22,570	165,050	11,440	80,240
Maize	6,590	46,530	3,700	35,615
Cassava	3,130	83,040	2,400	65,360
Tobacco	685	3,740	1,200	14,925
Sugarcane	145	1,630	12,140	754,830
Other	4,145		8,665	

Source: Lao Statistics Bureau (2013)

as well as statistics, policies, and legislation on cassava farms were also obtained from central and provincial government offices, online sources, and scholarly publications.

ANALYTICAL FRAMEWORK

Stochastic Frontier Production Function Model

The analytical techniques of this study used the well-known stochastic frontier analysis. The simultaneous estimation of the parameters of the stochastic frontier production function and technical inefficiency effect models was done by applying the maximum likelihood method to analyze the data collected. The stochastic frontier production function composed of two error components (Farrell 1957; Aigner, Lovell, and Schmidt 1977; Meeusen and van den Broeck 1977) is defined by:

$$y_i = f(x_i)exp(v_i - u_i) \tag{1}$$

The Cobb–Douglas production function is assumed to be an appropriate model for the analysis and substituted into Equation 1. Thus, the model of the Cobb–Douglas stochastic frontier production function is formed as:

$$\ln y_i = \beta_0 + \sum_j^3 \beta_{ij} \ln x_{ij} + v_i - u_i \tag{2}$$

The model identified in Equation 2 basically combines a single output and three inputs. y_i is cassava yield (in kg) of ith farm; x_1 is cassava farm size in hectare; and x_2 is value of labor use in terms of number of working days (man-days) in the cassava farm including family, exchange, and hired labor; x_3 is the cost of planting materials (in Lao Kip, LAK); ln denotes a natural logarithm, and subscript i represents the ith farmers. β_0, β_1, β_2, and β_3 are unknown parameters to be estimated; v_i is referred to as noise, which is a random error and covers the effects of other random factors (e.g., weather, luck, strikes, etc.) that the firm cannot control,

and is assumed to be an independent and identically distributed normal random variable $v_i \sim iidN(0, \sigma_v^2)$. u_i represents a non-negative random variable or one-side error term referred to as technical inefficiency in production. This model is needed to set up the assumption that u_i is an independently non-negative truncated normal distribution $u_i \sim idN^+(\mu_1, \sigma_u^2)$ (Battese and Coelli 1995; Stevenson 1980; Battese and Corra 1977). In addition, it assumes that heteroskedasticity is not present for the two error components, $Var(v) = \sigma_v^2$ and $Var(u) = \sigma_u^2$.

Technical Inefficiency Effect Model

Following the proposed model on determinants of technical inefficiency obtained from the stochastic frontier production function model (Battese and Coelli 1995), the inefficiency term is constructed to be the dependent variable for the inefficiency determinant specification and is defined to be explicit functions of firm-specific factors (Kumbhakar, Ghosh, and McGuckin 1991; Reifschneider and Stevenson 1991), which is mathematically expressed as follows:

$$u_i = \delta_0 + \sum_j^8 \delta_j Z_{ij} + \omega_i \tag{3}$$

where

$i =$ the ith farmer

$\delta_0, \delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6, \delta_7, \delta_8$
= the unknown parameters to be estimated

$Z_1 (age_i)$ = age of farmers (years)

$Z_2 (age^2_i)$ = age square in years, which are included in this model with the expectation of a non-linear relationship between age and technical inefficiency

$Z_3 (Experience_i)$
= cassava farming experience (years)

$Z_4 (Education_i)$
= farmers' education (years)

Z_5 *(Dlandpreparation$_i$)*

= farm land preparation before cassava plantation (1 if farm land was prepared before cassava planting, 0 otherwise)

Z_6 *(DFarmCare$_i$)*

= ratio of the number of working days with labor use for weeding during the time of cassava plantation over the number of working days with total family members

Z_7 *(DPlantperiod$_i$)*

= cassava plantation period (1 if time period of cassava plantation is not more than 9 months, 0 otherwise)

Z_8 *(DProvince$_i$)*

= province (1 if Vientiane; 0 if Savannakhet)

$\omega_i \sim N(0, \sigma_\omega^2)$

= denotes unobservable random errors.

Model Specification Tests for Inefficiency

In this study, there are several tests of the null hypotheses pertaining to the Cobb-Douglas production function, absence of technical inefficiency, and absence of technical inefficiency effects. The tests use the generalized likelihood ratio test statistic computed as:

$$LR_{stat} = -2 * [\log L(H_r) - \log L(H_{ur})] \quad (4)$$

where $\log L(H_r)$ is the value of the log likelihood function of a restricted frontier model as specified by the null hypothesis (H_0) and $\log L(H_{ur})$ is the value of log likelihood function of unrestricted frontier model under the alternative hypothesis. If the null hypothesis is true, then the test statistic has an appropriate Chi-square distribution.

Model Specification Tests for Constant Returns to Scale

The returns to scale can be estimated from the sum of the coefficient parameters (β_j) value of the individual inputs as specified in Equation 2. If the value is greater (or less) than 1, then the production function displays increasing (or diminishing) returns to scale. This study tests whether the sum of the coefficients of the Cobb-Douglas stochastic frontier production function equals 1 or whether the null hypothesis on constant returns to scale can be rejected as follows:

$$H_0^{CRS}: \beta_1 + \beta_2 + \beta_3 = 1 \quad (5)$$

The t-statistic for testing the constant returns to scale for multiple input vectors can be identified as follows:

$$t = \frac{(\widehat{\beta_1} + \widehat{\beta_2} + \widehat{\beta_3}) - 1}{se(\widehat{\beta_1} + \widehat{\beta_2} + \widehat{\beta_3})} \quad (6)$$

In order to find $se(\widehat{\beta_1} + \widehat{\beta_2} + \widehat{\beta_3})$, we estimate a different model that directly delivers the standard error of interest. It is done by first defining a new parameter as the sum of β_1, β_2, and β_3, which is $\theta_1 = \beta_1 + \beta_2 + \beta_3$ (Wooldridge 2009). Then the test of the null hypothesis is:

$$H_0^{CRS}: \theta_1 = 1 \quad (7)$$

So, the *t*-statistic is defined as: $t = \dfrac{\widehat{\theta_1} - 1}{se\widehat{\theta_1}}$.

Then we rewrite $\theta_1 = \beta_1 + \beta_2 + \beta_3$ as $\beta_1 = \theta_1 - \beta_2 - \beta_3$. After that, we replace this into the Cobb–Douglas stochastic frontier production function (Equation 2) and we get:

$$\ln y_i = \beta_0 + (\theta_1 - \beta_2 - \beta_3) \quad (8)$$
$$\ln x_{1i} + \beta_2 \ln x_{2i} + \beta_3 \ln x_{3i} + v_i - u_i$$

$$\ln y_i = \beta_0 + \theta_1 \ln x_{1i} + $$
$$\beta_2 (\ln x_{2i} - \ln x_{1i}) + \quad (9)$$
$$\beta_3 (\beta_3 \ln x_{3i} - \ln x_{1i}) v_i - u_i$$

RESULTS

This section is divided into three parts. The first part analyzes the summary statistics of the output and input variables of a cassava farm. The second part investigates tests of the stochastic frontier production function, inefficiency effect models, and constant returns to scale. The last part presents results of the measurement and determinants of technical inefficiency. The tests of correlation of all variables were done, but not presented in this paper.

Statistics of Output and Input Variables

The summary statistics of output and input of variables in the pooled, Vientiane, and Savannakhet data are presented in Table 2. In the pooled data, the statistics indicate that the mean cassava yield is about 25.67 tons/ha, while its average is about 16.14 tons/ha, which is relatively lower than the national mean of 24.12 tons/ha (MAF 2014). When examined by province, the average cassava yield of Vientiane is 18.83 tons/ha, which is relatively higher than Savannakhet at 11.47 tons/ha. These figures, however, are still lower than the national level. Crop production in these areas were based on natural practices and used simple techniques, which do not take advantage of the resources' optimal potential. Most farmers are small-scale and poor and most of them were not able to access sufficient financial support to purchase machines and apply new technologies. In addition, soil testing in the cassava fields of the two provinces indicated that intensive and consecutive cassava croppings in the same area has led to soil nutrient depletion, which reduced harvested yield (Soukkhamthat 2014; National Economic Research Institute [NERI] 2015).

The average cassava farm size in the two provinces is about 1.59 ha. The average cassava farm size in Vientiane is 1.78 ha, which is higher than in Savannakhet (1.34 ha). These figures are lower than the average size of

agriculture land throughout the country, which is 2.11 ha (Messerli et al. 2008). Most farmers in the two provinces, however, do not use all of their agriculture land for cassava plantation (Soukkhamthat 2014), which means that farmers can choose to increase their cassava farm size when it provides significant economic returns.

The average labor use for a cassava plantation is about 193, 246, and 125 man-days for both provinces, Vientiane, and Savannakhet, respectively. The highest value of labor use for cassava plantation is about 767 man-days in Vientiane, while the lowest labor use is 26 man-days in Savannakhet. Cassava farming activities (e.g., planting, weeding, and harvesting) require labor over the year's planting cycle because farmers in these areas do not use machines, except for land clearing at the beginning. Therefore such intensive labor use is a key input factor for cassava farms, particularly in the rural areas.

The mean cost of planting materials of high-quality varieties of cassava in Savannakhet is USD 398, about eight times higher than in Vientiane (USD 47). The variety cost is high due to contract farming arrangements between farmers and investors, particularly in Savannakhet. Farmers have to pay the high cost for the variety to the local investor who made a formal contract with them because farmers were not able to understand the terms and obligations defined in the contract. In addition, they also lack the opportunity and capacity to bargain about the cost as compared with the market price (Soukkhamthat 2014).

The household characteristic variables of the inefficiency determinant effects model are shown in Table 2. Household data indicate similar mean age of farmers at about 40 years, which implies that most cassava farmers are middle-aged. Most farmers have planted cassava for about two years, a few farmers in Vientiane have planted cassava for five years while a

Table 2. Statistic data for pooled, Vientiane, and Savannakhet data

Variable	Units	No.	Mean	Std. Dev.	Min	Max
Pooled Data						
Yield (y)	kg	193	25,675	20,809	1,500	136,590
Farm size (x_1)	ha	193	1.59	0.85	0.34	5.50
Labor (x_2)	man-day	193	193.33	145.39	26.00	767.00
Seed cost (x_3)	USD	193	199.70	252.14	0	2,187.50
Age (Z_1)	year	193	40.01	12.71	19.00	78.00
Experience (Z_3)	year	193	2.08	0.95	1.00	5.00
Education (Z_4)	year	193	4.28	3.17	1.00	14.00
Dlandpreparing (Z_5)	1=yes, 0=otherwise	193	0.6010	0.4909	0	1
Farmcareness (Z_6)	ratio	193	0.4268	0.1924	0.1000	1.0000
Dplantperiod (Z_7)	1=yes, 0=otherwise	193	0.6114	0.4887	0	1
Dprovince (Z_8)	1=yes, 0=otherwise	193	0.5648	0.4971	0	1
Vientiane Province						
Yield (y)	kg	109	33,524	21,189	8,900	136,590
Farm size (x_1)	ha	109	1.78	0.92	0.34	5.50
Labor (x_2)	man-day	109	246.02	159.51	42.00	767.00
Seed cost (x_3)	USD	109	47.01	25.25	10.00	136.50
Age (Z_1)	year	109	41.00	13.31	19.00	78.00
Experience (Z_3)	year	109	2.41	1.01	1.00	5.00
Education (Z_4)	year	109	5.63	3.05	1.00	14.00
Dlandpreparing (Z_5)	1=yes, 0=otherwise	109	0.3761	0.4866	0	1
Farmcareness (Z_6)	ratio	109	0.4894	0.2079	0.1000	1.0000
Dplantperiod (Z_7)	1=yes, 0=otherwise	109	0.7523	0.4337	0	1
Savannakhet Province						
Yield (y)	kg	84	15,491	15,219	1,500	95,000
Farm size (x_1)	ha	84	1.35	0.70	0.50	5.00
Labor (x_2)	man-day	84	124.96	86.10	26.00	502.00
Seed cost (x_3)	USD	84	397.84	275.48	0	2,187.50
Age (Z_1)	year	84	38.71	11.85	20.00	72.00
Experience (Z_3)	year	84	1.64	0.65	1.00	3.00
Education (Z_4)	year	84	2.54	2.37	1.00	12.00
Dlandpreparing (Z_5)	1=yes, 0=otherwise	84	0.8928	0.3111	0	1
Farmcareness (Z_6)	ratio	84	0.3456	0.1326	0.1111	0.6667
Dplantperiod (Z_7)	1=yes, 0=otherwise	84	0.4286	0.4978	0	1

Source: Estimated from household survey data in 2012; exchange rate is USD 1 = LAK 8,000.

small proportion of farmers in Savannakhet have about three years of experience. These results show that farmers have relatively low experience in cassava farming making it difficult for them to cope with problems in their cassava farms. On the other hand, farmers with more than five years' experience are able to readily employ their advantage (Ogisi, Begho, and Alimeke 2013).

As shown in Table 2, most farmers have low level of education with an average of not more than six years in both provinces. This indicates that it might be difficult for farmers to adopt new technology and innovation practices for cassava farming, specifically effective techniques in input utilization (Ogisi, Begho, and Alimeke 201; Asogawa, Umeh, and Penda 2012). In addition, educational infrastructure and facilities are not available within or near their villages. It takes time and high transportation cost for them to go to the city center to study. In addition, most farmers are poor,[1] some of them could not even pay school fees and their children have to drop out of school in order to support their family as farm laborers (Soukkhamthat 2014). Previous evidence also estimated that in 2006 the percentage of girls and boys who have never been to school in Savannakhet province was about 14.8 percent and 12.5 percent,[2] respectively.

The farm care ratio also indicates that the average labor use for weeding in the cassava fields in Vientiane is 49 percent of total labor, which is higher than those in Savannakhet at about 34 percent. This variable is expected to have a negative effect on technical inefficiency.

If the farm is clean and plants are well cared for, cassava roots will have more opportunity to absorb more nutrients from the soil and cassava yields will increase.

In terms of land preparation before cassava planting, only 37 percent of the farmers in Vientiane focused on this activity, while 89 percent did so in Savannakhet. Well-prepared loose soil and proper drains, done by plowing and creating ridges to clear all grass and brush, could facilitate better cassava growth and reduce soil nutrient absorption by weeds (Seesahai, Ramlal-Ousman and Vine 2008; Howeler 2007).

For about 75 percent of farmers in Vientiane, they wait up to nine months for cassava to mature from planting to harvest, while about 42 percent of the farmers in Savannakhet take as long. From the survey, most farmers in Vientiane plant cassava in April–May and harvest in November–December, while the farmers in Savannakhet plant cassava in May–June and harvest in March the year after. This result is consistent with Seesahai, Ramlal-Ousman, and Vine (2008) and Howeler (2007), who suggest that in order to obtain the highest yields, cassava should be planted in the early wet season with the highest starch generated when plants are harvested in the middle of the dry season. In Thailand, cassava is usually planted in May, the start of the rainy season, which could significantly increase yields. All in all, the appropriate time to plant and harvest cassava does not only depend on seasonal conditions, but also on the marketing conditions at the time of expected harvest.

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1 In 2009, there were 2,287 poor households (or 37.1 percent) in Phin district, the study site, out of the total 14,286 poor households in Savannakhet Province (Provincial Planning and Investment Department of Savannakhet Province 2009)

2 Estimated by the authors based on the data provided in the Summary of Implementation of Education Development Plan 2005–2006 of Savannakhet Province.

Results of the Tests for Stochastic Frontier Production Function and Inefficiency Effect

The parameters of the stochastic frontier production function and inefficiency effect models can be estimated through the application of the maximum likelihood method (Coelli 1996). The generalized likelihood ratio (LR), resulting from such a method, is used to examine whether the Cobb-Douglas function is not a stochastic frontier, whether there is an absence of technical inefficiency, whether there is an absence of technical inefficiency effect, and to determine the impact of farmer-specific characteristics (Table 3).

The first test is the examination of model specifications to see whether the stochastic frontier is in Cobb-Douglas form. The null hypothesis states that the coefficient parameters of the Cobb-Douglas production function are zero. The results in the upper part of Table 3 clearly show that the LR statistics are higher than the Chi-square critical value ($p<.05$) for all data sets—pooled, Vientiane, and Savannakhet. Thus, the assumption of the stochastic frontier production function in Cobb-Douglas form is appropriately represented for this technology in the data sets.

Table 3. Generalized likelihood ratio test of hypotheses involving the parameters of the stochastic frontier and inefficiency model

Test and Null Hypotheses	LR STAT	Degrees of Freedom	Critical value at $p<.05$	Decision
Test for frontier is not Cobb-Douglas form; Null: Stochastic frontier is not Cobb-Douglas form				
Pooled	209.48	3	7.81	Reject H_0
Vientiane	130.83	3	7.81	Reject H_0
Savannakhet	99.34	3	7.81	Reject H_0
Test for absence of technical inefficiency (in the case of the truncated-normal model) Null: absence of inefficiency				
Pooled	20.94	2	5.99	Reject H_0
Vientiane	14.35	2	5.99	Reject H_0
Savannakhet	16.84	2	5.99	Reject H_0
Test for absence of inefficiency effect. Null: No technical inefficiency effect				
Pooled	117.60	10	18.31	Reject H_0
Vientiane	41.45	9	16.92	Reject H_0
Savannakhet	22.55	9	16.92	Reject H_0
Test for household's characteristic effects. Null: Determinants have no effect				
Pooled	96.65	8	15.51	Reject H_0
Vientiane	27.10	7	14.07	Reject H_0
Savannakhet	4.80	7	14.07	Cannot reject H_0

Source: Estimated from household survey data in 2012

Note: The test statistics are defined by $LR_{stat} = -2^*[\log L(H_r) - \log L(H_{ur})]$, where L($H_0$) and L($H_1$) are the value of the likelihood function of the restricted and unrestricted models, respectively. The LR statistics approximately follow a Chi-square distribution and the degrees of freedom equal the number of parameters assumed to be zero in the null hypothesis $\gamma = \sigma_u^2/\sigma^2$ and $\sigma^2 = \sigma_v^2 + \sigma_u^2$. The critical value is drawn from Wooldridge (2009).

The second test is to examine whether inefficiencies are present for this technology in the case of the truncated-normal model. The null hypothesis denotes the absence of inefficiency in Equation 2. The results shown in Table 3 indicate that the null hypotheses of the three data sets can be rejected ($p<.05$) since the LR statistics are greater than the critical value. These results imply that the average production function, in which all farmers are assumed to be fully technically efficient, is insufficient representation in the case of the three data sets.

The third test is to investigate whether the technical inefficiency effect exists in the inefficiency effect model. The null hypothesis presents that the Equation 3 has no technical inefficiency effect. As shown in Table 3, the LR statistics of the three data sets are higher than the critical value ($p<.05$). Therefore, the null hypotheses of the three data sets can be rejected. This implies that technical inefficiency effects can represent these data sets.

The fourth test is to ensure whether the determinants of farmers' characteristics present effects on technical inefficiency. The null hypotheses state that the coefficients of farmer-specific characteristics are zero. Likewise, Table 3 demonstrates that the LR statistics of the pooled and Vientiane data sets are higher than the critical value ($p<.05$) and the null hypotheses can be rejected. Meanwhile the LR statistic for the Savannakhet data set is lower than the critical value, therefore, the null hypothesis for the Savannakhet data set cannot be rejected. This indicates that determinants of farmers' characteristics of the pooled and Vientiane data sets have an effect on technical inefficiency, while those of Savannakhet have no effect on technical inefficiency.

To sum up, the above test results support the use of the Cobb-Douglas stochastic frontier production function, truncated normal distribution, and inefficiency effect specification for the three data sets.

Results of the Test of Returns to Scale

The results of the tests in Table 4 indicate that the *t*-statistic for the pooled (0.7132) and Vientiane (-0.3720) data are lower than the critical value ($p<.05$). Therefore, the null hypotheses on constant returns to scale cannot be rejected for the Cobb-Douglas stochastic frontier production function. This implies that there are no economies of scale for cassava plantations in Vientiane province. The reason might be that the famers in Vientiane have been planting cassava for at least a couple of years and they could optimally utilize the inputs well. Therefore, increasing returns to scale for cassava farming in Vientiane is not a factor. In addition, Vientiane farmers use simple planting methods without using new varieties and technologies, therefore, even if they increase the volume of inputs, their yield or output will not increase. In other words, the optimum efficiency of production at the current level of resource use for cassava farming in Vientiane has been attained under current practices.

On the other hand, the *t*-statistic of the Savannakhet (5.0034) case is statistically significant ($p<.01$) and higher than the critical value. This indicates that the Cobb-Douglas stochastic frontier production function in Savannakhet presents evidence of increasing returns to scale with 1.54 as the sum of the coefficients. This indicates that a proportionate increase in all the input factors would result in a more than proportionate increase in the cassava output.

The increasing returns to scale mean that optimum efficiency of production or the current level of resource use for cassava farming in this area has not been attained under the current practices. One thing to note is that while farm size in Savannakhet is only marginally smaller than Vientiane, the yields are significantly much lower (Table 2). This could mean that Vientiane is already relatively optimal in

terms of production. This finding is consistent with the work of Asogawa, Umeh, and Penda (2012), which suggests that cassava farms in Savannakhet can still increase their level of output using the current level of resources by improving their technical efficiency. Thus, one implication of this finding is that policies related to agriculture extension service should target improvements in technical efficiency for cassava farmers in Savannakhet to boost farm outputs.

Estimation of Stochastic Frontier Function and Technical Efficiency Analysis

The maximum likelihood estimate of the parameters of the Cobb-Douglas stochastic frontier production function for cassava farms in the pooled, Vientiane, and Savannakhet data are presented in Table 5. As expected, the input parameters of farm size, labor, and seed cost in the three data sets had positive signs which show direct relationship with output in terms of cassava yield. In other words, the elasticity of the mean value of cassava output is estimated to be an increasing function of farm size, labor, and seed cost.

The results indicate that farm size was the factor with the most influence on production, determining the amount of output ($p<.01$) for all three data sets. The elasticity of different outputs with respect to the mean farm size of the pooled, Vientiane, and Savannakhet data were estimated to be 0.94, 0.81, and 1.42, respectively. The high elasticity of the farm size value in the three data sets suggests that expansion in production among the farmers was mainly due to an increase in farm size rather than an increase in technical efficiency. This implies that if farmers enlarge their cassava farm area by 1 percent, it will lead to an increase in cassava output of 0.94 percent for the pooled data, 0.81 percent for Vientiane, and 1.42 percent for Savannakhet, ceteris paribus.

Besides land area already used for cassava, several farmers in the two areas, in fact, still have available agricultural land (Soukkhamthat 2014) and they could choose to expand their cassava farm size if the farm generates enough benefit for them. This finding is also in line with the work of Asogawa, Umeh, and Penda (2012).

Labor used in this estimation also presented a positive correlation ($p<.10$) for the pooled data and Savannakhet. This means that a 1 percent increase in labor will increase the yield of cassava in the pooled data and Savannakhet by 0.07 percent and 0.11 percent, respectively. This evidence could indicate that cassava farmers apply simple but labor-intensive methods. Most farmers do not use any machinery or herbicides for planting, growing, weeding, and harvesting. Therefore, the more labor used in the farm, the more output in terms of cassava yield attained. These results are consistent with previous work by Ibrahim et al. (2014) and Ogunniyi et al. (2012).

The other interesting point that should be mentioned here is that only the estimated coefficient of variety cost in Vientiane is statistically significant ($p<.10$). This implies that the expenditure for improved varieties for cassava plantations in Vientiane has an effect on cassava yield. If farmers increase their capital in terms of expenditure for improved cassava varieties, they could choose healthy and disease-free planting materials and better root-soaking fertilizers. Farmers in the two areas usually soak the cassava roots in available fertilizers for a few days before planting in order to accelerate growth and hopefully increase yields. This finding is in agreement with the work of Vanisaveth, Yabe, and Sato (2012) and Ibrahim et al. (2014). The effect of variety cost, however, contradicts work on technical efficiency of maize farmers in northern Laos (Southavilay, Teruaki, and Shigeyoshi 2012). The implication of this finding, however, is

Table 4. Result of the regression test on returns to scale

Variables	Parameters	Pooled		Vientiane		Savannakhet	
		Coeff	Std. Err.	Coeff	Std. Err.	Coeff	Std. Err.
Constant	β_0	9.7594***	0.2700	8.3349***	0.9587	8.7807***	0.3387
ln x_1	θ_1	1.0308***	0.0433	0.9828***	0.0464	1.5379 ***	0.1075
ln x_2 – ln x_1	β_2	0.0737*	0.0436	0.0188	0.0520	0.1174 *	0.0655
ln x_3 – ln x_1	β_3	0.0082	0.0114	0.1445*	0.0825	0.0060	0.0088
$\widehat{\theta_1} = \widehat{\beta_1} + \widehat{\beta_2} + \widehat{\beta_3}$		1.0308		0.9828		1.5379	
$se\ \widehat{\theta_1}$		0.0433		0.0464		0.1075	
t-statistic		0.7132		-0.3720		5.0034***	
df (n–k–1)		189		105		80	
Critical value ($p<.05$)		1.980		1.987		2.000	
H$_0$: Constant returns to scale		Can't reject H$_0$		Can't reject H$_0$		Reject H$_0$	

Source: estimated results from household survey data in 2012
Notes: The dependent variable is yield for the stochastic frontier production function.
         ***, **, * denote significant level at 1, 5, and 10% respectively

Table 5. Maximum likelihood estimation for parameters of the Cobb–Douglas stochastic frontier production function and inefficiency effect models

Variables	Parame-ters	Pooled		Vientiane		Savannakhet	
		Coeff	*t*-ratio	Coeff	*t*-ratio	Coeff	*t*-ratio
Constant	β_0	9.7594	34.0180***	8.3348	8.5926***	8.7914	26.0969***
ln (Farm size)	β_1	0.9490	18.2242***	0.8194	9.9198***	1.4211	12.1940***
ln (Labor)	β_2	0.0737	1.7370*	0.0188	0.3773	0.1156	1.7667*
ln (Seed cost)	β_3	0.0082	0.5623	0.1445	1.7605*	0.0058	0.6528
sigma-squared		0.2131	6.0399***	0.1544	2.6121**	2.5972	1.1106
gamma		0.9576	39.9728***	0.9103	14.4419***	0.9783	46.208***
log likelihood function		–68.327		–7.205		–38.683	
Observations		193		109		84	

Source: Estimated from household survey data in 2012

Notes: The dependent variable is yield for the stochastic frontier production function
         ***, **, * denote significant level at 1, 5, and 10% respectively

that policies that provide affordable farm land, planting materials, and labor would improve farm production.

The minimum, maximum, and mean values of technical efficiency for cassava plantations in the pooled, Vientiane, and Savannakhet data sets are presented in Table 6. The maximum technical efficiency for the three data sets was estimated to be higher than 90 percent. This means that the best practices of cassava farming operate as high as over 90 percent. On the other hand, the lowest technical efficiency of cassava farms in Savannakhet has the minimum score of about 17 percent, lower than that in Vientiane at about 33 percent, while the overall minimum technical efficiency is even lower at about 8 percent. On average, the mean score of technical efficiency for cassava farmers are 56 percent, 72 percent, and 75 percent for the pooled, Vientiane, and Savannakhet data sets, respectively. This implies that technical efficiency could be improved by about 28 percent for Vientiane and 25 percent for Savannakhet on the average to attain the level of best farming practice using the current set

of inputs and the given technology in the study area. In comparison to the technical efficiency reported in previous work in Lao PDR, the mean technical efficiency of this study was found to be higher than that in other studies (Southavilay, Teruaki, and Shigeyoshi 2012) that assessed the technical efficiency of maize farms in Borkeo province, which found a mean technical efficiency of 65 percent. It is, however, lower than the work by Vanisaveth, Yabe, and Sato (2012) that analyzed the technical efficiency of maize farms in Sayaboury Province, which reported a mean technical efficiency of 85 percent.

The table also provides the frequency distribution of the technical efficiency of the data sets. In Vientiane, approximately 19 percent of cassava farmers achieved a high level of technical efficiency (91–100%). About 43 percent of farmers had technical efficiencies in the range of 71–90 percent. Less than a fourth of farmers (22%) had technical efficiencies in the range of 51–70 percent, while the lower technical efficiency range (31–50%) for Vientiane cassava farmers was about 16

Table 6. Distribution of the technical efficiency of cassava plantation

Technical Efficiency Range	Pooled		Vientiane		Savannakhet	
	No.	%	No.	%	No.	%
0.0−0.1	2	1.04	0	0.00	0	0.00
0.1−0.2	5	2.59	0	0.00	2	2.38
0.2−0.3	15	7.77	0	0.00	1	1.19
0.3−0.4	49	25.39	7	6.42	1	1.19
0.4−0.5	22	11.40	10	9.17	4	4.76
0.5−0.6	10	5.18	9	8.26	5	5.95
0.6−0.7	28	14.51	15	13.76	10	11.90
0.7−0.8	20	10.36	27	24.77	12	14.29
0.8−0.9	27	13.99	20	18.35	40	47.62
0.9−1.00	15	7.77	21	19.27	9	10.71
Total	193	100.00	109	100.00	84	100.00
Min Efficiency	0.0818		0.3337		0.1723	
Max Efficiency	0.9678		0.9602		0.9377	
Mean Efficiency	0.5587		0.7196		0.7496	

Source: Estimated from household survey data in 2012

percent. In Savannakhet, approximately 11 percent of farmers achieved a high level of technical efficiency (between 91–100%). Most (62%) cassava farmers had technical efficiencies ranging between 71–90 percent. The proportion of farmers who had technical efficiency ranging between 51–70 percent is about 18 percent, while 10 percent of farmers had technical efficiency lower than 50 percent.

Determinants of Technical Efficiency for Cassava Farms

Table 7 reveals the effect of household characteristics and farming practices on technical inefficiency. The dependent variable is the inefficiency score of each farm estimated from the stochastic frontier production function through the application of the maximum likelihood model. The independent variables are age and its squared term, education and experience of households, farm care, land preparation (dummy), period of cassava plantation (dummy), and province (whether it is Vientiane or not). It is noteworthy that when

considering the coefficient of the explanatory variables in the inefficiency effect model, a negative sign for a parameter implies an increase in technical efficiency. In addition, the results of the Savannakhet data set in terms of effects on technical inefficiency is shown but they are not suitable for analyses due to results of the LR statistics test (Table 3), which indicate that farmers' characteristics had no effect on technical inefficiency. Furthermore, the results of all coefficients of famers' characteristics in Savannakhet (Table 7) do not indicate any evidence of statistically significant correlation with technical inefficiency.

In this study, the important features of the effect of the explanatory variables on technical inefficiency are the age of household members, land preparation, and planting period for Vientiane.

The coefficient of the dummy variable for land preparation had a negative sign and was statistically significant for Vientiane ($p<.10$) and the pooled ($p<.01$) data sets, respectively. This indicates that cassava farmers with good

Table 7. Maximum likelihood estimates of inefficiency effect determinant

Variables	Para-meters	Pooled		Vientiane		Savannakhet	
		Coeff	*t*-ratio	Coeff	*t*-ratio	Coeff	*t*-ratio
Constant	δ_0	2.6537***	5.1563	1.6829*	2.4453	10.5555	1.0476
Age	δ_1	−0.0566***	−2.6989	−0.0630*	−1.9285	−0.7192	−1.0413
Age²	δ_2	0.0006**	2.5121	0.0006*	1.7718	0.0083	1.0335
Experience	δ_3	0.0536	1.0004	0.1082	1.4846	0.3560	0.9343
Education	δ_4	−0.0199	−1.0480	0.0264	0.9857	0.0487	0.4407
Dlandpreparing	δ_5	−0.3687***	−2.8447	−0.5157*	−1.8559	−2.4511	−1.0761
Farmcareness	δ_6	−0.1837	−0.6425	−0.2573	−0.7620	−9.5760	−0.9343
Dplantperoid<=9	δ_7	−0.0957	−1.0244	−0.3047*	−1.8721	2.7550	0.8077
Dprovince	δ_8	−1.0437***	−5.7954				
Observations		193		109		84	

Source: Estimated from household survey data in 2012

Notes: The dependent variable is inefficiency score for the technical inefficiency effect models, respectively.
      ***, **, * denote significant level at 1, 5, and 10% respectively.

land preparation before planting tend to be more efficient than those who do not do both, with other factors fixed. Cassava can be grown in a wide range of soils but it is more suitable to light, deep soils. Land preparation should be deep enough and the soil should be ploughed, harrowed, and rowed up with adequate drainage in order to accommodate the effective growth of cassava tubers (Seesahai, Ramlal-Ousman, and Vine 2008).

The other important parameter that has an effect on technical efficiency of cassava plantations is the planting period. The coefficient of the dummy variable on planting period of Vientiane had a negative sign and is statistically significant ($p<.10$). This implies that a cassava plantation cultivated for nine months has a greater potential of increased technical efficiency. This means that the longer time taken for cassava growth would not contribute to an increase in technical efficiency. As previously mentioned, farmers in Vientiane prefer to plant cassava in April–May, the beginning of the wet season, and harvest in December in the dry season. This evidence is also consistent with suggested timing as identified in the work of Seesahai, Ramlal-Ousman, and Vine (2008) and Howeler (2007). This result confirms that harvesting in the dry season this might be a suitable time period for cassava to obtain a higher yield which could respond to the high demand for raw materials of the cassava processing industry in the area.

Even though the estimated coefficient of farm care in terms of labor used for weeding in the cassava field is not statistically significant, a negative sign is shown in relation to its correlation with technical inefficiency. It was expected to have a positive and significant impact on technical efficiency since farmers pay more attention to the care of their cassava farms and often spend time clearing weeds to let the cassava tubers obtain maximum fertility from the soil. It might, however, be a better variable

to capture the effect of technical inefficiency for cassava plantations.

In terms of control variables, the coefficients of age in the pooled ($p<.10$) and Vientiane ($p<.01$) data have negative signs and are related to technical inefficiency. In addition, their square terms have positive signs and are statistically significant for the pooled ($p<.01$) and Vientiane ($p<.10$) data. These results show that age has a U-shaped relationship with technical inefficiency, which implies that technical efficiency tends to increase, ceteris paribus, when younger farmers work in cassava plantations, but as farmers age, technical efficiency decreases. The reason might be that cassava farms in this area are labor intensive and cassava farming practices need manpower for growing, weeding, and harvesting to increase productivity and obtain high yield. Therefore, when young farmers work in a cassava farm, technical efficiency has the potential to increase. On the other hand, aging farmers tend to have less energy for farming practices. This suggests that age leads to technical inefficiency in cassava farming practice and this is consistent with other related studies (Khan, Huda, and Alam 2010; Shehu, Mshelia, and Tashikalma 2007).

The estimated coefficients of farming experience for the pooled and Vientiane data have positive signs but are not correlated with technical inefficiency. This implies that farmers' experience had no effect on the technical efficiency of cassava farming practices. This condition can be explained in that most farmers prefer to cultivate cassava using simple practices (i.e., rainfed without irrigation). Farmers have also just begun to grow cassava with few innovations learned in planting, caring, and harvesting. Therefore, farmers' experience did not support improvements in technical efficiency for cassava farms in the areas during the study period.

The estimated coefficient of education is statistically insignificant and implies that farmers' education does not affect technical efficiency. The result shows a conversely estimated direction from the work of Bravo-Ureta and Pinherio (1997) and Asogawa, Umeh, and Penda (2011) who found that farmers' education had the effect of reducing technical inefficiency. In this study, most farmers have a low level of education (Table 2) but are still able to grow cassava in their traditional farming system. Thus, there may be insufficient variation in the education variable to capture its effect on technical efficiency.

CONCLUSION

This study was carried out to investigate whether cassava farming demonstrates returns to scale under the given input factors and available technology, as well as to estimate the level of technical efficiency through the application of the Cobb-Douglas stochastic frontier production function. The study then extends to determine farming performance in terms of technical efficiency from the data of 193 small-scale farmers in rural areas of Vientiane and Savannakhet provinces, Lao PDR in 2012.

From the analyses, four main significant results were revealed. First, the study found that farm size, labor, and seed costs were the key input factors that have the potential to increase output in terms of cassava yield in Vientiane and Savannakhet. But obviously there are constraints to just increasing farm investment capital; availability of labor and land, especially for the smallholders, are also challenges. So taking into account these constraints, there is still room for increasing returns to scale and improvements in technical efficiency. Second, the existence of increasing returns to scale for smallholder cassava farming in Savannakhet implies that a proportionate

increase in all the input factors would result in a more than proportionate increase in cassava outputs. This means that small-scale cassava farming has not optimized the use of the current resources available with current practices. This evidence could not be found in Vientiane, which means that cassava farming in this area perform constant returns to scale. Third, the estimated mean scores of technical efficiency are 72 percent and 75 percent for Vientiane and Savannakhet, respectively. This indicates that the technical efficiency of cassava plantations could be improved by about 28 percent for Vientiane and 25 percent for Savannakhet through the better use of the current set of inputs and the given technology. Finally, the key determinants of technical efficiency are to plant cassava with good land preparation, to select the most suitable time period for cultivation, and for farmers to be young. This is significant particularly for Vientiane.

The results of the study on the economies of scale and technical efficiency indicates the important implication that opportunities still exist to increase cassava output by maximizing the utilization of current input factors and to improve inefficient farming practices. From this point of view, it is recommended that cassava farmers use techniques that support the optimum use of their resources especially land, labor, and capital in order to ensure that cassava production can reap optimal benefits. In addition, further comprehensive and careful study on the improvement of technical efficiency for cassava production should be done to support cassava farming practice toward commercial crop promotion to achieve the agricultural development goals of food security, better livelihoods, and sustainable farming in Lao PDR.

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