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Full Length Research Paper

Analysis on technical efficiency of maize farmers in the northern province of Laos

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Since the last decade, cash crop farming in Laos has significantly been changing. The changes have made farmers required high input factors (labor, land, fertilizer and so on) to increase productivity. Meanwhile, farmers have low level of technical efficiency and operating farms unproductive. Therefore, the objectives of this study were to estimate the technical efficiency (TE) of maize farmers and identify an inefficient factor that affects maize yield in Northern Laos. The Cobb-Douglas and translog stochastic frontier production function were used to estimate the technical efficiency and its determinants in maize yield. This study was the first to report on technical efficiency of maize farmers in Laos. The finding of this study revealed that the labor and machinery costs were found to have positive and significant effect on maize yield. The mean technical efficiency was 65%; this implies that the output per farm can be increased on an average by 35% for maize farmers under prevailing technology, without increasing any additional inputs. Only 30.6% of the total sample farmers obtained more than 81% of technical efficiency score. Other factors which affect maize yield showed that farmers with higher level of maize growing experiences and their farms on low elevation (<360 m) can reduce the farmer's inefficiency. For the educated farmers, elder farmers, farm size, and hybrid seeds variable has a potential to reduce technical inefficiency.

Key words: Maize, farmers, stochastic frontier, productivity, Laos.

INTRODUCTION

Lao rural livelihood is mainly based on natural resources and agricultural sector. The agriculture contributed 30% of GDP in 2010 and it provides employment of 71% of overall labor forces (Department of Planning, 2010). In the year 2000, the Commercialization of Agricultural Production Policy was introduced throughout country. The objectives of the policy were aimed at modifying the farming systems, enhancing of rural livelihoods through economics and agricultural reforms. It is envisioned that this policy will fulfill the government`s goal in poverty reduction and to progress from least developed country status by 2020 (DOP, 2010). In Laos, the agricultural system is characterized by two major type of farms: namely the upland farm is on slope or plateau areas, rain-fed, slash-and- burn cultivation, the rotational shifting and traditional practices (human`s labor based); and the lowland farm is rain-fed and /or irrigated farming system is usually located on flatland along the foothill and river flood plains with machinery based for cultivation. In the northern Laos, various cash crops have been introduced to the local farmers. Among the cash crops, maize is ranked second in terms of production areas. Maize production was also successful in generating incomes for farmers, and

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contributed in reducing poverty in several rural areas in Laos. The maize production area in the country has increased rapidly from 154,000 ha in 2007 to 213,000 ha in 2010. The maize has become the main cash crop within just a few years, provided short term economic development and improved living condition for farmers.

However, maize production in northern Laos has received in low productivity, especially in upland area the average maize yields are generally between 1.5 to 2.5 t/ha, compared to national average maize yields is 3.8 ton/h (DOP, 2010). In order to meet demand of maize's markets, farmers were encouraged to produce maize under situation of low productivity. Consequently, forest land is one of the most practical options for farmers to expand their cultivated land under such condition. Thongmanivong and Fujit (2006) have shown that the deforestation in the northern Laos was mainly caused by the conversion of forest into commercial agricultural land. For example, the increasing maize production volume as under low productivity may need more farmland and tendency effect to change in land use and land covers. Therefore, one of the key factors for improving maize productive efficiency is to increase the technical efficiency of maize farmers.

The concept of productive efficiency is composed of technical, allocative and economic efficiencies. Farrel (1957) had defined that the technical efficiency (TE) is the ability of a firm (farm) to produce maximum possible output with a minimum quality of inputs, under a given technology. In other words, it is to produce a given level of output from the minimum amount of inputs for a given technology. While, allocative efficiency (AE) reflects the ability of a firm to use the inputs in optimal proportions. Economic efficiency (EE), which combines technical and allocative efficiency, is a measure of firm's (farm) overall performance.

The limited capacity of farmers could be attribute to low productivity. Farmer needs more inputs namely, technology, farm size and fertile soil (pioneer slash and burn). Elibariki et al. (2008) noted that increasing the productivity can not only be achieved through inputs and technological innovation, but also through more efficient use of resources and skill at farmer`s level. On the other hand, increasing productive efficiency by improving technical efficiency would be more cost effective than introducing a new technology as a means of increasing output.

There is limited literature on investigating agricultural production efficiency. In particular, analysis of productive efficiency of maize production has never been done in Laos. Therefore, we could confirm that, this study is a pioneer research on the analysis of technical efficiency of maize production in Laos. The finding of this study will be important and useful to maize farmers for increasing the maize productivity. Therefore, the objective of this study was to estimate the technical efficiency (TE) of maize farmers and inefficient factors which affects maize production in Northern Laos.

DATA AND METHODOLOGY

Study area and data collection

The study area is located in the Bokeo province, Laos (Figure 1). The province is mountainous, bordering Myanmar and Thailand. It has a total land area of 6,196 km^2 and with a population of about 157,500 people, and most of them live in small rural areas and practice agriculture. In this study area, the maize production was one of main commercial crops to boost local economics and the maize harvested area had sharply increased during last 10 years from 1,600 ha in 2000 to 21,000 ha in 2010 (PAFO, 2010).

This study used both primary and secondary data from various sources. The primary data was collected from maize growing farmers in Houixay District, Bokeo province during cropping season of 2010. Face to face interviews were conducted from a total of 98 maize farmers with harvested area of 154.5 ha, that were randomly selected from 8 villages identified as maize growing zones. The farmland elevations are both on upland and lowland area. The structured questionnaires were used to extract from the selected farmers on their household and farming activities. Data related to farm inputs and outputs were collected. The data on farm inputs included labor, fertilizer, seed and machinery, while data on farm output includes production quantities of maize. Socio-economic variable of the farmers were also collected, which include farmer`s age, farm size, level of education, household size, farming experience, source of credit and seed variety.

Theoretical and analytical framework

Developing and adopting the new production technologies and improving access to resources can improve productive efficiency. The Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are the most extensively used methods for predicting the level of productive efficiency and its determinant. The SFA also is widely used in estimating the technical efficiency of production system with one output and multi-inputs, while DEA uses a nonparametric approach or mathematical programming method that is useful for multiple-input and multiple outputs production technologies.

In this study, the stochastic frontier production function was used to estimate the Technical Efficiency (TE) of individual maize farmers and the factors that influence inefficiency. The use of stochastic frontier production has some advantages. Coelli and Battese (1996) pointed out that the stochastic frontier production is more appropriate than DEA in agricultural productions, especially in developing countries where data are more likely to be heavily influenced by the measurement two sided errors, other effects outside the control of the farmers such as weather conditions, disease, pest, etc., and a one-side component that account for inefficiency. Therefore, the stochastic frontier production function which developed by Aigner et al. (1977) and Meeusen and van Broeck (1997) was used in this study.

In order to determine the effect of input factors and socio-economics to productivity and efficiency estimation, both of Cobb-Douglas and translog stochastic production frontiers were used. Wilson et al. (2001), Alvarez and Arias (2004) and Rahman and Hasan (2008) used translog function to estimate technical efficiency because this function provides second-order approximation to the technology at the geometric mean of the sample. While the reason of Cobb-Douglas function is widely used in the literature.

The Cobb-Douglas stochastic production frontier is written as:

$$lny_i = \beta_0 + \sum_{j=1}^{4} \beta_{ij} lnX_{ij} + v_j - u_i \quad (1)$$

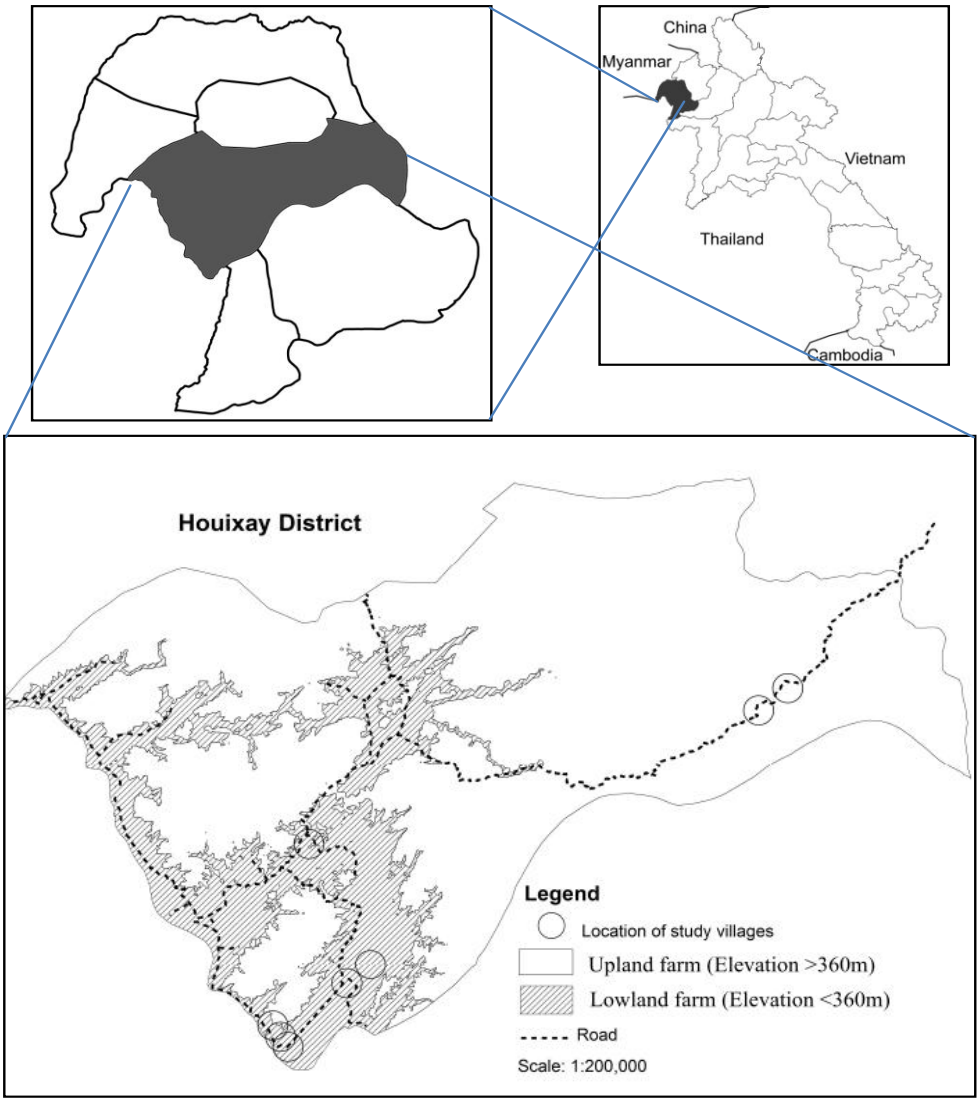

Figure 1. Map of study site.

The Cobb-Douglas functional form against a tranlog model has been tested. The translog function is written as:

$$lny_i = \beta_0 + \sum_{j=1}^{4} \beta_j lnX_{ji} + \sum_{k=1}^{4} \beta_{1,4-k} lnX_{1i} lnX_{4-k,i} + \sum_{m=1}^{3} \beta_{2,4-m} lnX_{2i} lnX_{4-m,i} + \sum_{n=1}^{2} \beta_{3,4-n} lnX_{3i} lnX_{4-n,i} + \beta_{4,4} lnX_{4i} + v_i - u_i \quad (2)$$

where, *ln* is natural logarithm, Y_i is maize yield of the i-th farm in ton per hectare, β_0 is the intercept and $\beta_{1\text{-}4}$ are response parameters to be estimated or elasticity corresponding to each input (i=1,2,3,4), X_1 is labor cost in LAK/ha, X_2 is seeds cost in LAK/ha, X_3 is fertilizer cost in LAK/ha, X_4 is hired machinery service cost in LAK/ha. j,k,m and n represent the interaction between the four inputs in the second order, level of tranlog frontier model. This is the main strength of translog frontier model over Cobb-Douglas frontier model, as it is possible to represent the interaction between various inputs in production.

V_i is two sided error component that represent random variations in output due to factor outside the control of the farmers as well as the effects of the measurement error in the output variable and other statistic noise. It is assumed to be normally distributed with zero mean and variance, σ^2_v and u_i is a non-negative random variable, associated with technical inefficiency (*TIE*) in production assumed to be independently and identically distributed and truncation (at zero) of the normal distribution with mean, μ_i and variance σ^2_u where μ_i is defined by:

$$u_i = \delta_0 + \sum_{n=1}^{7} \delta_i lnZ_{ni} \quad (3)$$

where, μ_i is inefficiency effects, δ_0 is the intercept term and $\delta_{1\text{-}7}$ are parameter for the ith explanatory variable, Z_1 is farm size (ha); Z_2 is maize farming experience (years); Z_3 is age of farmer (years); Z_4 is household size (number of persons in household); Z_5 is education level of farmers, if $Z_5 = 1$ then farmer has completed elementary

Table 1. Summary statistics of output and input variables of maize production in the study size

Variable	Units	Mean	Standard deviation	Maximum	Minimum
Variables for production function model					
Yield (Output)	Ton/ha	5.67	2.22	9.09	1.58
Labor (X_1)	LAK*/ha	1.558.267	986.018	5.198.020	250.000
Seeds (X_2)	LAK/ha	417.129	171.568	843.750	163.500
Fertilizer (N:P:K) (X_3)	LAK/ha	464.743	346.910	1.458.333	0
Machinery service (X_4)	LAK/ha	738.724	406.412	2.156.250	62.500
Variables for inefficiency model					
Farm size (Z_1)	Ha	1.48	0.98	7.00	0.30
Farm experiences (Z_2)	Year	9.70	5.73	20.00	1.00
Age of farmer (Z_3)	Year	46.04	9.89	70.00	27.00
Number of Household member (Z_4)	Person	4.73	1.36	9.00	3.00
Farmer education(Z_5)	Dummy	0.90	0.30	1.00	0.00
Farmland elevation (Z_6)	Dummy	0.52	0.50	1.00	0.00
Hybrid seeds (Z_7)	Dummy	0.54	0.50	1.00	0.00

*LAK: Lao`s Currency (USD1=8,000 kip). Source: Field Survey Data, 2010. Dummy of education (Z_5), taking a value of 1 if farmers completed elementary school, 0 is otherwise. Dummy of farmland elevation (Z_6), taking a value of 1 if farmland is located on the land elevation that equal or lower 360 m from mean sea level and identified as lowland farm, 0 is otherwise. Dummy of hybrid seeds (Z_7), taking a value of 1 if farmers used hybrid seed, 0 is otherwise.

school or higher and zero otherwise; Z_6 is farmland elevation, if Z_6 = 1 the farmland is located on the land elevation less than 360 m from mean sea level and zero otherwise, Z_7 is maize hybrid seed, if Z_7 =1 then farmer used hybrid seeds and zero otherwise.

The Maximum likelihood estimates (MLE) for all parameters of the stochastic frontier production and inefficiency model defined by Equations 1, 2 and 3 were simultaneously estimated using the program FRONTIER 4.1 (Coelli, 1996). This program also estimated the variance parameters in terms of parameterization:

$$\sigma^2 = \sigma^2_v + \sigma^2_u \quad (4)$$

and

$$\gamma = \sigma^2_u / \sigma^2 \quad (5)$$

So that $0 \leq \gamma \geq 1$

The value of γ range from 0 to 1 with values close to 1 indicating that random component of the inefficiency effects makes a significant contribution to the analysis of the production system (Coelli et al., 2005). The technical efficiency of production of the ith farmer (TE_i) given the levels of inputs used is defined by:

$$TE_i = \exp(-U_i) \quad (6)$$

The TE of a farmer was between 0 and 1 and is inversely related to the level of the technical inefficiency effects (Battese and Coelli, 1995). The TE is also predicted using the FRONTIER 4.1 package, which calculates the ML estimate of the predictor for Equation (6) that is based on its conditional expectation, given the observed value of (V_i-U_i). If U_i is equal to 0, the production is on the frontier and the farm is technical efficiency. If U_i is greater than 0, the production will lie below the frontier and the farm is technical inefficiency (Coelli et al., 2005). The technical inefficiency can only be estimated if the inefficiency effects are stochastic and have a particular distribution specification (Battese and Coelli, 1995).

Model specification tests

Various tests of null hypotheses for the parameters in the frontier production functions and in the inefficiency models are performed using the generalized likelihood-ratio test statistic defined by:

$$\lambda = -2\{\log[L(H_0)/[L(H_1)]\} = -2\{\log[L(H_0) - \log[L(H_1)]\} \quad (7)$$

where L (H_0) is the value of likelihood function of a restricted frontier model as specified by the null hypothesis (H_0) and L (H_1) is the value of likelihood function of unrestricted frontier model under alternative hypothesis (H_1). If the null hypothesis is true, the test statistic has approximately a Chi-square or a mixed Chi-square distribution with degree of freedom (df) equal to likelihood ratio (LR) in difference between the parameters involved in the null (H_0) and alternative (H_1) hypotheses.

RESULTS AND DISCUSSION

Summary statistics of output and input variables of maize production are shown in the Table 1. The result indicates that the average yield per hectare in maize production is about 5.67 tons, which is relatively higher than the national mean yield of 5.10 tons (MAF, 2009). However, the interval between minimum and maximum of maize yield was about 1.56 and 9.09 tons respectively.

Statistic of output and input variables

The labor cost has the highest mean, which was about LAK1.55 million per hectare or equivalence to 62 man-days per hectare (the labor cost = LAK25, 000/person/day). This is followed by hired machinery service and fertilizer cost, with a value of LAK738, 724 and LAK464, 743 respectively. The results are in line with the finding of Linkham and Bounthong (2006) who analyzed the pathways out of poverty through maize and

Table 2. Maximum livelihood estimates for parameters of the Cobb-Douglas and translog production.

Variable	Parameter	Dobb-Douglas production function		Translog production function	
		Coefficient	t-value	Coefficient	t-value
Production function					
Constant	β_0	-0.30921	1.64	0.70746	0.756
ln labor	β_1	0.27224***	3.80	0.31968*	1.72
ln seed	β_2	0.21663	0.17	-0.96768	-0.62
ln fertilizer	β_3	-0.59806	-1.36	-0.29672	-1.51
ln machine	β_4	0.92803*	1.80	0.27831**	2.32
1/2ln labor*ln labor	β_5	-	-	0.24203	0.66
1/2ln seed*ln seed	β_6	-	-	0.60213	-1.67
1/2ln fertilizer*ln fertilizer	β_7	-	-	-0.57395**	-2.56
1/2ln machine*ln machine	β_8	-	-	-0.35837*	-1.69
ln labor*ln seed	β_9	-	-	0.23816	0.84
ln labor*ln fertilizer	β_{10}	-	-	-0.17084***	3.23
ln labor*ln machine	β_{11}	-	-	0.29499***	3.24
ln seed*ln fertilizer	β_{12}	-	-	0.86936***	3.72
ln seed*ln machine	β_{13}	-	-	-0.74590***	3.65
ln fertilizer*ln machine	β_{14}	-	-	-0.11271	0.49
Variance parameter					
Sigma-squared $\sigma^2_s = \sigma^2_v + \sigma^2_u$	δ^2	0.100***	4.362	0.234*	1.82
Gamma $\gamma = \sigma^2_u / \sigma^2$	y	0.687***	4.238	0.975***	57.99
Log likelihood		-12.07		25.130	
LR test of one sided error		34.81		81.40	

*** Significant at 1%, ** significant at 5%, significant at 10%. Source: Survey Data, 2010 (computed by Frontier 4.1) .

Job`s Tear in Laos. However, based on field survey we found that about 38% of maize farmers did not apply fertilizer and most of them grow maize on the upland area. In terms of educational attainment, 90% of maize farmers were elementary graduates. About 54% of the farmers use hybrid maize seed, while the remaining 46% of the farmers use traditional seeds. Also, 52% of farms are on the lowland areas.

Technical efficiency

The maximum-likelihood estimates (MLE) for the parameters of the Cobb-Douglas function defined by Equation 1 is presented in Table 2.The result suggests that labor and machinery have a positive and significant on maize yield in both Cobb-Douglas function and translog. The coefficient of labor has a positive and statistically significant at 1% level (P<0.01) with Cobb-Douglas function. It means that 1% increase in labor cost will lead to increase in maize yield of 0.72% and 10% with translog function. This increase in maize yield might be due to better weeding and other farm activities since maize farming is labor intensive in this study area. This is expected because most of the maize production in Laos relies heavily on labor usage, particularly during clearing field, planting, weeding and harvesting. This is in line with findings of Khamphou and Daniel (2006) who studied the production and market conditions of Maize in Northern Laos.

The coefficient of seed expenses is estimated to be statistically insignificant. This suggests that seed does not affect the yield of maize. It was observed that, farmers use different varieties of seeds such as hybrid seeds and traditional seeds.

The coefficient of machinery has a positive and statistically significant at 10% level with Cobb-Douglas function and 1% with translog function, meaning that the increasing in yield is the result of a better land preparation because in the lowland farmers relied on using machinery for land preparation. It is mainly used for land plowing, planting and weeding (three weeks after planting). The latter use is important to control the weeds and to cover fertilizers after sowing. The land preparation of upland maize farms is done using conventional methods (human`s labor based). This means that after slash and burn, the maize planting is done using manual tillage method. However, both areas of the upland and lowland maize are not using the irrigation and insecticide. The coefficient of the fertilizer was negative and statistically insignificant input in the production of maize. However, the negative sign of fertilizer might be due to farmers using more fertilizer than the recommended level. This implies that fertilizer does not affect the yield of the

maize significantly. This finding is in the agreement with the works of Abedullah et al. (2006) on the technical efficiency and its determinants in potato production in, Pakistan, and Idiong (2007) estimated farm level technical efficiency in small-scale swamp rice production in cross river state of Nigeria. Nonetheless, the finding of this study contradicts with the work of Boshrabadi et al (2008) who studied technical efficiency and environmental-technological gaps in wheat production in Kerman province of Iran.

It was observed that fertilizers are not applied in the upland maize farms because of farmer belief soil is fertile in upland area. The lowland maize farmers use chemical fertilizer (NPK: 46-0-0). Nitrogen fertilizer (150 kg/ha), P fertilizers (0 kg/ha) and K fertilizer (0 kg/ha) were applied after three weeks of planting (when 3rd to 4th maize`s leaf appeared) during May and June. This amount and method are different from the recommended application procedures. The Laos Extension for Agriculture Project (LAEP) suggested that the standard procedures on fertilizer application for maize production should be done two times during production period. First, N 1/3 (33kg/ha), K: 1/2 (30kg/ha) should be applied when the 3rd to 4th leaf appeared. Second, N (66 kg/ha) and K (30 kg/ha) should be applied when the 8th to 9th leaf appeared. Using fertilizer application on the second time is very important because it has increasing effect to the yield of maize (LEAP, 2001). This answers the question on why fertilizer does not affect the maize yield in this study area.

With the translog estimation, the parameter of half-squared variable show that the farmers get a lower yield if the increase in the cost of fertilizer and machinery exceeds the maximum amount. However, the parameters of interaction between labor and machinery, seed and fertilizer show that if farmers used more those inputs it will lead to get a higher yields. The interaction variables have shown a negative impact on the maize yield. It follows the theory of production function that the margin of the yield will be going down when input bundle exceeds to the maximum point.

Test of hypothesis

The parameter γ defined by Equation 5 ($\gamma = \sigma^2_u / \sigma^2$) lies between 0 to 1 (Table 2). The value equal to 0 suggests that technical efficiency is not present. While a value less or equal to 1 implies that the frontier model is appropriate. The value of γ associated with the variance in the stochastic frontier was 0.687 and highly statistically significant at the 1% level. This implies that 68.7% of the difference between observed output and maximum production frontier output is caused by difference in farmers` level of technical efficiency rather than random variability.

The Likelihood Ratio (LR) test of the one side error of γ is defined by the Chi-square (χ^2) distribution and is used to test the null hypothesis of Cobb-Douglas and translog $H_0 = \delta_0 = \ldots \delta_7 = 0 = \gamma$. The test statistics was defined by Equation (6) and estimated the value of "LR" of Cobb-Douglas and translog equal to 34.811 and 81.40 respectively and exceeding the value of mixed Chi-square distribution at 1% level of the 9 degree of freedom, which is equal to 20.927. In this case, critical values for the generalized likelihood-ratio test are obtained from Table 1 of Kodde and Palm (1986). This implies that the null hypothesis of no technical inefficiency effect on among maize farmers was rejected. The rejection of the null hypothesis supports the existence of inefficiency in the data set effects on the maize production of the sampled farmers. This implies that the Cobb-Douglas and translog production function is an adequate representation of the data.

Source of inefficiency

The one-side error term (the technical inefficiency function model) μ_i idefined by Equation (3) are represented in Table 3. The result of technical inefficiency model shows that the estimation of parameters for source of inefficiency variables is similar between the Cobb-Douglas and translog production function.

The coefficient of farm size has a negative impact but insignificant (positive relationship with technical efficiency) in both Cobb-Douglas and translog functions. The result suggests that the farm size seems can lead to an increase in maize yield. In other words, the technical inefficiency of maize farmers decreases as the farm size increases. The result is similar with the works of Basnayake et al. (2002) studied on Scottish cereal producers and Sri Lanka tea smallholders respectively; Alvarez and Arias (2004) studied technical efficiency and farm size and Elibariki et al. (2008) studied on the technical efficiency of smaller maize in Tanzania.

The coefficient of the farming experiences variable has a negative (positive relationship with efficiency) and significant at 1% level in Cobb-Douglas and 10% in translog function. It means that farmers with more years of farming experiences tend to be more efficient in maize production. On other hand, the technical efficiency increases with increasing farmer`s experience. Obviously, the experienced farmers are more efficient than less experiences ones in managing and allocating productive resources. This is consonance with the finding of Shehu et al. (2007) who studied the technical efficiency of rice farmers in Northwest of Nigeria.

The coefficient of the age of farmer has negative sign in Cobb-Douglas and positive sign in translog function but insignificant. For the Cobb-Douglas function implies that the technical inefficiency trend to decrease as the age of farmers increases. This is because older farmer has more experiences than younger farmer (younger farmer

Table 3. Maximum-likelihood estimate for parameters of the inefficiency model Cobb-Douglas and Translog production function .

Variable	Parameter	Cobb-Douglas production function		Translog production function	
		Coefficient	t-value	Coefficient	t-value
		Production function			
Constant	δ_0	0.905	1.164	-0.404	-1.394
Farm size	δ_1	-0.058	-0.583	-0.231	-0.399
Farm experiences	δ_2	-0.296***	-4.490	-0.279	-1.945*
Age of farmers	δ_3	-0.034	-0.177	0.1000	1.478
Household size	δ_4	0.238	1.330	0.928	1.791*
Education of farmers	δ_5	-0.202*	-1.835	-0.782	-1.794*
Land elevation	δ_6	-0.577***	-2.777	-0.145	-1.890*
Hybrid seeds	δ_7	-0.090	-0.632	-0.213	-0.078
Total number of observations = 98					

***, ** and * Significant at 1, 5 and 10% level respectively. Source: Survey data, 2010 (computed by Frontier 4.1).

tend to more inefficient). This finding is in line with the finding of Abedullah et al. (2006) studied on technical efficiency and its determinants in [potato production Pakistan. Nonetheless, the findings of this study contradict the work of Akhtaruzzaman et al. (2010), Shehu et al. (2007) and Sumy et al. (2009). Their works reported that the coefficient of the age of farmer has positive impact on the inefficiency model, suggesting that age led to technical inefficiency of farmers. A possible explanation for such findings could be that adoption of technology and general ability to supervise farming activities decrease as farmers advanced in age.

The coefficient of household size has a positive impact on the inefficiency model (negative effect on efficiency) insignificant in Cobb-Douglas but significant at 10% in the translog functions. It means that family member is not contributing to technical efficiency of maize farmers. This may be due to less number of adult (laborer) members in the households. Conversely, perhaps the adult member of the household has non-farm activities (off-farm), and thereby low quality labor in farming activities would be unavailable for carrying out farming activities in time. However, this finding contradicts with the work of Shehu et al. (2007).

The coefficient of education of maize farmer has a negative impact on the inefficiency model (positive relationship with efficiency) and significant at 10% level of both Cobb-Douglas and translog functions. It implies that better educated farmers produce maize efficiently. The highly educated farmers are more efficient than farmers with low level of education. This is because farmers who have high education level can easily understand and adapt to new technologies than less educated farmers. This finding is in agreement with the work of Akhtaruzzaman et al. (2010), Onphanhdala (2010) and Shehu et al. (2007). Nonetheless, the finding of study contradicts with the finding of Ephraim (2007) who studied the sources of technical efficiency among smallholder maize farmers in Southern Malawi. One explanation is that, in Malawi, maize is mainly produced for subsistence using traditional methods, and the education of farmers does not play a role in the optimal combination outputs.

The coefficient land elevation has a negative effect on the inefficiency model (positive relationship with efficiency) and statistically significant at the 1% in Cobb-Douglas and 10% in translog function. This implies that the maize planted on land elevation as less than 360 m (lowland) tend to be more technically efficient than maize planted on elevation above 360 m (upland). According to field survey the percentage of sample lowland maize farmers can be estimated that 95% of their farm activities are done by using machineries, while upland maize farmers are usually done by conventional methods (human`s labor based) of their farm operating.

The coefficient of hybrid seeds has a negative effect on the inefficiency model (positive relationship with efficiency) but insignificant in both Cobb-Douglas and translog function. This indicates that the plots with hybrid maize seeds are more efficient that plots using local seeds. This is in the line with the work of Ephraim (2007). During field survey, it was observed that a large majority of Lao farmers used hybrid maize seeds. This is because hybrid seeds do not require a very high level of technology and provide good yield. However, some upland maize farmers usually preferred local seeds more than hybrid seeds.

Frequency distribution of technical efficiency scores

Stochastic frontier production function was estimated for this study to determine technical efficiency. Table 4 shows the frequency distribution of the farm specific technical efficiency. The maximum and minimum values of technical efficiency are 93 and 20, suggesting that the best practice farmer operates at 93% while the least practice farmers operate at 20% efficiency level,

Table 4. Frequency and percentage distribution of the farm specific TE of individual farmers during cropping season in 2010.

Efficiency interval	Total of farmers	Total % of farmers
0.20-0.30	6	6.1
0.31-0.40	8	8.2
0.41-0.50	16	16.3
0.51-0.60	15	15.3
0.61-0.70	6	6.1
0.71-0.80	12	12.2
0.81-0.90	30	30.6
0.91-1.00	5	5.1
1.00	0	0.0
Total	98	100.0
Mean	0.65	
Minimum TE	0.20	
Maximum TE	0.93	

Source: Field Survey Data, 2010 (computed by Frontier 4.1).

respectively. Averaged over the period for which each farm appears in this study area shows that the mean efficiency was found 65%, indicating that there were high opportunities for improving technical efficiency by some 35% on average with the current set of inputs and the given technology at that time. On the other hand, average farmers could reduce the production cost by 30.1% if all farmers achieved the highest level of technical efficiency of 93% (Bravo-Ureta and Pinheiro, 1997; Khai and Yabe, 2011; Obare et al., 2010). From the results, compare to other previous studies, the mean technical efficiency of sample farmers is lower than the work of Koc et al. (2011) who studied technical efficiency of maize farmers in three areas of Turkey, and the study showed that the mean technical efficiency of 72, 81 and 88%. Vanisaveth et al. (2012) showed the mean of technical efficiency of maize farmer in Laos of 85%. However, the mean technical efficiency of sample farmers is higher than the work of Elibariki et al. (2008) who showed that the mean technical efficiency of 60% with the technical efficiency ranged from 10 to 90%.

CONCLUSIONS AND POLICY IMPLICATIONS

This study has presented measure of technical efficiency and identified factors related with efficiency of a sample of 98 maize farmers in Bokeo province, Laos. The technical efficiency and its determinant have been investigated through the Cobb-Douglas and translog functional form.

This study revealed that the labor and machinery costs were found to have positive and significant on maize yield. There is potential for increasing maize yield by increasing the levels of labor and machinery costs. Surprisingly, one of the input variables shows that the fertilizer is negative and insignificant input in the production of maize. This could imply that some farmers might be using inappropriate technique in the application of fertilizer.

The mean technical efficiency of the total sample farmers was 65% of maximum attainable output for given a set of input levels and the technology. This implies that the output per farm can be increased on an average by 35% for maize farmers under prevailing technology, without increasing any additional inputs. There was only 30.6% of the total sample farmers obtained more than 81% of technical efficiency score. However, there was no farmer was found to be fully efficient. For the other factors that affect maize yield were shown that farmers with higher level of maize growing experiences and their farms are on low elevation (<360 m) can reduce the farmer's inefficiency. For the educated farmers, elder farmers, farm size, and hybrid seeds variable has a potential to reduce technical inefficiency.

Therefore, from the policy maker point of view, farm experiences, education of farmers and characteristic of land elevation are key factors to increase technical efficiency of maize farmers in the study site. Thus, the provision of literacy campaigns, training, and field demonstration on best practice farms as well as to encourage farmers to engage in adult continuing education programs or simply techniques such as brochure, study tour and installation of demonstration center in the area may help inefficient farmers to become better off in short run. Likewise, the agricultural sector should clarify and provide characteristic of land elevation for maize production by providing land use, land suitability map and guidelines that may help maize farmers in right direction.

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