



**Asian Journal of Agricultural Extension,  
Economics & Sociology**  
3(1): 37-49, 2014; Article no. AJAEES.2014.004



SCIENCEDOMAIN *international*  
[www.sciencedomain.org](http://www.sciencedomain.org)

---

## **Factors Affecting Technical Efficiency of Small-holder Coffee Farming in the Krong Ana Watershed, Vietnam**

**Thong Quoc Ho<sup>1</sup>, John F. Yanagida<sup>2</sup> and Prabodh Illukpitiya<sup>3\*</sup>**

<sup>1</sup>*Department of Economics, Tay Nguyen University, Vietnam. 567 Le Duan, Buon Ma Thuot, DakLak, Vietnam.*

<sup>2</sup>*Department of Natural Resources and Environmental Management, University of Hawai'i at Manoa, 1910 East-West Road, Honolulu, HI 96822, USA.*

<sup>3</sup>*Department of Agricultural and Environmental Sciences, Tennessee State University, 3500 John A. Merritt Blvd, Nashville TN 37209, USA.*

### **Authors' contributions**

*This research was part of author TQH's M.S. thesis. Authors JFY and PI were members of his thesis committee. All authors read and approved the final manuscript.*

**Original Research Article**

**Received 27<sup>th</sup> August 2013**  
**Accepted 12<sup>th</sup> November 2013**  
**Published 13<sup>th</sup> December 2013**

---

### **ABSTRACT**

Coffee production is a major source of income for farmers in the DakLak province in Vietnam. Although Vietnam is one of the largest coffee producers in the world, research to improve the coffee industry is lacking, in particular, evaluating production efficiency in coffee farming could highlight factors that improve technical efficiency. The overall objective of this study is to estimate the technical efficiency of coffee production and determine which factors affect technical efficiency of small holder coffee farmers in the Krong Ana Watershed of the DakLak province. Based on the stochastic production frontier, the estimated mean technical efficiency scores were 0.7466 and 0.6836 respectively for the Cu Kuin district and the three combined districts (Krong Ana, Krong Bong and Lak). Formal education of the household head, amount of financial credit obtained, ethnicity, coffee farming experience of the household head, and agricultural extension service used were key factors that can increase technical efficiency in coffee production.

---

\*Corresponding author: E-mail: [pillukpi@tnstate.edu](mailto:pillukpi@tnstate.edu);

*Keywords: Coffee production; Krong Ana watershed; technical efficiency; stochastic production frontier.*

## 1. INTRODUCTION

Coffee farming was first introduced to Vietnam by the French in the 1850's; however, following that introduction, coffee production remained relatively low. It was not until after the country's re-unification in 1975 and implementation of the national policy, involving setting "new economic zones" in the Central Highlands, that migrants from across the country began settling in the Central Highlands to establish coffee production in this area. After this occurrence, Vietnamese coffee production increased significantly and Vietnam soon became the fourth largest coffee exporter in the world in 1998 with a share of approximately 6.5% of the world's coffee production [1]. This share continued to increase in subsequent years contributing 12.4% of the world's coffee production in crop year 2008/09 [2]. According to the International Coffee Organization (ICO), Vietnam had become the second largest coffee producer worldwide trailing only Brazil in the 2000/01 to 2008/09 period.

Coffee is the primary export crop for Vietnamese agriculture and plays an important role in the country's economy. This is especially true for the Central Highlands of Vietnam and its role in the world coffee market. The DakLak province has been the largest coffee producing province in Vietnam in terms of both coffee yield and planted area. Agricultural production in this province has been dominated by coffee production [3]. The Krong Ana watershed, known for its large coffee plantations, lies along the Krong Ana River and includes parts of the Krong Bong, Lak, Cu Kuin, and Krong Ana districts within the DakLak province.

A number of studies have examined input factors affecting agricultural production e.g., [4,5,6,7]. More specifically, labor in person-days, fertilizers in physical units and pesticide costs were considered as input factors for the coffee production function [7]. Similar factors were evaluated for small food crop production in Nigeria [8]. In addition, labor, and inorganic and organic fertilizers were primary input factors for paddy production in Sri Lanka [9]. These factors were also employed for Chinese farms and also by other studies [10] (see [5,11,12]). Irrigation is another key factor, influencing coffee production. However, previous studies suggest conflicting optimal strategies with varied water application amounts (see: [13,14]).

Following a benchmark study in 1957, a plethora of empirical studies have evaluated production efficiency [15]. Many studies highlighted effects of common socio-economic variables such as age, education, experience, gender, etc. on technical efficiency (see [5,9,16–18]).

The educational level of the household head, commonly is positively related to the technical efficiency (see for example, [5,7,9,19]). Access to credit positively and significantly affects technical efficiency of coffee production in Cameroon [7] (also see: [8,12]). Educational level, experience, age of the household head, and extension contacts, had positive and significant impacts on technical efficiency [9] (also see: [5] and [20]).

Agricultural production and farm specific characteristics vary amongst different ethnic households. In Vietnam, resource-richer households belong to the Kinh majority, while the ethnic minority is usually unable to participate in production activities involving high investment costs and encounters more difficulties in obtaining credit and loans [21]. Young people or children may not contribute to agricultural production activities because they are likely to be in school. Thus, the ratio of the number of children to family size can represent

the household's child dependency index that may affect technical efficiency of agricultural production [22].

Improving technical efficiency can result not only in efficient use of inputs or production resources, but also to increases in coffee production and subsequently, higher profits from coffee farming. For the major agricultural production activity in the DakLak province, improving technical efficiency in coffee production can have positive impacts on other business activities in the province. The objectives of this study are three-fold:(1) Estimate technical efficiency in coffee farming utilizing the stochastic production frontier methodology; (2) Identify factors contributing to technical efficiency in coffee production, and (3) Evaluate the economic effects from increasing (decreasing) technical efficiency.

## 2. METHODOLOGY AND DATA SPECIFICATION

### 2.1 Theoretical Model

Since the seminal article on efficiency measurement [15], the basic stochastic frontier model was independently proposed (see [16] and [23]). The efficient frontier can be considered as either the maximum level of output for a given set of inputs (an output orientation), or the minimum set of inputs required to produce a given set of output (an input orientation) [24].

A single-stage approach in which explanatory variables are incorporated directly into the inefficiency error component was adopted(see: [25,26,4,21]). For this method, the variance of the inefficiency error component is hypothesized to be a function of firm specific factors. For this study, the following production model was chosen (see [18]):

$$y_i = f(x_{ij}; \beta_j) \cdot \exp\{V_i - U_i\} \quad (\text{Eq.1})$$

Where  $y_i$  is the production of the  $i$ -th firm,  $i = 1, \dots, n$ ;  $x_{ij}$  is a vector of  $j$  inputs,  $j = 1 \dots m$  used by the  $i$ -th firm;  $\beta_j$  is a vector of parameters to be estimated; the random error,  $V_i$  captures the effects of statistical noise, which are assumed to be independently and identically distributed as  $N(0, \sigma_v^2)$ ;  $U_i$  are non-negative random variables, associated with technical efficiency in production, which are assumed to be independently and identically distributed exponential or half-normal variable [ $U_i \sim (|N(0, \sigma_u^2)|)$ ]. The deterministic production function is written as:  $f(x_i; \beta)$ , while  $[f(x_{ij}; \beta_j) \cdot \exp\{v_{ij}\}]$  is the stochastic production frontier. Both exponential and half-normal distributions have been criticized for arbitrarily restricting the mean of technical efficiency effects to zero and related consequences for estimated technical efficiency levels. A few authors have proposed alternative specifications for the technical efficiency effects (see [27], and [18]). Although there is generally no *priori* justification for the choice of any particular distributional form for the technical inefficiency effects, the generalized truncated-normal distribution has been most frequently applied in empirical applications due to its computational simplicity. The model to measure technical inefficiency effects proposed by Battese & Coelli [18] has become quite popular because of its computational ease as well as its ability to examine the effects of various firm-specific variables on technical efficiency in an econometrically consistent manner, as opposed to the two-step approach [28]. A study estimates variance parameters in terms of:  $\sigma_s^2 = \sigma_v^2 + \sigma_u^2$  and the parameter,  $\gamma = \sigma_u^2 / \sigma_s^2$ , which takes on a value between zero and one [18].

Technical efficiency is defined as the ratio of observed output to the maximum feasible output in an environment characterized by  $\exp \{V_i\}$ . Technical efficiency of the  $i^{\text{th}}$  producer can be described as:

$$TE_i = \frac{y_i}{f(x_{ij}; \beta_j) \cdot \exp\{V_i\}} = \exp(-u_i) \quad (\text{Eq.2})$$

Where  $u_i$  are the non-negative random variables, called technical inefficiency effects. These  $u_i$  are assumed to be independently distributed and defined by the truncated normal distribution, with mean,  $\mu_i$ , and variance  $\sigma_u^2$ .  $u_i$  is defined by:

$$u_i = Z_i \delta + W_i \quad (\text{Eq.3})$$

where,  $W_i$  for  $i = 1, \dots, n$  are random errors, defined by the truncation of the normal distribution with mean zero and variance,  $\sigma_u^2$ . The point of truncation is  $-Z_i \delta$  i.e.,  $W_i \geq -Z_i \delta$ . The  $Z_i$ s are the firm-specific variables which may also include input variables in the stochastic production frontier, provided that the technical inefficiency effects are stochastic.

## 2.2 Data Sources

A questionnaire was developed to gather both farm level coffee production data as well as household demographic information for the 2008/9 crop year in the research site consisting of 4 districts, namely, Cu Kuin, Krong Ana, Krong Bong, and Lak, in DakLak province, Vietnam, which lies in the Krong Ana watershed. The method of data collection adopted was personal interviews with a sample size of 198 coffee farms [29]. A pre-test survey of 48 coffee farms in the research site was conducted. In the case of missing data, the actual sample size accounted for this possibility by including an additional 10% of coffee farms. The total number of farms in the sample was 203, but there were 5 farms with missing data. Thus, the total observed farms were 198. This consisted of 103, 70, 14, and 11 farms in the Cu Kuin, Krong Ana, Krong Bong and Lak districts respectively. Each district is considered as a stratum, the sub-sample size of each stratum was equal to the total sample size multiplied by the proportion of population of each stratum in the 4 strata. However, the total number of farms in the 4 strata was not available. Thus, this proportion was replaced by the proportion of coffee planting area in each stratum. Total coffee planting area was 21,865 hectares in which Cu Kuin accounted for about 51% and Krong Ana, Lak and Krong Bong comprised 36%, 5% and 7% respectively [36].

A likely question for this study is whether the independent variables have different impacts for different districts of the population. If differences exist then the data for all districts cannot be pooled into one sample. To answer this question, the Chow test was performed to test the equivalence of the two regressions. The results of the Chow test suggested that the sample should be split (Cu Kuin and the other districts). Accordingly, two separate regression models were specified for Cu Kuin and the three other districts.

Common problems with regression estimation are multicollinearity and heteroskedasticity (especially in the case of spatial analysis). See [30] for more information about the results from multicollinearity and heteroskedasticity testing. For both types of violations, the test results confirm the absence of these problems.

## 2.3 Empirical Models

Many empirical studies have employed the log model to examine technical efficiency in agricultural production (for example: [19] and [22]). The stochastic frontier coffee production function for this study is specified as:

$$\ln y_i = \beta_0 + \sum_{j=1}^6 \beta_j \ln x_{ij} + V_i - U_i \quad (\text{Eq.4})$$

Where subscript  $i$  refers to the  $i$ -th coffee farm in the sample;  $\ln$  denotes natural logarithms;  $y$  is coffee yield (tons per hectare) and  $x_j$  are input variables per hectare ( $j = 1, 2 \dots 6$ ) defined as:  $x_1$  is labor (man-days),  $x_2$  is cost of inorganic fertilizer (million VNDs),  $x_3$  is cost of organic fertilizer (million VNDs),  $x_4$  is cost of pesticide (million VNDs),  $x_5$  is amount of water applied (thousand cubic meters) and  $x_6$  is age of coffee trees (in years);  $\beta_s$  are parameters to be estimated;  $V_s$  are iid  $N(0, \sigma_v^2)$  random variables;  $U_s$  are independently distributed ( $|N(Z\delta, \sigma_u^2)$ ) technical inefficiency effects, which are, following [18], further defined as follows:

$$U_i = \delta_0 + \sum_{m=1}^7 \delta_m Z_{mi} + W_i \quad (\text{Eq.5})$$

Where the  $Z$ s represent farm-specific variables defined as:  $Z_1$  is age of household head (years),  $Z_2$  is number of years of household head,  $Z_3$  represents ethnicity of household head (if Vietnamese Kinh = 1 or otherwise 0),  $Z_4$  represents extension services (yes = 1 or otherwise 0),  $Z_5$  is amount of formal credit (million VNDs),  $Z_6$  is number of years of experience in coffee farming by household head, and  $Z_7$  is child dependency index (number of children divided by family size);  $\delta_s$  are unknown parameters to be estimated; and  $W_i$  is a random variable as defined in Equation 5.

The parameters for the stochastic production frontier model in Equation 4 and those for the technical inefficiency model in Equation 5 were also simultaneously estimated by employing the maximum-likelihood estimation (MLE) program, FRONTIER 4.1 [31]. Cobb-Douglas production models are a popular choice in farm-firm production analyses. This algebraic form provides an adequate fit of the data and the estimation coefficients can be interpreted as output elasticities.

## 3. RESULTS AND DISCUSSION

### 3.1 Analyses of Maximum Likelihood Estimates

The maximum-likelihood parameter estimates for the stochastic production frontier model and those for the technical efficiency model for coffee production in the Cu Kuin district and the combined districts are described in Table 1. The  $\gamma$ -parameter associated with the variances in the stochastic production frontiers for the Cu Kuin model and the combined districts model are estimated to be 0.9999 and 0.8041 respectively. Although the  $\gamma$ -parameter cannot be interpreted as the proportion of the total variance explained by technical efficiency effects, the relative contribution of the efficiency effects to the total variance term ( $\gamma^*$ ) are calculated based on the  $\gamma$ -parameter. The relative contributions are 99.99% and 59.84% for the Cu Kuin model and the three districts model respectively. This means that almost 100% of the variance for the total residual is explained by the inefficiency effects for the Cu Kuin model and approximately 60% of the variance for the combined districts model.

A likelihood ratio test was performed to test the null hypothesis whether a Cobb- Douglas stochastic production function or the traditional average production function (OLS) should be chosen for this study. The null hypothesis assumes all parameters in the stochastic production function are zero. The likelihood ratio test results are 72.16 and 5.14 for the Cu Kuin model and the combined districts model respectively. Both values exceed the critical Chi-square value of 2.71 at the 95% confidence level. Thus, the traditional average production function is not an appropriate representation of the sample data which is similar with many other empirical studies (see: [6–9]).

**Table 1. MLE of stochastic production frontier and technical inefficiency models**

Label	Para-meter	Coeff- icient	Cu Kuin district		Three combined districts		
			S.E	t-ratio	Coeff- icient	S.E	t-ratio
<b>Production frontier</b>							
Constant	$\beta_0$	-0.1991	-0.4129	0.4822	-0.5168	-0.5616	0.9203
Ln (Labor)	$\beta_1$	0.1094	0.0730	1.4991	0.1872	0.0985	1.9009*
Ln (Inorf)	$\beta_2$	0.0729	0.0515	1.4148	0.1741	0.0496	3.5056**
Ln (Orf)	$\beta_3$	0.0105	0.0026	3.9834**	0.0071	0.0025	2.8482**
Ln (Pes)	$\beta_4$	0.1294	0.0417	3.1023**	0.0018	0.0043	0.4159
Ln (Water)	$\beta_5$	0.3157	0.1003	3.1466**	0.0232	0.0983	0.2358
Ln (Cfage)	$\beta_6$	0.2359	0.0657	3.5923**	0.1320	0.0684	1.9290**
<b>Technical inefficiency model</b>							
Constant	$\delta_0$	0.1204	0.2907	0.4143	1.0200	0.3329	3.0640**
AgeHH	$\delta_1$	-0.0007	0.0071	-0.0929	-0.0019	0.0039	-0.4771
Edu	$\delta_2$	-0.0137	0.0100	-1.3639	-0.0349	0.0174	-2.0098**
Eth	$\delta_3$	0.1463	0.0762	1.9208**	-0.2945	0.1316	-2.2382**
Ext	$\delta_4$	-0.0991	0.0477	-2.0794**	0.0598	0.0637	0.9389
Cre	$\delta_5$	0.0010	0.0017	0.5544	-0.0049	0.0024	-2.0344**
Exp	$\delta_6$	0.0106	0.0089	1.1936	-0.0223	0.0101	-2.2065**
Cdpindex	$\delta_7$	0.5975	0.1116	5.3537**	0.9458	0.3470	2.7258**
<b>Variance of parameters</b>							
sigma-squared	$\sigma^2$	0.0179	0.0034	5.18**	0.0753	0.0170	4.44**
Gamma	$\gamma$	0.9999	0.0063	159.23**	0.8041	0.1378	5.83**
Log (likelihood)		72.1552			5.1341		
Mean of exp (Ui)		0.7466			0.6876		

\* Significant at 10% level;

\*\* Significant at 5% level.

The second test examines the null hypothesis that technical inefficiency effects are not present, i.e.,  $H_0: \gamma = 0$ . This null hypothesis was rejected on statistical grounds for both models (Cu Kuin and the three districts). The former results confirm the stochastic nature of coffee production in the study sites.

## 3.2 Stochastic Production Frontier

### 3.2.1 Factors affecting coffee yield

As expected, the slope coefficients of the stochastic production frontier for both Cu Kuin and the three combined districts models were positive. For the Cu Kuin district model, labor and inorganic fertilizer had insignificant effects while for the combined districts model, pesticide and the amount of water applied were insignificant. In the case of labor and inorganic

fertilizer, variability in usage of these inputs (e.g., standard deviation and/or coefficient of variation) is higher in the three combined districts model than the Cu Kuin model. For labor, this variability can probably be explained by the more difficult topographic conditions in the combined districts requiring more labor in coffee production. Farmers in the combined districts tend to spend more on fertilizers than the Cu Kuin district because of lower soil quality.

On the other hand, the models' results for pesticides and irrigation water application are not easily interpreted. Perhaps, the higher density of coffee plantations in Cu Kuin may enable farmers to better control the spread of pests than in the three combined districts. In the case of irrigation, the average amount of water applied in the Cu Kuin district is significantly higher than that in the three combined districts. Lack of rainfall data makes explanation of these irrigation differences difficult to explain. The result from previous studies of the effect of irrigation water on coffee yield was also different (see: [13,14]).

### **3.2.2 Cost- benefit analysis for coffee production**

Should farmers invest more on each factor (input)? Table 2 describes the relationship between changes in benefits (revenues) and changes in costs with respect to each corresponding input factor. This analysis assumes that changes in an input factor will not affect other factors of production (i.e., *ceteris paribus* assumption)

**Table 2. Change in revenue as the inputs increase by 1%**

Factors	Cu Kuin			3 combined districts		
	Change in revenue (VND)	Change in input	Sig <sup>a</sup>	Change in revenue (VND)	Change in Input	Sig <sup>a</sup>
Labor	99,356	1.99		139,852	1.94	*
Inorganic fertilizer	66,207	115,200		130,065	128,045	*
Organic fertilizer	9,536	18,892	*	5,304	27,193	*
Pesticide	117,520	7,386	*	1,345	7,518	
Irrigation water	286,716	0.01744	*	17,332	0.01597	
Age of coffee tree	214,242	0.17	*	98,614	0.13	*

<sup>a</sup>indicates 95% significance level of the MLE regression model

Fertilizers are key inputs in coffee farming. The three combined districts model has a larger estimated coefficient (0.1741) for inorganic fertilizer expenditures than the Cu Kuin model. Given the price of coffee output and fertilizer costs, the effect of inorganic fertilizer expenditure on revenue from coffee output was estimated. Accordingly, if farmers (on average) in this sub-region could spend 1% more on inorganic fertilizer (equal to 128,045 VND) coffee output would increase by 0.1741% (equal to 130,065 VND). Since the mean inorganic fertilizer expenditure for the three combined districts was 12,804,500 VND, 1% of this number is equal to 128,045 VND. Given these estimates, it would be economical on average for farmers in the combined districts area to invest more on inorganic fertilizer. However, for the Cu Kuin region, the effect of inorganic fertilizers on coffee production is not statistically significant.

Similarly, a 1% increase in organic fertilizer (18,892 VND for the Cu Kuin district, and 27,193 VND for the three other districts) would increase coffee output for Cu Kuin by 0.0105% (9,536 VND in terms of additional revenue) and by 0.0071% for the three other districts

(5,304 VND). Therefore, in both sub-regions, (on average) the additional application of organic fertilizers would not be economical.

Similar calculations suggest that on average farmers in the Cu Kuin district could be cost effective by investing more on pesticides and applying more irrigation water. By increasing expenditures on pesticides by 1%, coffee output would increase 0.1294% for the Cu Kuin district. This suggests that if farmers spent an additional 7,386 VND on pesticides, they would receive (on average) an additional revenue of 117,520 VND. Likewise, if farmers in the Cu Kuin district could apply 1% more irrigation water (about 17.44 cubic meters), coffee output would increase by 0.3157% (286,716 VND). For the other three districts, the effects from either additional expenditures on pesticides or increased application of irrigation water are not statistically significant on coffee production. Therefore, based on this evidence, recommendations regarding pesticide and irrigation water application can only be made for farmers in the Cu Kuin district.

However, for sustainable development in coffee production, application of chemical fertilizers, pesticides, and irrigation water should be carefully considered. Application of more chemicals can directly damage the environment. Sustainable coffee production is now considered to be a more suitable strategy for future development.

### 3.3 Technical Efficiency

As shown in Table 3, the distributions of technical efficiency scores in the two sub-regions are different. In the combined districts region, the distribution tends to be nearly rectangular i.e, equal from lower to higher intervals, while in the Cu Kuin district, technical efficiency scores decrease for farms in the upper intervals. It is noticeable that the Cu Kuin district has a smaller percentage on farms in the lower technical efficiency intervals as compared to the combined districts. This is probably due to differences in topographic conditions and soil quality which are more favorable for coffee farming in Cu Kuin than for the combined districts.

As shown in Table 1, ethnicity, availability of extension services, and the child dependency index have statistically significant effects on technical efficiency for coffee farmers in the Cu Kuin district. On the other hand, the MLE results for the combined districts show that most of the selected explanatory variables except extension services and age of the household head significantly affect technical efficiency. These results indicate that factors significantly affecting technical efficiency vary by area or location. The MLE results show that the average technical efficiency score for farmers in the Cu Kuin district is 74.66%, which is significantly higher than 68.76%, the average technical efficiency score for the three combined districts (from a pairwise t-test with  $t = 2.84$ ). The estimated efficiency scores also explain that coffee farmers from Cu Kuin can increase coffee output by 25% with the given amount of inputs, while the three remaining districts can increase coffee output by approximately 31%. This is consistent with average coffee yield per hectare being significantly higher for Cu Kuin than for the three other districts (from a pairwise t-test with  $t = 5.05$ ).



**Table 3. Frequency distributions of technical efficiency estimates**

Categories	Cu Kuin		3 combined districts	
	Farms	Percentage	Farms	Percentage
TE ≤ 40%	0	0.00%	4	4.21%
40% < TE ≤ 50%	1	0.97%	13	13.68%
50% < TE ≤ 60%	14	13.59%	16	16.84%
60% < TE ≤ 70%	19	18.45%	13	13.68%
70% < TE ≤ 80%	39	37.86%	18	18.95%
80% < TE ≤ 90%	19	18.45%	20	21.05%
TE > 90%	11	10.68%	11	11.58%
Total	103	100.00%	95	100.00%
Max	0.9992		0.9478	
Min	0.4822		0.3071	
Mean*	0.7466		0.6876	
Std	0.1188		0.1712	

*Note: These efficiency scores for the two sub-regions are not strictly comparable because the two models have two different corresponding stochastic frontiers.*

*\* Results of a pair-wise comparison show that the mean efficiency levels of the two sub-regions are statistically different ( $t = 5.28$ ).*

Of interest is the estimated coefficient for formal education of the household head which has an estimated negative sign in both models. However, the educational variable is statistically significant only for the three districts model. This result suggests that increasing formal education in the combined districts model tends to significantly increase technical efficiency. Similar results were found (see: [32,33,34,7,12]). However, in the Cu Kuin district, the effect of education on technical efficiency is statistically insignificant. This difference in estimated results can be explained as the Cu Kuin district having a statistically higher average education level than the combined districts (from a pairwise t-test with  $t = 3.14$ ). These results help explain why the actual coffee output of farmers from Cu Kuin is closer to its stochastic frontier on average than those from the combined districts.

In an integrated world, education is a key factor for success. More than four decades ago, it was suggested that educated workers are better able to gather and utilize information useful for decision making [35]. Welch explained that workers not only improve their standard of work, but also contribute to production by effectively utilizing the firm's resources. This also involves allocating their time efficiently among different responsibilities or tasks which significantly affects worker productivity.

The ethnicity factor is another variable in the efficiency model, where model results differ by area. In the combined districts model, the coefficient on ethnicity is negative and significant which means that as the ethnicity factor changes favoring the majority, coffee production becomes less technically inefficient. On the other hand, the influence of this factor on technical efficiency is positive and statistically significant for the Cu Kuin model. This suggests that a change in the ethnicity factor favoring the majority, leads to coffee production becoming more technically inefficient. For the Cu Kuin district, though minority farmers are less productive than majority farmers (a t-test for pairwise comparison of coffee yields per hectare between majority farmers and minority farmers is 4.14), minority farmers used less inputs in coffee production (e.g., inorganic fertilizer expenditure ( $t = -3.86$ ), organic fertilizer expenditure ( $t = -2.22$ ), labor ( $t = -2.05$ ), and the amount of irrigation water ( $t = -2.52$ )). This may explain why minority farmers, as compared to majority farmers in the Cu

Kuin district, may be relatively more efficient than shown simply by comparing yields per hectare. On the other hand, for the combined districts, majority farmers had a statistically lower coffee yield ( $t = 4.30$ ) and these farmers used more inputs for several factors of production, e.g., expenditure on inorganic fertilizers ( $t = 6.13$ ), expenditure on organic fertilizers ( $t = 2.34$ ) and amount of irrigation water ( $t = 4.17$ ). These conflicting results do not satisfactorily explain the effects of ethnicity on technical efficiency in the two sub-regions. It is likely that multiple effects should be investigated to illustrate the effects of ethnicity.

The amount of credit loaned positively and significantly affects technical efficiency in the Krong Ana, Krong Bong and Lak districts (combined districts). This can be explained as loaned credit helps to mitigate financial problems that farmers may face during the production period by enabling them to purchase more of the needed inputs. This is similar to the results obtained by [7] for the analysis of factors affecting the technical efficiency in Arabica coffee production in Cameroon (also, see [5]). However, the effect of loaned credit on technical efficiency levels for the Cu Kuin model is statistically insignificant. Farmers in the combined districts were able to obtain higher amounts of loaned credit as compared to those in the Cu Kuin district ( $t = 4.32$ ).

For the combined districts, the MLE results suggest that more farming experience increases technical efficiency in coffee production. This result is similar to findings for agriculture production in Sri Lanka (see: [12]). However, there is insufficient evidence to conclude that this relationship also holds for coffee production in the Cu Kuin district. Comparing both sub-regions, farmers from the combined districts have significantly less experience in coffee farming than farmers from Cu Kuin ( $t = 3.50$ ).

Last, for both models, the MLE results suggest that the child dependency index negatively and significantly affects technical efficiency. It is likely that farm households with larger child dependency indexes will have more household expenses for children e.g., school fees, books, clothes, medicine, etc. These children are also not expected to work on the family's coffee farm. This is perhaps one of the problems that households have to deal with thereby reducing technical efficiency. Similar results were found by [22], indicating that young household members may not be able to contribute to labor supply since they are often pre-occupied with school during peak periods of agricultural production activities. Age of the household head was also not a statistically significant factor affecting efficiency of coffee production in this study.

#### **4. CONCLUSIONS AND POLICY RECOMMENDATIONS**

The estimated mean technical efficiency scores were 0.7466 and 0.6836 respectively for the Cu Kuin district and the combined districts. Formal education of the household head, amount of financial credit obtained, ethnicity, coffee farming experience of the household head and agricultural extension services used were key factors that can increase technical efficiency. To increase profitability, farmers from both regions should consider expanding use of pesticides and irrigation water. However, increasing the amount of organic fertilizers may reduce profits for coffee farmers. Also, coffee farmers from Cu Kuin were less efficient in using inorganic fertilizers and labor in comparison to those from the three remaining districts.

In regards to the Cu Kuin district, greater availability of extension services can increase technical efficiency. Extension activities assist coffee producers in the DakLak province by providing services, e.g., farm workshops where farmers participate and share information, farmers' tours of highly productive farms, demonstrations of new seed varieties, fertilizer

application trials, etc. In 2010, the provincial center for agricultural extension implemented 13 extension programs with 46 on farm experiments (including crops such as rice, rubber, avocado, pepper, and coffee). Other programs have commenced in the province, including Good Agricultural Practices (GAP) for Robusta coffee, using the Farmer Field School methodology, where farmers can apply the so-called Farmer Field Book (FFB), supported by GTZ [36]. Also, a few collaborative programs between the centre for extension, district extension stations and research institutions in the province have been established. Therefore, policies with governmental involvement should be considered to: (1) enhance activities of agricultural extension; (2) promote intensive collaboration among institutions, governmental extension departments and farmer associations in order to implement coffee farming experiments and best management practices (e.g., optimizing input application of fertilizers, pesticides, and irrigated water); and (3) provide adequate funding and human resources to strengthen extension activities. . A recent study reported that in China, middle and high school educated families systematically make better input decisions than primary school educated families [37] (also see [7] and [19]). Therefore, providing basic education services (i.e., extending coverage of formal education, basic use of computers and the Internet etc.) may help farmers from the combined districts region to update and effectively utilize information related to coffee production and marketing. For long term strategies, education is usually an important stepping stone for a growing economy.

Also for the combined districts region, estimated results indicate that increased credit availability can increase technical efficiency by providing credit services that help coffee producers overcome financial constraints and thereby improve efficiency. The local government can work with credit lenders to suggest effective strategies for using and managing capital in coffee production.

Successful implementation of these strategic recommendations will help increase technical efficiency for small-holder coffee producers, thereby increasing profits for coffee farmers and producing positive economic effects for the region.

## **ACKNOWLEDGEMENTS**

The funding for this field research was provided by the Professional Enhancement Fund of the International Fellowship Program and the Graduate Student Organization of University of Hawai'i at Manoa. We deeply acknowledge their support.

## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

## **REFERENCES**

1. Fontenay P de, Leung S. Managing commodity price fluctuations in Vietnam's coffee industry. APSEG Economics and Development Working; 2002.
2. International Coffee Organization. Historical data [Internet]; 2010. [cited 2010 Feb 20]. Available: [http://www.ico.org/new\\_historical.asp](http://www.ico.org/new_historical.asp). Available from: [http://www.ico.org/new\\_historical.asp](http://www.ico.org/new_historical.asp)
3. Business and Investment Information Portal Dak. Coffee production in Dak Lak Province [Internet]; 2010. [cited 2010 Mar 10]. Available from: <http://www.daklakdpi.gov.vn/Default.aspx?tabid=216>

4. Huang CJ, Liu J-T. Estimation of a non-neutral stochastic frontier production function. *Journal of Productivity Analysis*. 1994;5(2):171–80.
5. Binam JN, Tonyè J, Wandji N, Nyambi G, Akoa M. Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. *Food Policy*. 2004;29(5):531–45.
6. Vedenov D, Houston J, Cardena. Production Efficiency and Diversification in Mexican Coffee-Producing Districts. *Journal of Agricultural and Applied Economics*. 2007;39(3):749–763.
7. Nchare A. Analysis of factors affecting the technical efficiency of arabica coffee producers in Cameroon. *African Economic Research Consortium*; 2007.
8. Kolawole O, Ojo SO. Economic Efficiency of Small Scale Food Crop Production in Nigeria : A Stochastic Frontier Approach. *Agricultural Economics*. 2007;14(2):123–30.
9. Illukpitiya P, Yanagida JF. Improving agricultural production through technical efficiency: a case study of small-holder paddy farming in Sri Lanka. *Tropical Agriculture (Trinidad)*. 2004;8(2):114–120.
10. Chen Z, Huffman WE, Rozelle S. Farm technology and technical efficiency: Evidence from four regions in China. *China Economic Review*. 2009;20(2):153–61.
11. Alvarez A, Arias C. Technical efficiency and farm size: a conditional analysis. *Agricultural Economics*. 2004:241–50.
12. Illukpitiya P, Yanagida JF. Farming vs forests: Trade-off between agriculture and the extraction of non-timber forest products. *Ecological Economics [Internet]*; 2010. [cited 2010 Oct 11];69(10):1952–63.  
Available from: <http://linkinghub.elsevier.com/retrieve/pii/S0921800910001977>
13. Cheesman J, Bennett J, Tran VHS, Thuy TD, Vu VDH. The total economic value of sustainable coffee irrigation practices in Dak Lak, Vietnam. 2007:32–4.
14. D'haeze D, Deckers J, Raes D, Tran AP, Nguyen DMC. Over-irrigation of Coffea canephora in the Central Highlands of Vietnam revisited Simulation of soil moisture dynamics in Rhodic Ferralsols. *Agricultural Water Management*. 2003;63(3):185–202.
15. Farrell MJ. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society Series A (General)*. 1957;120(3):253–90.
16. Aigner DJ, Lovell CAK, Schmidt P. Formulation and Estimation of Stochastic frontier production function models. *Journal of Econometrics*. 1977;6(1):21–37.
17. Battese G. Frontier production functions and technical efficiency: a survey of empirical applications in agricultural economics. *Agricultural Economics*. Elsevier. 1992;7(3-4):185–208.
18. Battese GE, Coelli TJ. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*. 1995;20(2):325–32.
19. Kehinde AL, Awoyemi TT, Omonona BT, Akande JA. Technical efficiency of sawnwood production in Ondo and Osun states, Nigeria. *Journal of Forest Economics*. Elsevier. 2010;16(1):11–8.
20. Binam JN, Sylla K, Diarra I, Nyambi G. Factors affecting technical efficiency among coffee farmers in Cote d'Ivoire: Evidence from the centre west region. *African Development Review*. 2003;15(1):66–76.
21. D'haeze D, Deckers J, Raes D, Phong TA, Loi HV. Environmental and socio-economic impacts of institutional reforms on the agricultural sector of Vietnam Land suitability assessment for Robusta coffee in the Dak Gan region. *Agriculture, Ecosystems & Environment*. 2005;105(1-2):59–76.
22. Muhammad-Lawal A, Omotesho OA, Falola A. Technical efficiency of youth participation in agriculture: a case study of the youth-in- agriculture programme in Ondo State, South-Western Nigeria. *Nigerian Journal of Agriculture, Food*. 2009;5(1):20–6.

23. Meeusen W, van Den Broeck J. Efficiency estimation from Cobb-Douglas production functions with composed error. *International economic review*. 1977;18(2):435–44.
24. Tingley D, Pascoe S, Cogan L. Factors affecting technical efficiency in fisheries: stochastic production frontier versus data envelopment analysis approaches. *Fisheries Research*. 2005;73(3):363–76.
25. Kumbhakar SC, Ghosh S, McGuckin JT. A generalized production frontier approach for estimating determinants of inefficiency in US dairy farms. *Journal of Business & Economic Statistics*. 1991;9(3):279–86.
26. Reifschneider D, Stevenson R. Systematic departures from the frontier: a framework for the analysis of firm inefficiency. *International Economic Review*. 1991;32(3):715–23.
27. Stevenson RE. Likelihood functions for generalized stochastic frontier estimation. *Journal of Econometrics*. 1980;13(1):57–66.
28. Leung P, Sharma KR. Technical efficiency of carp production in Pakistan. *Research Collection Book*. Bangkok, Thailand: Network of Aquaculture Centers in Asia-Pacific (NACA); 2001.
29. Johnson RA, Bhattacharyya GK. *Statistics: Principles and Methods* 5th Edition Binder Ready Without Binder. 5th ed. Canada: John Wiley & Sons Canada, Limited; 2006.
30. Ho T. Analysis of Socio-economic factors affecting small -holder coffee production in the Krong Ana Watershed, Vietnam. *Change*. University of Hawaii at Manoa; 2011.
31. Coelli TJ. *A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation*. Production; 1996.
32. Phillips JM, Marble RP. Farmer education and efficiency: a frontier production function approach. *Economics of Education Review*. 1986;5(3):257–64.
33. Seyoum ET, Battese GE, Fleming EM. Technical efficiency and productivity of maize producers in eastern Ethiopia: a study of farmers within and outside the Sasakawa-Global 2000 project. *Agricultural Economics*. 1998;19(3):341–8.
34. Weir S, Knight J. *Adoption and Diffusion of Agricultural Innovations in Ethiopia: The Role of Education*; 2000.
35. Welch F. Education in production. *The Journal of Political Economy*. 1970;78(35-59).
36. GTZ G fur TZ. *Coffee Value Chain in Dak Lak Province*. GTZ-MPI Small and Medium Enterprise Development Programme in Vietnam, Component 3:Competitiveness of selected agricultural sub-sector; 2009.
37. Tao Yang D. Education and allocative efficiency: household income growth during rural reforms in China. *Journal of Development Economics*. 2004;74(1):137–62.

© 2014 Ho et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Peer-review history:*

*The peer review history for this paper can be accessed here:*  
<http://www.sciencedomain.org/review-history.php?iid=309&id=25&aid=2719>