Efficiency of Lowland and Upland Farming in Lao PDR[1]

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ABSTRACT

Agriculture has long characterized the economy of Laos in terms of employment share and output. Yet, the sector is still dominated by subsistence farming with low inputs, low yields and inadequate farming incomes. Enhancement of efficiency and productivity of the sector is critical for national output, farmers' incomes and the industrialization process in terms of labor supply. However, efficiency analysis in the agricultural sector for Laos is still a rare case, especially, research studies at the disaggregate level.

In view of filling this study gap, the present paper examines technical efficiency and its determinants for farm households by applying a DEA-regression analysis to the data from LECS2 and LECS3 at the district level. The study has revealed some important findings: (i) within a district, efficiency spillovers in lowlands are more significant than in uplands; (ii) farmer education plays an important role in improving farm efficiency, whereas most of physical inputs do not help enhance farm efficiency; and (iii) market access is crucial for farm efficiency augmentation. The findings suggest that government policies should be directed toward education at the grass-roots level, promoting commercial production and reform in development of agricultural infrastructure.

Key words: *technical efficiency, agriculture, DEA-Tobit, Laos*

JEL Classification: C14, C24, O13

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1. INTRODUCTION

The Lao People's Democratic Republic (hereafter called Lao PDR or Laos) has experienced rapid economic growth over the last decade, achieving an annual average rate of 6.9% during 2001-2010 (ADB, 2011). Yet, Laos still remains predominantly a rural society with the agricultural sector as the main source of employment and income for the bulk of its population. The sector contributes some 30 percent to the GDP, but employs over three-quarters of the country's labor force. Subsistence farming is still widely characterized by low inputs and low yields, resulting in very low farming incomes. Another noticeable characteristic of Lao agriculture is the widespread use of shifting cultivation practices, traditional production systems, and predominantly household labor, and private land holdings (Onphanhdala, 2010).

Agriculture has grown at a healthy annual rate of 4.4% averaged over 1990-2006 and this greatly contributes to the progress in rural poverty reduction (World Bank, 2006). The essential role of agriculture and the analysis of this crucial sector in the Lao economy can hardly be overlooked. Published research studies have addressed a number of issues related to land reform and farm practices (Ducourtier et al., 2005; Takai and Sibounheauang, 2010), land use and livelihood changes (Thongmanivong and Fujita, 2006; Thongmanivong et al., 2009), commercialization of farm products in rural communities (Foppes and Phommasane, 2006; Onphanhdala and Suruga, forthcoming; and Yokoyama, 2010).However, most of these studies are based on case studies. To our knowledge, empirical studies on the performance and development of Lao agriculture in still very limited. As a pioneer work, Bourdet (1995) reviews the process of rural reforms and evaluates the impact of co-operatives on rice production using data of 1980-88. In a similar vein, Onphanhdala (2009, 2010) examine the effect of farming equipment and conditions, farm experience, and several alternatives of farmer education on farm efficiency, using household data of 1997/98 and 2002/03.The studies also look into the differences in farm performance in terms of farming systems/types (upland and lowland farming).

The analysis in Onphanhdala (2009, 2010) is relatively comprehensive. However, with a country-wide coverage some aspects of regional characteristics, even within the upland and lowland farming areas, may not be sufficiently controlled for or insulated. Therefore, in view of expanding and refining the analysis on farm performance in Laos, the present paper evaluates the impacts of farmer education and experiences, farm and household characteristics, and market access on technical efficiency of farm households in upland and lowland farming areas at a more disaggregated level (district level). Following the classification of agricultural practices applied in World Bank (2006), this study also compares the differences between lowland rice farming (center-south) and upland rice farming (north-east).By adopting this classification, certain features or unique characteristics of a region or locality can be insulated.

Despite using statistical data extracted from the same surveys of 1997/98 and 2002/03 – the only household survey series available for Lao PDR – this study distinguishes itself from previous works in two critical points: (1) the household data applied in Onphanhdala (2009, 2010) are pooled by provinces according to their classification to lowland or upland, and (2) direct rice output is used as a proxy for farm efficiency/productivity to assess the impacts of farmer education and other determinants. On the other hand, this paper applies the data at the district-level based on the location and classification of such districts, and thereby ensuring greater homogeneity in terms of characteristics and farming practices of

the households in the samples. Moreover, in this analysis farm efficiency is calculated from two inputs and one output using a nonparametric approach; and the resulting technical efficiency score is applied as an explained variable in a regression model to evaluate the effects of certain determinants of interest. While lending support to previous studies, the findings in this paper provide further clues on efficiency spillovers in the upland and lowland classifications.

The remainder of the paper is structured as follows. Section 2 presents some characteristics and issues of Lao agriculture. Section 3 introduces the approach of data envelopment analysis and the econometric model, and describes the data for the empirical analysis. Section 4 presents and discusses the empirical results. Conclusions are presented in the last Section.

2. BRIEF OVERVIEW OF LAO AGRICULTURE

General features: Agriculture is one of the main sectors of the Lao economy, engaging roughly three-quarters of the labor force and contributing nearly half of the GDP. Rice paddy was the single most important crop accounting for over 40% of agricultural output. Recently, however, production of other crops has increased rapidly, with some products expanding at an average growth rate of over 10% during the decade, such as maize, cassava, nuts, soybeans and vegetables (Table 1).On top of this, cereal production has overtaken rice output and reached 3.9 million metric tons in 2008.For some products the output expansion might result from increased external demand in form of contract farming, such as sugar cane, etc.

Farming system: Broadly speaking, the farming system in Laos consists of two main practices: the lowland rain-fed and/or irrigated farming along the Mekong River and its tributaries, and the upland farming practicing slash-and-burn cultivation in the northern and eastern mountain regions. The sector is characterized by subsistence farming (self consumption), low-productivity rice production, low-level use of purchased inputs (improved seeds, fertilizers, and tractors), traditional farming techniques, primarily household labor, and private land holdings (World Bank, 2006; Table 2).About 60 percent of rice farmers practice lowland cultivation, and some 10 percent do both lowland and upland farming. Rotational shifting cultivation is the most common agricultural practice in the country, while pioneering slash-and-burn practices are more frequent in northern region (Onphanhdala, 2009).

Table 1: Agricultural production in Lao PDR 1998-2008

Agricultural Production (1000 tons)	1998	2004	2005	2006	2007	2008	Average growth rate (1998-2008)
Rice paddy	1,674.5	2,529.0	2,568.0	2,663.7	2,710.1	2,927.1	4.3
Maize	109.9	203.5	372.6	403.6	620.6	946.8	25.3
Cereals3000	1,784.4	2,732.5	2,940.6	3,067.3	3,330.6	3,873.9	6.4
Cassava	70.0	55.5	51.3	174.5	233.4	262.0	18.5
Sweet potatoes	107.9	119.7	129.9	109.7	126.5	126.0	2.7
Potatoes	33.0	36.0	36.0	36.0	36.0	36.0	1.1
Roots and tubers	210.9	211.2	217.2	320.2	395.9	424.0	8.2
Pulses (dry seeds)	14.7	16.1	17.9	17.7	16.9	18.3	2.1
Ground nuts in shell	15.0	12.4	27.0	27.6	35.1	32.7	10.3
Soybeans	4.3	4.7	11.1	12.0	10.5	10.6	11.8
Primary oil crops	9.6	7.9	13.5	14.4	16.5	16.0	7.5
Fruits (total) excluding melons	177.1	201.0	206.1	206.1	200.4	202.4	1.2
Citrus fruits	67.0	68.5	70.5	70.5	70.5	70.5	0.5
Vegetables excluding melons	160.2	779.9	859.1	782.2	875.1	899.6	13.3
Sugar cane	170.2	223.3	196.1	218.4	323.9	416.7	5.5
Coffee (green)	17.0	23.1	25.0	25.3	33.2	39.0	6.1
Tea	0.3	0.3	0.3	0.2	0.3	0.6	2.2
Chillies and peppers (green)	6.0	13.0	13.6	13.6	13.6	13.6	8.4

Source: *Selected indicators of food and agricultural development in the Asia-Pacific Region 1999-2009*, 2010, Rome: Food and Agriculture Organization.

Land use: In recent years, land use for agricultural production in Lao PDR has been expanding from 4.1% of the total land in 1998 to 5.8% in 2008. In addition, paddy output, harvested areas and paddy yield have all increased over the same period. With nearly a quarter of agricultural land being irrigated the country has achieved relatively good performance in agricultural infrastructure development (Table 2).However, the land utilization ratio is still very low compared to other developing countries in the region. For example, over the period 1998-2008 the land use ratio for Cambodia was 21.7-23.0%, Vietnam 22.8-30.4%, Myanmar 15.5-17.9%, Indonesia 17.5-20.5%, and Thailand 37.7-36.9% (FAO, 2010).

The distribution of agricultural land is relatively equitable across provinces, with average land size of 1.62ha. Most of farmers hold agricultural land. Overall, 36% of farmers own less than one hectare, another 36% have 1-2 hectare a, and 27% own 2 hectare or more (Onphanhdala, 2009).On the other hand, a decrease in agricultural population and a steady ratio of agricultural land to agricultural population of 0.24-0.29could suggest a slight upward trend in land holding (Table 2).

Table 2: Land use for agricultural production in Lao PDR

	1998	2004	2005	2006	2007	2008
Agricultural land (1000 ha) (% of total)	940 (4.1)	n.a.	n.a.	1182 (5.1)	1215 (5.3)	1345 (5.8)
Agricultural population (% of total)	77.0	n.a.	n.a.	75.7	75.5	75.3
Agricultural land/agricultural population	0.24	n.a.	n.a.	0.26	0.26	0.29
Irrigated land (% of agricultural land)	22.2	n.a.	n.a.	27.8	25.4	22.3
Number of tractors	1,050	1,080	1,080	1,080	1,080	n.a.
Rice paddy output (1000 tons)	1,674.5	2,529.0	2,568.0	2,663.7	2,710.1	2,927.1
Rice paddy yield (kg/ha)	2,712	3,283	3,489	3,348	3,469	3,547
Rice paddy harvested area (1000 ha)	617.5	770.3	736.0	795.5	781.2	825.4

Source: *Selected indicators of food and agricultural development in the Asia-Pacific Region 1999-2009*, 2010, Rome: Food and Agriculture Organization.

Import of agricultural products: Although the Lao economy is largely based on agriculture, the subsistence farming-dominated production is apparently unable to meet the increasing demand for food and other agricultural commodities. The country imports many of basic food products, including rice, wheat and flour, cereals and tea, while exports of such products are not existing or negligible (except for cereals with a drastic increase in recent years). Overall, imports of agricultural products are as much as five to eight times of exports (Table 3).

Flood and other constraints: Lao farmers are facing several restrictions, such as lack of technical skills and knowledge, inadequate agricultural infrastructure, insufficient credits, and poor market access, and insects and animal diseases. For rice growers the top-three serious constraints are flood, drought and storm disasters, particularly in the lowland areas in the center and the south. According to records in the database CRED/EM-DAT, during 1966-2008 there were 31 floods in Laos, of which eight severe flood disasters happened in 1966, 1971, 1978, 1995, 1996, 2002 and 2008. Hence, on average severe flood occurs in every 5-6 years.

Table 3: Trade in agricultural products 1997-2007

	1997	2003	2004	2005	2006	2007
Rice imports (1000 tons)	19.9	23.6	32.9	21.3	14.6	24.0
Wheat and flour imports (1000 tons)	6.9	3.0	3.0	4.1	4.2	4.3
Tea imports (tons)	5.0	0.0	113.0	113.0	70.0	103.0
Cereal imports (1000 tons)	26.9	27.8	37.3	26.5	20.4	32.0
Cereal exports (1000 tons)	0.2	8.4	34.7	47.1	127.0	22.9
Imports of agricultural products (US$ mil.)	87.8	93.7	119.9	170.4	187.2	201.4
Exports of agricultural products (US$ mil.)	17.4	14.6	20.6	21.2	24.4	39.1

Source: *Selected indicators of food and agricultural development in the Asia-Pacific Region 1999-2009*. 2010, Rome: Food and Agriculture Organization.

3. EFFICIENCY STUDY IN AGRICULTURE AND ANALYTICAL FRAME-WORK

Empirical measurement of efficiency was introduced by Farrell (1957), who defined technical efficiency (TE) as measuring the extent of success in producing as large as possible an output from a given set of inputs (output-orientation). In this paper we apply the data envelopment analysis (DEA) to calculate the efficiency scores for individual farms and a regression model to evaluate determinants of technical efficiency. Representing the nonparametric approach DEA has some advantages over the parametric approach in that it does not require specification of production function, allows for investigating scale and congestion efficiency, and can accommodate multiple inputs and multiple outputs.

DEA has been extensively applied in efficiency analysis for a wide range of sectors, such as education (Charnes et al., 1978), health care (Kooreman, 1994; Chilingerian, 1995; Puig-Junoy, 1998), manufacturing (Vixathep, 2011; Vixathep and Matsunaga, 2012), banking and finance (Pasiouras, 2008), and many others. Specificallyfor the agricultural sector, this methodology has been used extensively for many countries [see for example, Wadud and White (2000) and Wadud (2003) for farm households in Bangladesh, Wu et al. (2003) for sugarbeet farms in the USA,Umetsu et al. (2003) for the rice sector in the Philippines,Odeck (2007) for Norwegian crop production, and Ajibefun (2008) for food crop production in Nigeria]. Derived from published studies, determinants of technical

efficiency at the farm level could be summarized into three groups of variables: characteristics of farm and technology, environmental and locational variables, and human capital variables. For example, farm and household efficiency in Bangladesh has been found significantly affected by environmental degradation and irrigation infrastructure (Wadud and White, 2000), while soil quality, the degree of integration with downstream markets and education are important for crop farms in Poland (Latruffe et al., 2004).

1. Data Envelopment Analysis

The empirical analysis applies a two-stage DEA-Tobit model. First, the technical efficiency score for individual farm households is obtained by means of DEA. Second, the resulting TE score is used as a dependent variable in a regression analysis to determine possible factors affecting household farm's efficiency.

In DEA efficiency is defined as the ratio of weighted output to weighted input. DEA uses the distance functions and the mathematical programming to maximize this ratio. In view of expanding farm output under the constraint of fixed inputs, including farm land and labor, the analysis employs an output-oriented constant returns to scale model (CRS-model) with two inputs (land, labor) and one output (rice).This model, first developed by Charnes et al. (1978),operates on the assumption of CRS and measures how much more output could be obtained, while keeping inputs at the observed level. Technical efficiency (*CRSTE*) from a CRS-model contains pure technical efficiency(*VRSTE*) and scale efficiency (*SE*).

The CRS-model is written in envelopment form as follows:

$$\max_{\eta,\mu} \quad \eta \tag{1}$$

Subject to $\quad \mathbf{x}_i - \mathbf{X}\mu \geq 0 \tag{2}$

$$\eta \mathbf{y}_i - \mathbf{Y}\mu \leq 0 \tag{3}$$

$$\mu \geq 0 \tag{4}$$

where $(\mathbf{X},\mathbf{Y})$ is a matrix of inputs and outputs, η is a real variable (efficiency measure), and μ denotes a transpose of a non-negative vector $\mu = (\mu_1,...,\mu_n)^T$ of activity variables. The index i denotes the farm to be evaluated at any trial (i=1,2,…,n).A farm with a TE score of unity ($\eta^* = 1$) and zero slacks (no input excess and output shortfall) is identified as technically efficient.

If variable returns to scale are assumed for production, an additional restriction is added to the CRS-model to ensure that a convex frontier exists in a VRS-model (Banker et al., 1984).

$$\mathbf{e}\mu = 1 \tag{5}$$

The CRS-model with expressions (1)-(4) yield a CRSTE score for each firm, while the VRS-model with expressions (1)-(5) yields a VRSTE score. Scale Efficiency is defined as the ratio of the two efficiency measures, i.e. $SE = CRSTE / VRSTE$.

Figure 1: Production frontiers of CRS-model and VRS-model

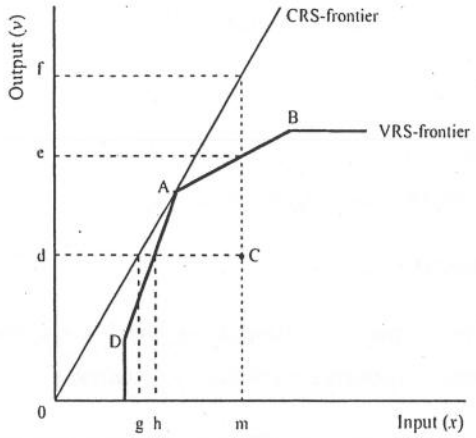

Figure 1 illustrates the CRS-frontier and VRS-frontier and the relationship between the two models for a single-input and single-output case (four firms are depicted in the figure). Firm A is both technically and purely technically efficient, because it is located on both frontiers. Firm B and D are purely technically efficient (VRS-efficient), as they are located on the VRS-frontier, but they are not technically efficient (CRS-efficient). CRS-efficiency implies VRS-efficiency. Firm C is inefficient regardless of frontiers or models. The corresponding output-oriented efficiency scores are $CRSTE = od / of$, $VRSTE = od / oe$ and $SE = oe / of$.

2. Efficiency Effect Equation

The second stage is to evaluate possible determinants of technical efficiency of the farm households. For this purpose, the TE score has been conceptualized in Chilingcrian (1995) and Kooreman (1994) to represent a censored normal distribution. Thus, in a regression model the TE score can be used as an explained variable, whose observations are concentrated at single value above a threshold (Puig-Junoy, 1998).The DEA-regression analysis has been widely applied with OLS (Wadud and White, 2000; Umetsu et al., 2003) or truncated regression/Tobit model (Kooreman, 1994; Chilingerian, 1995; Puig-Junoy, 1998; Wadud, 2003; Latruffe et al., 2004; Odeck, 2004; Pasiouras, 2008; Vixathep, 2011, Matsunaga and Vixathep, 2012). The CRSTE[4] score is assumed to be a function of certain certain explanatory variables in additive form:

$$CRSTE_i = \beta_0 + \beta_j \mathbf{z}_{ij} + \varepsilon_i \ , (j = 1,2,\ldots,q) \qquad (6)$$

Where β_j is a vector of coefficients to be estimated, $\mathbf{z}_{ij}$ represents a vector of explanatory variables, which are expected to have certain effects on efficiency of the *i-th* farm. For our purpose, Equation (6) can be specified as in the following two specifications with δ_j and

[4] The regression analysis with VRSTE as independent variable yields comparable coefficient estimates and would not alter the results or conclusions presented in this study. Therefore, owing to space limitation the regression results of VRSTE are not presented in the paper. A summary of all three efficiency scores (CRSTE, VRSTE, SE) are presented in Table 8 and Table 9.

γ_j denoting vectors of estimated coefficients. The specificationsare based on the availability of variables in the two datasets used in the analysis.

Specification 1 for 1997/98

$$CRSTE_i = \delta_0 + \delta_1 dryland_i + \delta_2 buffalo_i + \delta_3 tractor_i + \delta_4 mktacc_i + \delta_5 hhbiz_i + \delta_6 hhsch_i + \delta_7 farmexp_i + \delta_8 farmexp2_i + \varepsilon_i \quad (7)$$

Specification 2 for 2002/03

$$CRSTE_i = \gamma_0 + \gamma_1 tractor_i + \gamma_2 mktacc_i + \gamma_3 hhbiz_i + \gamma_4 hhsch_i + \gamma_5 farmexp_i + \gamma_6 farmexp2_i + \gamma_7 irracc_i + \gamma_8 spsch_i + \gamma_9 ethnic_i + \gamma_{10} poultry_i + \varepsilon_i \quad (8)$$

where CRSTE denotes 'overall' technical efficiency obtained from DEA, *dryland* type of agricultural land, *buffalo* and *tractor* the use of buffaloes and tractors, *mktacc* access to the market, *hhbiz* household business, *hhsch* school level of household head, *farmexp* farm experience, *irracc* access to irrigation facilities, *spsch* school level of spouse, *ethnic* households belonging to non-Lao ethnic groups, and *poultry* households keeping poultry. ε is the error term and the index i denotes the *i-th* farm household. The coefficients $\delta_j (j = 1,2,...,8)$ and $\gamma_j (j = 1,2,...,10)$ are to be estimated. Equation (7) and Equation (8) are estimated by using the Tobit model. The variables are defined in the next section.

4. DATA AND VARIABLES

4.1. Data Set

This study employs the national household survey data, the so-called Lao Expenditure and Consumption Survey in 1997/98 (LECS 2) and 2002/03 (LECS3) conducted by the Department of Statistics (formerly: National Statistical Centre), Ministry of Planning and Investment and Swedish International Development Agency. It covers about 1 percent of the total population. The data were collected from March 1997 to February 1998 for LECS2 and from March 2002 to February 2003 for LECS3.

As mentioned in Section 1, the analysis puts emphasis on homogeneity of the households in terms of farming practices and on controlling for differences in regional and environmental conditions, and thereby applying data pooled at the district level. The districts included in the analysis are selected based on two criteria: (1) the district clearly belongs either to lowland or upland farming category (within a province the emphasis is put on districts with a larger sample size); and (2) the district should have a significant role in rice production, i.e. the selected districts should come from leading rice producing provinces in each category. There are three representatives of lowland farming areas (Xaythany, Hadsaifong, KaysonePhomvihane Districts) and three of upland farming areas (Bounneua, Xay, and Namor Districts) to ensure a balance of the two types of farming (Table 4).

Table 4: Composition of data

District (Province)	Obs.	Harvested Area (hectare)	Labor (persons)	Rice Output (kg)	Education (years of schooling)	Farm Experience (years)
LECS2 (1997/98)						
Lowland						
Xaythany (VTE)	37	1.67	2.9	3,160	6.1	30.0
Hadsaifong (VTE)	42	1.19	2.6	1,671	4.9	36.6
Kaysone Ph. (SVN)	36	1.82	3.4	2,519	5.1	30.3
Upland						
Bounneua (PSL)	58	1.05)	3.2	1,047	2.6	31.0
Xay (ODX)	59	1.21	3.4	1,775	4.3	31.3
Namor (ODX)	55	1.26	3.3	1,288	3.1	33.2
LECS3 (2002/03)						
Lowland						
Xaythany (VTE)	81	2.15	4.9	4,353	7.2	34.3
Hadsaifong (VTE)	28	1.09	4.6	3,138	6.9	32.9
Kaysone Ph. (SVN)	53	1.60	3.7	2,822	5.8	32.8)
Upland						
Bounneua (PSL)	38	0.88	4.6	2,275	2.6	31.8
Xay (ODX)	64	1.32	4.3	1,870	2.9	33.1
Namor (ODX)	28	1.14	4.5	1,953	2.0	34.5

Source: Authors compiled (data from National Statistical Center, LECS2 and LECS3).
Notes: 1. Figure in the table is average value. 2. VTE: Vientiane Capital. 3. SVN: Savannakhet Province. 4. PSL: Phongsaly Province. 5. ODX: Oudomxay Province. 6. Kaysone Phomvihane District is formerly named Khanthabouly District. 7. "Education" and "Farm experience" refer to education and farm experience of the HH head.

As can be observed, the samples in individual districts vary between 28 and 81. The sample size is comparable to many previous studies applying frontier analysis methodologies on farm level data (for example, Odeck, 2007; Latruffe et al., 2004; Wu et al., 2003; Ajibefun, 2008). One interesting feature in the table is that the average land size (harvested area) and farm labor are comparable among the districts under study, but the resulting rice output in lowlands is clearly exceeding that of uplands. Similarly, the education level of head of households in lowlands (more developed area) is on average higher than that of their counterparts in uplands (less developed areas), although farm experience does not differ much in both categories. The trends revealed from the observation appear to imply a positive association between farmer education and farm efficiency. Yet, a quantitative analysis is necessary to ascertain the claim.

4.2. Variable Definition

The application of empirical models and the choice of proxy variables for this study are mainly constrained by the availability of statistical data. The CRS- and VRS-models are applied with two factors of production and one output. The variables for the DEA and efficiency effect model (Specification 1 and 2) are defined in Table 5.

Table 5: Definition of variables

Variable	Definition/description
Variables for DEA (CRS-model, VRS-model)	
Output (Rice)	is rice output of each individual households in kilogram in 1997/98 and 2002/03;
Input 1 (T)	is the land for farming practices (harvested area in hectare) is used as it is considered to represent rice yield more precisely;
Input 2 (L)	is the total number of farmers engaged in rice farming.
Explanatory variables for efficiency effect equation	
dryland	is the dummy for dry land (1 if true, 0 if land is irrigated, partly or wholly);
buffalo	denotes the ownership of buffalo for farming (binary variable: 1 if farmers reported to own buffaloes, 0 other wise);
tractor	denotes the ownership of tractor – two-wheel or four-wheel vehicles – for farming (binary variable: 1 if farmers reported to own tractors, 0 other wise). In LECS2, *tractor* is applicable for lowland farming only, as tractors are not commonly used for upland farming practices. But in LECS3 it is applicable for both types of farming;
mktacc	is the dummy for market access of farmers (1 if farmers sold some products on the market, 0 other wise);
hhbiz	is the binary variable for household business (1 if a household has a business, 0 other wise);
hhsch	is a measure for the educational level of the household head defined as the year of schooling of the household head;
farmexp	denotes the farming experience of the household head, which and is defined as (age of HH head - years of schooling of HH head – 6);
farmexp2	is defined as (farmexp*farmexp)/100;
irracc	is the dummy for having access to irrigation facilities (1 if true);
spsch	is the number of years of schooling of spouse;
ethnic	is the dummy for households belong to non-Lao ethnic groups (1 if true);
poultry	is the dummy for households keeping poultry as livestock (1 if true).

The summary statistics from LECS2 (1997/1998) are presented in Table 6.The figures are the average of the three lowland districts (Xaythany, Hadsaifong, and Kaysone Phomvihane) and the three upland districts (Bounneua, Xay, and Namor), respectively. Similarly, Table 7 shows the summary statistics from LECS3 (2002/2003).

Table 6: Summary statistics of LECS2 (1997/98)

Farming area	Lowland farming		Upland farming	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Land (ha, harvested area)	1.54	1.05	1.17	0.57
Labor (persons)	2.95	1.57	3.28	1.61
Rice output (kilogram)	2,416	1,814	1,374	1,032
TE (technical efficiency)	0.42	0.24	0.40	0.21
dryland (dummy dry land)	0.51	0.50	0.57	0.50
buffalo (use of buffalo)	0.64	0.48	0.72	0.45
tractor (use of tractor)	0.15	0.36	-	-
mktacc (market access)	0.42	0.50	0.27	0.45
hhbiz (household business)	0.26	0.44	0.10	0.31
hhsch (HH school years)	5.33	3.32	3.33	3.44
farmexp (years)	32.52	12.87	31.80	12.24
Observation	115		172	

Source: Authors' calculations.

Data from LECS2 reveal that, on average, a lowland farm household produces more rice output (2,416 kg) than the upland counterpart (1,374 kg), while using somewhat less labor (2.95 persons vs. 3.28 persons). With respect to household head's characteristics, while having comparable age and farm experience (one-year difference), an average farmer in lowlands tends to stay two years longer in school (5.3 years) than her counterpart in

uplands (3.3 years). Other characteristics of farming, such as the use of irrigation facilities and buffaloes (and tractors for lowlands), do not differ from one another significantly. However, the commercialization of agricultural products is more developed in lowland areas as it is shown by a greater market access indicator (Table 6).

In the more recent survey (LECS3), more information on farming was collected and more variables can be created, such as schooling of spouse, ethnicity, and livestock-holding (Table 7). Similar to the previous case, compared to upland agriculture, an average lowland farm household utilized more farm land (1.77ha vs. 1.16ha) and produced more rice (3,585kg vs. 2,006kg), while employing about the same amount of labor (about 4.5 persons). Both lowland male and female farmers tend to stay 3-4 years longer in school than their upland counterparts, whereas farm experience of household head is comparable. Other characteristics of farming and markets, such as the use of tractor, market access, and household business are more developed in lowland areas. Another interesting feature of LECS3 is that it shows the ethnic diversity of the northern part of Lao PDR. Overall, farmers in Laos tend to keep some livestock, such as poultry or pigs, in the household for self-consumption or smoothing expenditure.

Table 7: Summary statistics of LECS3(2002/03)

Farming area	Lowland farming		Upland farming	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Land (ha, harvested area)	1.77	1.38	1.16	0.62
Labor (persons)	4.50	1.85	4.44	1.96
Rice output (kilogram)	3,585	3,860	2,006	1,186
TE (technical efficiency)	0.34	0.20	0.37	0.18
irracc (access to irrigation)	0.17	0.37	0.02	0.15
tractor (use of tractor)	0.32	0.47	0.14	0.35
mktacc (market access)	0.48	0.50	0.32	0.47
hhbiz (household business)	0.29	0.46	0.08	0.27
hhsch (school year of HH head)	6.66	4.09	2.61	3.02
farmexp (farm experience)	33.62	12.54	33.02	11.08
spsch (school year of spouse)	4.22	3.30	1.20	2.13
ethnic (non-Lao ethnics)	0.04	0.19	0.96	0.19
poultry (HH keeping poultry)	0.79	0.41	0.83	0.38
Observation	162		130	

Source: Authors' calculations.

5. EMPIRICAL RESULTS

5.1. Efficiency Performance

Table 8 summarizes the efficiency scores from DEA for constant returns to scale, variable returns to scale and scale efficiency(CRSTE, VRSTE, SE) for individual districts, and for lowland and upland areas for 1997/98 and 2002/03.In interpreting the DEA results it should be borne in mind that the average efficiency scores of individual districts are a relative measure and cannot be directly compared across districts, because they are calculated based on separate frontiers. In other words, the efficiency score of each household in one district is calculated relative to the production frontier constituted by the most efficient households (the reference group) in that respective district. Hence, the

average score is a measure of dispersion of the households in a district in terms of efficiency performance.

Table 8: Efficiency scores of Lao farmers (CRSTE, VRSTE, SE)

	Obs.	CRSTE Score		VRSTE Score		SE Score	
		Mean	Std. dev	Mean	Std. dev	Mean	Std. dev
LECS2 (1997/98)							
Xaythany (VTE)	37	0.504	0.229	0.580	0.261	0.885	0.133
Hadsaifong (VTE)	42	0.487	0.262	0.563	0.302	0.878	0.150
Kaysone Ph. (SVN)	36	0.476	0.280	0.549	0.317	0.891	0.139
Lowland average (one frontier)	*115*	*0.424*	*0.245*	*0.493*	*0.274*	*0.870*	*0.129*
Bounneua (PSL)	58	0.312	0.262	0.366	0.273	0.828	0.132
Xay (ODX)	59	0.400	0.269	0.437	0.294	0.929	0.102
Namor (ODX)	55	0.445	0.236	0.546	0.268	0.837	0.182
Upland average (one frontier)	*172*	*0.398*	*0.206*	*0.577*	*0.237*	*0.695*	*0.180*
LECS3 (2002/03)							
Xaythany (VTE)	81	0.515	0.213	0.604	0.246	0.874	0.149
Hadsaifong (VTE)	28	0.324	0.204	0.501	0.256	0.667	0.233
Kaysone Ph. (SVN)	53	0.406	0.221	0.546	0.247	0.746	0.189
Lowland average (one frontier)	*162*	*0.342*	*0.204*	*0.468*	*0.242*	*0.729*	*0.171*
Bounneua (PSL)	38	0.656	0.227	0.722	0.236	0.909	0.082
Xay (ODX)	64	0.440	0.189	0.561	0.211	0.801	0.185
Namor (ODX)	28	0.623	0.248	0.704	0.229	0.872	0.121
Upland average (one frontier)	*130*	*0.370*	*0.180*	*0.492*	*0.211*	*0.768*	*0.200*

Source: Authors' calculations.

Notes: 1. Abbreviations: CRS-TE denotes constant returns to scale technical efficiency; VRS-TE represents variable returns to scale technical efficiency; and SE stands for scale efficiency. 2. For the average of 'upland farming' and 'lowland farming', the TE score of individual households has been recalculated under a new frontier using the pooled data of the respective districts (it is not the simple average of the three districts in each category). 3. Refer to notes in Table 4 for abbreviation of province names.

Three interesting trends can be drawn from the DEA results. First, during 1997/98 farm households in Xaythany district have achieved, in relative terms, the lowest efficiency dispersion (highest CRSTE and VRSTE), while those in Bounneua district are the most widespread (lowest CRSTE and VRSTE) among the six districts studied. However, the trend reverse during 2002/03, in which farmers in Bounneua district have achieved the lowest efficiency dispersion, whereas farm households in Hadsaifong district turn out to be the most scattered. Second, with respect to farm size, most of farm households in Xay district appear to have achieved an optimal scale (highest SE) for 1997/98, whereas most farms in Bounneua district have attained that status in 2002/03 (highest SE). Third, the DEA using a grand frontier and pooled data for lowlands and uplands reveals that the degree of technical efficiency dispersion among farm households in lowland and upland areas has increased (CRSTE and VRSTE decrease between 1997/98 and 2002/03), and that farm households in lowlands are more widespread than those in uplands in the later period (average SE score in 2002/03 for lowlands is 0.73 and for uplands 0.77).

There are three likely explanations for the above results. First, the relatively lower average CRSTE and VRSTE scores of the three upland districts during 1997/98 imply that the gap between the best performing households and the remaining are relatively large. This would reflect the differences in capabilities and skills among farmers that could have a significant impact on farming practices and output. Furthermore, the capability differences and the associated efficiency gap might have resulted from the educational background of farmers in accessing and absorbing new farming practices, and/or from the land reform and resettlement policies of the government implemented in the 1990s aimed

at eliminating slash-and-burn agriculture and stimulating sedentary farming in the Northern provinces. However, a proof of its existing and the degree of any policy impact in the study areas would require further detailed investigation and is beyond the scope of the paper. Second, the use of two inputs for DEA would exert some effect on the resulting efficiency scores of individual households. Derived from our experience in DEA application, the larger the number of inputs, the higher is the average efficiency score in a sample (for example, Matsunaga and Vixathep, 2011; Vixathep and Matsunaga, 2012). Finally, the relatively higher SE scores, as compared to CRSTE and VRSTE regardless of time period, are most likely attributable to a high degree of homogeneity among the samples in terms of household members, because the household data for the analysis are pooled by district.

Table 9: Efficiency scores of Lao farmers (DRS, CRS, IRS)

	Obs.	CRSTE Score		Returns to Scale		
		Mean	Std. dev	DRS	CRS	IRS
LECS2 (1997/98)						
Xaythany (VTE)	37	0.504	0.229	31(83.8)	3(8.1)	3(8.1)
Hadsaifong (VTE)	42	0.487	0.262	11(26.2)	19(45.2)	12(28.6)
Kaysone Ph. (SVN)	36	0.476	0.280	27(75.0)	2(5.6)	7(19.4)
Lowland average (one frontier)	*115*	*0.424*	*0.245*	73(63.5)	*5(4.4)*	*37(32.2)*
Bounneua (PSL)	58	0.312	0.262	45(77.6)	10(17.2)	3(5.2)
Xay (ODX)	59	0.400	0.269	40(67.8)	14(23.7)	5(8.5)
Namor (ODX)	55	0.445	0.236	48(87.3)	5(9.1)	2(3.6)
Upland average (one frontier)	*172*	*0.398*	*0.206*	147(85.5)	*21(12.2)*	*4(2.3)*
LECS3 (2002/03)						
Xaythany (VTE)	81	0.515	0.213	57(70.4)	4(4.9)	20(24.7)
Hadsaifong (VTE)	28	0.324	0.204	22(78.6)	3(10.7)	3(10.7)
Kaysone Ph. (SVN)	53	0.406	0.221	41(77.4)	10(18.9)	2(3.8)
Lowland average (one frontier)	*162*	*0.342*	*0.204*	134(82.7)	*23(14.2)*	*5(3.1)*
Bounneua (PSL)	38	0.656	0.227	26(68.4)	4(10.5)	8(21.1)
Xay (ODX)	64	0.440	0.189	46(71.9)	3(4.7)	15(23.4)
Namor (ODX)	28	0.623	0.248	22(78.6)	6(21.4)	0(0.0)
Upland average (one frontier)	*130*	*0.370*	*0.180*	99(76.2)	*28(21.5)*	*3(2.3)*

Source: Authors' calculations.

Notes: Abbreviations: DRS denotes decreasing returns to scale; CRS stands for constant returns to scale; and IRS represents increasing returns to scale. 2. Column 4-6: number of firms with corresponding returns to scale is presented. Percentage share is in parentheses. 3. Refer to notes in Table 4 for abbreviation of province names. 4. See notes in Table 8 for more detail on lowland and upland average.

In addition to constant and variable returns to scale, Table 9 presents the number and percentage share of farm households with decreasing, constant and increasing returns to scale (DRS, CRS, IRS). A higher share of farms with DRS reveals that farm households in Laos tend to face decreasing returns to scale and that this trend has not changed since the mid-1990s (Column 4-6). This result would imply that the current farm practices in Laos are not yet efficient, because in spite of having low yields, increasing production inputs, such as land and/or labor, would not lead to a higher efficiency level in most cases. The issue of low efficiency/productivity is generally recognized and efforts have been made by various stakeholders to improve farm practices, yields and productivity in the country. Moreover, despite the fact that the analysis in this paper relies on observations at a disaggregated level, any analysis on farm production in Laos assuming CRS should be conducted with caution, as this assumption might not hold.

5.2. Farmer Education and Experience

In order to empirically evaluate the effects of famer education and experience, household characteristics and other determinants on farm efficiency, Equation (7) and Equation (8) are estimated by using a Tobit model (Table 10). The result suggests that in the mid-1990s farmer education contributes to efficiency enhancement in both lowlands and uplands,as shown by a positive significant coefficient in four of sixdistricts.Overall, the result on farmer education is consistent with previous studies regardless of methodologies employed (for example, Parikh et al. (1995) for Pakistan and Coelli and Battese (1996) for India). Of particular interest is a comparison with the analysisfor Laos at a more aggregate level (geographical region/countrywide), which applieda different estimation method andvarious proxies for farmer education to the same LECS2 dataset (Onphanhdala, 2009). Although the analysis in this study is limited to schooling years of household head (due to the use of data at the district level), the result found in this study lends strong support to the finding of positive education impact on rice production in Lao PDR.

On the other hand, the impact of farmer educationseems to lessen and disappear in the early 2000s, as the education coefficient is statistically insignificantin all districtsand negative in two upland districts (Xay, Namor) for LECS3. This result could be explained bytwo reasons. First, upon a period of learning-by-doing the skill level and experience of farmers would have become more comparable and offset the education impact. Particularly, this process is more likely for farmers living in the same district in lowlands, where information exchanges and spillovers can occur within a short period of time. Second,most of the farmers in the multi-ethnic uplands would spend much time in school to learn reading and writing (Lao language), and numeracy at the primary level. Their skill levels would be likely comparable, despite differences in schooling years. In sum, the homogeneity of the samplesat the district level (disaggregate level) appears to have suppressed the positive impact of farmer education found for the whole country (aggregate level) in Onphanhdala (2010).

Similarly, the negative estimate for spouse's education in LECS3 indicates that technical efficiency of farm households would not improve as farmers' spouses have more education. A plausible explanation for this result is that spouses with more education tend to engage in non-farm activities, such as trading, keeping small shops at home, selling products at markets, rather than just helping their husbands on the fields.

A significant contribution of this study is the comparative analysis of education impact on farm efficiency at the district level. Among the four significant cases in 1997/98 the magnitude for Hadsaifong district (lowland, Vientiane Capital) is larger than that of other districts. This could be attributable to the existence of many market conditions, such as market access and information, in which farmers with higher education could take more advantage in production and marketing of their products. Located at the outskirt of the capital city, farmers in Hadsaifong district would be able to capitalize on the proximity to a large market to sell their agricultural products and to absorb new development in agricultural production technologies, which would in turn lead to efficiency improvement in their farming practices. A significant contribution of irrigation schemesin this district also lends support to this argument, as irrigated land (partly or wholly) appears to be associated with higher efficiency than dry land (not irrigated land) (Table 10).

With respect to farm experience, the insignificance or negative significance of any coefficient estimate would imply that production technologies are relatively primitive or spillovers are relatively strong. In the Lao context the former would be more persuasive than the latter, as the majority of farmers are engaged in subsistence farming for self-consumption. In addition, the homogeneity of the samples would give rise to such a result, i.e. most of the farmers in the samples tend to have comparable experience in farming (see Table 4, column 6).

5.3. Farm and Household Characteristics

In this paper, production or farming characteristics include such conditions as access to irrigation (dry or irrigated land), the use of conventional factor of production (buffalo) and modern equipment in lowland areas (tractor), and holding livestock (poultry), while household characteristic implies the ethnicity. The result in Table 10reveals that owning buffaloes and tractors has not contributed to efficiency augmentation. Moreover, the estimate for access to irrigation facilities is largely insignificant except for Hadsaifong and Bounneua district. This would imply that the use of irrigation facilities does not improve farming in many districts in both lowland and upland areas. This result is not inconsistent with that of previous studies for Laos and other developing countries. For example, Wadud and White (1997) found that diesel-operated irrigation schemes in Bangladesh increased inefficiency.

Similarly, in Lao PDR public investment in the past tended to focus on large-scale infrastructure development projects, but the irrigation schemes were rather poorly maintained and do not seem to contribute to efficiency improvement. Only a very limited portion of farmers could benefit from the irrigation schemes in the dry season. Specifically, the absence of the impact of irrigation systems is argued to be a consequence of poor design and construction, inadequate scale and poor maintenance (Onphanhdala 2009, 2010). Therefore, it can be concluded that the characteristics and the use of agricultural infrastructure across countries is one of the key factors for differences in analysis results and that a more detailed study on the irrigation schemes and their usage would undoubtedly shed more light on this issue.

Two other interesting features of farm households are the ethnicity and livestock holdings of farmers, which are only available in LECS3 for 2002/03. The coefficients for both variables are mixed without any clear trend across the districts. The result implies that both Lao and non-Lao ethnic households are comparable in farming, and that households keeping poultry and those without livestock are of the same efficiency level. In particular, it appears that the coefficient for ethnicity tends to favor the majority ethnic group in a district (for example, negative significant for Xaythany district, but positive significant for Xay district). This is most likely caused by a distortion in data composition in the respective districts. Therefore, under such circumstances it would be more appropriate to address this issue at a more aggregate level in favor of a more balanced and larger sample size, and reliability of the result.

5.4. Market Access

The third group of determinants addressed in this study is related to market conditions and market access. The coefficient estimate for "household business" is significant only for Bounneua and Xay districts in the North, and implies an absence of impact of such an off-

farm activity. There are two likely explanations for this result: the one reason is that most of the rice output of farm households is for self-consumption and little is in excess for selling, and the other reason is that the members of farm households are engaged in businesses unrelated to farming and thereby simply drawing labor away from farming activities.

On the other hand, the analysis reveals an interesting trend for "market access". The estimate is positive significant for all three lowland-districts and one upland-district.Xaythany and Hadsaifong districts are located in Vientiane Capital, while Kaysone Phomvihane and Xay districts are provincial capitals. They are relatively more developed than the other two (Bounneua and Namor) in many aspects, including trade and market institutions. Hence, farmers in these districts would have good opportunities to sell their agricultural products and receive information from the markets. This would encourage them to produce more rice for consumption and marketing/selling. In addition, recently there is an upward trend in demand for agricultural products from China, which has partly led to increased Chinese investment in the agricultural sector in Laos, particularly the northern part of the country. Even in some rural villages in Oudomxay Province Chinese investment and other developments appear to have triggered agricultural transformation to market-oriented farming, and contributed to uneven development and income gaps among households and villages in the initial stage of development (Onphanhdala and Suruga, forthcoming). Hence, in such circumstances market access would reflect vibrant economic activities and the development in market institution, and thereby contribute to output increase and efficiency enhancement.

Table 10: Determinants of technical efficiency in lowland and upland farming (Tobit model)

Lowland farming	LECS2 (1997/98)						LECS3 (2002/03)					
dependent variable:	Xaythany		Hadsaifong		Kaysone Phomvihane		Xaythany		Hadsaifong		Kaysone Phomvihane	
Technical Efficiency	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Dry land	-0.036	0.099	-0.240**	0.092	-0.198	0.138	-		-		-	
Own buffalo	-0.020	0.102	0.014	0.075	0.086	0.150	-		-		-	
Own tractor	0.056	0.125	0.062	0.101	-0.156	0.143	0.133***	0.045	-0.188*	0.108	-0.109	0.089
Market access	0.142	0.091	0.257***	0.090	0.200*	0.113	0.083*	0.044	-0.090	0.061	0.058	0.066
HH business	0.041	0.094	0.118	0.092	-0.065	0.119	0.033	0.043	0.161	0.121	0.051	0.079
HH head's schooling	0.015	0.015	0.037**	0.017	-0.009	0.019	0.000	0.007	0.010	0.010	0.015	0.011
Farm experience	0.006	0.020	-0.017	0.020	0.006	0.015	-0.010	0.008	-0.038**	0.014	-0.009	0.014
Farm experience squared	-0.009	0.031	0.027	0.024	-0.013	0.021	0.012	0.011	0.051**	0.019	0.012	0.017
Access to irrigation scheme	-		-		-		-0.039	0.051	0.262***	0.073	n.a.	
Spouse's schooling	-		-		-		-0.002	0.008	-0.016	0.012	-0.016	0.011
Ethnicity	-		-		-		-0.261***	0.098	n.a.		-0.133	0.169
Own livestock (poultry)	-		-		-		0.172***	0.057	0.010	0.062	0.172	0.102
Constant	0.256	0.333	0.491	0.393	0.536*	0.276	0.445**	0.168	0.908***	0.288	0.375	0.31
Observations	37		42		36		81		28		53	
Log-likelihood	1.147		-2.556		-5.092		18.107		15.586		3.748	
Upland farming	Bounneua		Xay		Namor		Bounneua		Xay		Namor	
	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Dry land	-0.187***	0.065	-0.013	0.064	0.058	0.066	-		-		-	
Own buffalo	-0.037	0.062	-0.064	0.072	0.100	0.077	-		-		-	
Own tractor	n.a.		0.000	0.252	-0.185	0.116	0.163	0.118	0.113*	0.067	-0.055	0.256
Market access	0.108	0.079	0.287***	0.065	0.107	0.076	-0.163	0.097	-0.036	0.056	-0.039	0.107
HH business	0.324*	0.169	-0.008	0.081	-0.180	0.124	0.584***	0.200	0.431**	0.186	-0.072	0.107
HH head's schooling	0.022**	0.010	0.024**	0.010	0.027**	0.012	0.001	0.019	-0.008	0.010	-0.016	0.017
Farm experience	0.004	0.014	-0.005	0.014	-0.018	0.013	0.022	0.031	-0.006	0.009	-0.105***	0.027
Farm experience squared	-0.007	0.021	0.006	0.022	0.027	0.018	-0.032	0.043	0.008	0.012	0.133***	0.036
Access to irrigation scheme	-		-		-		n.a.		-0.227*	0.130	-0.153	0.217
Spouse's schooling	-		-		-		-0.038*	0.020	-0.010	0.021	-0.035	0.033
Ethnicity	-		-		-		-0.034	0.209	0.191*	0.097	n.a.	
Own livestock (poultry)	-		-		-		0.174	0.228	0.145***	0.063	-0.064	0.097
Constant	0.341	0.221	0.337	0.237	0.489**	0.242	0.269	0.696	0.275	0.191	2.673***	0.472
Observations	58		59		55		38		64		28	
Log-likelihood	5.087		-0.809		2.044		4.257		20.318		1.636	

Source: Authors' calculations.

Notes: (1) *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. (2) 'n.a.' denotes that data are not available or applicable for the respective variable.

6. CONCLUDING REMARKS

The education levels in Lao PDR are still low, particularly for farmers in more remote areas and in the northern part of the country. This seems to have a significant impact on efficiency and productivity in the agricultural sector. On the whole, subsistence farming and shifting cultivation with low inputs and low yields are still widespread, although the country has abundant fertile arable land. In view of addressing the issues of farmer education and farm efficiency, the study assesses the efficiency level of farm households and evaluates factors affecting farm efficiency. The analysis applies a two-stage DEA-Tobit model to household data of uplands and lowlands for 1997/98 and 2002/03.

The study reveals some important findings. First, education at the grass-roots levels is essential for enhancing efficiency and productivity in agriculture. Second, in the more urbanized lowland areas with sedentary farmers efficiency spillovers are more significant, while the resettlement and adaptation process to new conditions has led to large efficiency discrepancies among displaced farmers. Third, development in agricultural infrastructure is crucial for efficiency improvement, but the on-going investment, utilization, management and maintenance of irrigation schemes are still far from effective. Fourth, market institution-related development is essential for progress in the Lao agricultural sector. Particularly, the Northern Laos located next to the giant market in China with increasing demand for agricultural products would have massive opportunities for rapid development in future. However, farmers in this region would have to improve their knowledge, skills and farm efficiency, in order to meet the customers' requirements and materialize these opportunities.

The findings show that there is still much room for efficiency improvement, particularly by means of education development at the grass-roots levels and institutional development for enabling market conditions. This consequently raises the need for the government to focus on improving farmer education, linking agricultural production to markets (commercial farming), and strengthening and streamlining public expenditures on the agricultural sector. Of particular note, the principal policy implications of the findings in this study pertain to the potential social and economic benefits of improving education at the grass-roots level in rural areas.

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