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Technical Efficiency Analysis of Tea Production in the Northern Mountainous Region of Vietnam

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I. Introduction

Tea has a long history in Vietnam and has been cultivated and drunk there for thousands of years. Today, Vietnam is the fifth largest tea exporter in the world. Tea is grown in 39 of 64 Vietnamese provinces. The best quality products are achieved in the North area. Tea production is an important source of income. In 2012, total exported tea reached 146,700 tons and grossed 224.6 million dollars (Vietnam Tea Association 2012). Furthermore, tea production also plays an important role in generating employment. With 400,000 small households engaged in cultivation and process, tea industry created over 1.5 million jobs (Vietnam General Statistic Office, 2008). Tea is one of the five important agricultural products in Vietnam.

The Northern mountainous region, with its mountainous topography and temperate climate, is one of the main tea cultivation areas in Vietnam. It has a total of 93,000 ha under tea, accounting for 71.6 percent of the total cultivation area in Vietnam, and 64.7 percent of the country's total tea output (Vietnam General Statistic Office 2013). Tea is the largest cash crop in the region and provides income for many small households. Therefore, boosting tea production in the Northern mountainous area is expected to motivate the region's economic growth and have a positive impact on livelihood of small households.

However, Vietnamese tea production is faced with many challenges. Vietnam remains a small player in the world tea market. In 2011, Vietnamese tea production accounted for 7 percent of global tea market, much lower than China (16 percent), India (16 percent), Sri Lanka (16 percent), and Kenya (15 percent) (Potts *et al*. 2014). As Vietnam continues its drive onward into twenty-first century tea production, it is increasingly forced to compete with those top producers, many of which are achieving comparatively higher yield and more efficient production. Therefore, Vietnamese tea industry should increase production efficiency to improve its competitive edge in foreign tea markets.

Many researchers and policy makers have focused their attention on the impact that adoption of new technologies can increase farm productivity and income (Hayami and Ruttan 1985). In Vietnam, considerable work is being done to improve technology and yield in tea production. However, the implementation of these practices is lagging (Wenner. R 2011). In fact, the majority of Vietnamese tea production is done by small households who often lack money or interest in the implementation of new technology. Thus, in short run, Vietnamese tea productivity should be increased by using the existing production technology. The efficient use of existing input resources can result in a cost- effective way to increase the productivity of tea production. In designing appropriate policy measures to enable Vietnamese tea farms to increase productivity through improved efficiency, it may be useful to measure farm level technical efficiency and its determinants. Such a statement begs these questions: (1) Are tea farmers in Vietnam using their input efficiently? (2) Which factors affect the technical efficiency of tea production?

The main objective of this study is to assess whether or not the current technologies are efficient for the tea farmers in the Northern mountainous region of Vietnam. The study first analyzed the technical efficiency level of tea farmers using stochastic frontier analysis and then determined factors influencing the technical efficiency of tea farmers with two-limit Tobit regression model.

Although tea is a very promising crop not only for farmers' income but also national economy, until now there has been no obvious research concerned with the

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farm level technical efficiency and its determinants of tea production in Vietnam. This study also aims to fulfill the knowledge gap in this area.

The first section of this paper provides information on the current situation of Vietnamese tea production while the second section is analytical framework for measuring technical efficiency. In the third section, the detailed description of data and empirical model is presented. The forth section is the estimated results while the fifth section is discussion from model estimation. Some concluding remarks and recommendations are drawn in the final section.

II. Analytical Framework for Measuring Technical Efficiency

Economic efficiency takes on to increase output without using more conventional inputs. As farmers cultivate their crops with the existing technology inefficiently, applying new technologies results in less cost-effective than using the existing technology (Bellbase and Grabowki 1985; Shapiro 1977). Economic efficiency can be classified in two parts: technical efficiency and allocative efficiency. Technical efficiency measures the ability of a farmer to achievethe maximum output with given and obtainable technology, while allocative tries to capture farmers' ability to apply inputs in optimal proportions with respective prices (Farrell 1957; Coelli *et al.* 2005).

Measuring technical efficiency is to use inputs and output quantity without introducing their prices. Technical efficiency can be decomposed into three components such as: scale efficiency (the potential productivity gain from achieving optimal size of a firm), congestion (increase in some inputs could decrease output) and pure technical efficiency (Farrell 1957).

There are two methods widely used in the literature to estimate technical efficiency. The first one is an econometric approach - Stochastic Frontier Analysis (SFA) that simultaneously introduced by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977). The second one is non- parametric approach or mathematical programming - Data Envelopment Analysis (DEA). Two methods have partial strength and weakness. The econometric method is stochastic and parametric. It distinguishes the effects of noise with the effects of inefficiency and confound the effect of misspecification of functional form with inefficiency, but it generates good results for models that are single output and multiple inputs. Conversely, the mathematical programming approach is not stochastic and not parametric. It cannot separate the effects of noise and the effects of inefficiency during the calculation of technical efficiency, and it less sensitive to the type of specification error (Kebede 2001). Its advantage is that multiple inputs and output can be considered simultaneously, and inputs and outputs can be quantified using different units of measurement.

Since tea production in Vietnam is an example of single output and multiple-input production, this study focuses on the use of an econometric approach for measuring technical efficiency based on the production frontier model. A production frontier model can be written as:

$$Y_i = f(X_{ij}; \beta) + \varepsilon_i \qquad (1)$$

Where Y_i is output of the *i*farms, X_{ij} is a vector of inputs used by farm *i*, and ε_i is a "composed" error term. The error term ε_i is equal to $v_i - u_i$.The term v_i is a two-sided ($-\infty < v_i < \infty$) normally distributed random error ($v \sim N[0, \sigma_v^2]$) that represents the stochastic effects outside the farmer's control (e.g., weather; natural disasters, and luck), measurement errors, and other statistical noise. The term u_i is a one-sided ($u_i \geq 0$) efficiency component that represents the technical inefficiency of farm (Coelli *et al.* 2005). The distribution of term u_i can be half-normal, exponential or gamma (Aigner *et al* 1977; Meeusen and Broeek 1977). The assumption of term u_i in the study is half-normal distribution ($u \sim N[0, \sigma_u^2]$) mainly used in the other studies. The two components v_i and u_i are also assumed to be independent together.

Equation (1) estimated by the maximum likelihood analysis creates consistent estimators for β, λ, andσ where β is a vector of unknown parameters, $\lambda = \sigma_u / \sigma_v, \sigma^2 = \sigma_u^2 + \sigma_v^2$.

According to Battese and Corra (1977), the ratio variance parameter γ which relates to the variability of u_i to total variability σ^2 can calculated in the following manner:

$$\gamma = \sigma_u^2 / \sigma^2 \qquad (2)$$

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

If the value of γ is equal to zero, the difference between actual farmer yield and the efficient yield is entirely due to statistical noise. On the other hand, a value of one would indicate the difference attributed to the farmers' less than efficient use of technology i.e. technical inefficiency (Coelli *et al.* 2005).

The technical inefficiency of individual farms can be estimated by using conditional distribution of u_i given the fitted values of ε and respective parameters (Jondrow *et al.* 1982). If we assume that v_i and u_i are independent each other, the conditional mean of u_i given ε is identified by:

$$E(u_i|\varepsilon_i) = \sigma^* \left[\frac{f^*(\varepsilon_i\lambda/\sigma)}{1-F^*(\varepsilon_i\lambda/\sigma)} - \frac{\varepsilon_i\lambda}{\sigma}\right] \qquad (3)$$

Where: $\sigma^{*2} = \sigma_u^2\sigma_v^2 / \sigma^2$, f^* is the standard normal density function, and F^* is the distribution function, both functions being estimated at $\varepsilon\lambda/\sigma$.

With the assumption of half-normal model, a simple z-test will be used for examining the existence of technical inefficiency, the null and alternative hypotheses are: H_0: $\lambda = 0$ and H_1: $\lambda > 0$ (Coelli *et al.* 2005). The test statistic is:

$$z = \frac{\tilde{\lambda}}{se(\tilde{\lambda})} \sim N(0,1) \quad (4)$$

: $\tilde{\lambda}$ is the maximum likelihood estimator of λ and $se(\tilde{\lambda})$ is the estimator for its standard error.

The technical efficiency of farm will be determined by using the following equation:

$$TE_i = exp(-\hat{u}_i) = exp(-E(u_i|\varepsilon_i)) \quad (5)$$

The *TE* score is between zero and 1. A farm is fully efficient if it equals to 1 and fully inefficient if its value is zero.

To investigate the relationship between farms' technical efficiency and various farmers' socio-economic factors and specific farm characteristics, a two-limit Tobit regression model was applied as the second step analysis because the efficiency scores from stochastic frontier analysis are limited between 0 and 1 (Bravo-Ureta and Pinheriro 1997; Binam *et al.* 2003; Khai *et al.* 2008; Nyagaka *et al.* 2010). Therefore, a Tobit regression model was used in this study. According to Tobin (1958), a Tobit regression model can be specified in the following form:

$$TE_i = \delta_0 + \sum_i \delta_i W_i + e_i$$

Where: TE_i is the technical efficiency scores of each farm obtained from the function (4) as dependent a variable, W_i is the variables representing socio-economic characteristics of farmers and farms, δ_i is a vector of unknown parameters to be estimated, and e_i is error term that represents other factors outside model.

The maximum-likelihood estimates of parameters of function (1), the farm-level TE in function (4), and Tobit regression estimates in formula (5) are achieved by using STATA version 13 software.

III. Research Area, Empirical Model and Data

a) Research area

Thai Nguyen is a province in the Northern mountainous region of Vietnam. With 18,000 ha of tea trees, Thai Nguyen is the second largest tea plantation area in Vietnam. However, it is the largest province in tea production with about 172,000 tons per year (Vietnamese General Statistic Office, 2011). The suitable natural conditions and temperate climate make Thai Nguyen tea have the finest quality throughout Vietnam. Therefore, this research was conducted in Thai Nguyen province. Four representative communes of two famous tea-producing districts (Dong Hy district and Thai Nguyen city) in Thai Nguyen province were chosen for the survey. The selected tea farms are representative of topographical conditions in tea production areas of Thai Nguyen province.

Tan Cuong and PhucXuan commune are administratively in the Thai Nguyen City. Tan Cuong is the most well-known for having the highest tea quality in Vietnam. Most of the tea farms are situated along the sides of the Cong river where fields are flatter (with 20% slope). Whereas, in the PhucXuan commune, tea is grown on hillsides and uplands.

Two communes, Minh Lap and Song Cau, are in Dong Hy district. Minh Lap commune is located about 24 km east of Thai Nguyen town (the center of Thai Nguyen city) and borders the sides of the Cau river. Most of the tea farms in the Minh Lap commune are on uplands and hillsides with slopes ranging from 15% to 30%. The Song Cau commune, on the other hand, is located in the Northeast and about 20 km from the Thai Nguyen town.Tea farms in the Song Cau commune are similar to those in the Minh Lap.

The primary data for this study were collected in a field survey through direct interview with tea farmers from April to December 2013 by a group of enumerators. A pre-test was made to revise the questionnaire before the formal survey. A total of 258 tea growers were selected following a random sampling procedure.

The questionnaire in this study was structured to get responses from the selected tea farmers on their farming activities. An attempt was made to collect information on inputs and cost used for tea production as well as tea outputs. Socio-economic data of the farmers and tea farms' characteristics such as age, gender, level of education, ethnicity, farming experience, participation in cooperative, household size, farm size, agricultural income, off-farm income, tea age, slope, number of methods to control erosion and conserve water resource and accessing extension services were also collected. This is expected to increase the explanatory power of the analysis significantly.

b) Empirical model

There are several functional forms for estimating the physical relationship between inputs and output. According to Hanley and Spash (1993), Cobb-Douglas functional form is more popularly applied than other forms, if there are three or more independent variables in the model. Therefore, in this study, Cobb-Douglas production function with ten independent variables was applied. The study normalized the data set by dividing output and inputs by land input variable, resulting in dropping this variable in the regression model. The Cobb-Douglas stochastic frontier function was written as:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{10} \beta_{ij} \ln X_{ij} + v_i - u_i$$

Where: $Y_i$is fresh tea yield (kg/ha);

X_{ij} is the ten used inputs including: *Nitrogen fertilizer(kg/ha), Phosphorous fertilizer (kg/ha), Potash fertilizer (kg/ha), NPK fertilizer (kg/ha), Animal fertilizer (kg/ha), Pesticide (liter/ha), Labor used for tea production (man-day/ha), Irrigation water used for tea production (m³/ha), Capital (Values of machineries and tools for tea production were calculated in Vietnamese currency - thousand VND/ha), and Other cost (calculated in Vietnamese currency - thousand VND/ha).*
v_i is a two-sided ($-\infty < v_i < \infty$) normally distributed random error thatrepresents the stochastic effects outside the *i* farmer's control;

$u_i$is a one-sided ($u_i \geq 0$) efficiency component that represents the technical inefficiency of the *i* farm.

In the second step, theTobit regression function with a dependent variable of technical efficiency and fifteen independent variables are estimated to determine factors affectingtechnical efficiency of Vietnamese tea production. The regression function is given by:

$$TE_i = \delta_0 + \sum_{k=1}^{15} \delta_k W_{ik} + e_i$$

Where: $TE_i$is the level of technical efficiency; W_{ik} is the variables representing socio-economic characteristics of farmers and tea farms to explain technical efficiency: *Age* (the age of household head (years)) (*k=1*), *Gender* (gender of household head (dummy variable,1= male, 0=female) (*k=2*), *Education* (the number of completed years of schooling of household head) *(k=3)*, *Household size* (the number of family members in persons) *(k=4)*, *Ethnicity* (ethnicity of household head (dummy variable,1=*Kinh* ethnicity, 0= Otherwise) *(k=5)*, *Experience* (the number of tea growing years) *(k=6)*, *Tea age* (the age of tea tree in years) *(k=7)*, *Slope* (slope of tea farms, degree) *(k=8)*, *Soil and water conservation* (SWC) (dummy variable is used to capture whether farmer applied any SWC technologies on their fields such as : barrier to water movement, soil bund, stone bund, contour ridge, hedge grow, planting tree, grass trip, and digging hole to store rainwater, 1= farmer employed SWC technology, 0=otherwise) *(k=9)*, *Farm value* in natural log (the total value of agricultural products gained by farmers) *(k=10)*, *Non-agri. Income share* (proportion of total farmer's income from non-agricultural sources) *(k=11)*, *Labor-land ratio* (Ratio of labor to land) *(k=12)*, *Extension* (dummy variable, 1 = access to extension service, 0= otherwise) *(k=13)*, *Cooperative* (dummy variable, 1= farmer joining in cooperative, 0=otherwise) *(k=14)*; *Farm size* (ha) *(k=15)*.

e_i is error term that represents other factors outside model.

c) Data

Table 1 presents the descriptive statistics of some important variables applied in stochastic frontier production model and some specific farm characteristics.

The results show that the average tea yield was approximately 35,351.16 kilograms, with a range of 4,350 kilograms to 57,870 kilograms, and the standard deviation among yield levels was 16,883.99 kilograms. The large variability in standard deviation revealed that the sample farmers used inputs in different ways, which tended to affect their yield levels. Fertilizer is an important input to increase the productivity of tea. It was found that the major components of fertilizer used in tea farms were nitrogen, phosphorous, potash, and animal fertilizer. There was a high variation in the amount of fertilizer application per farm. Some farmers did not apply some kind of fertilizers, while others used significant amount. The average use of pesticide is approximately 67.43 liters per hectare, with a range from 0 liter to 216 liters, representing a large variability among farms. This variability may depend on farm size and farmers` attitude and preference regarding to pesticide application. The average utilization human labor per hectare including hired and family labors was approximately 1,647.5 man-days with the minimum at 332 man-days and the maximum at 3,554.5 man-days, indicating that farming activities are highly labor intensive.The average of irrigation water per hectare was between 1000 m^3 and 14,114 m^3 with a mean of 5,595.53 m^3, suggesting a wide range variation among farms.

The average education level is around 10 years, suggesting that most of tea farmers graduated secondary school in Vietnamese education system. The results also shows that farmers have much experience on tea cultivation with the mean nearly 22 years. The average area of tea farmer is around 0.26 ha with a range of 0.05 ha to 0.60 ha, suggesting the big variability of sizes among tea farmers in Vietnam. The results reveals that tea farmers in the Northern mountainous region of Vietnam have basic education leveland much experience in tea production, but have small-scale tea farming. The mean tea age in the sample is quite young (around 15 years). According to Do and Le (2000), the most productive period of the tea age's life is from 10 to 30 years old. The tea age in the sample had stands ranging from 8-36 years old suggesting that most survey tea farms are in the most productive period. The total value of farming that farmers earn from agricultural activities is averagely 77,193.16 thousand VND per hectare, while the average of off-farm income is 0.08. This suggests that tea production brings major income for farmers in the region.

Table 1 : Description of Variables

Descriptive of variables	Mean	Std. Dev	Min	Max
Tea production characteristics				
Fresh tea yield (kg/ha)	35,351.16	16,883.99	4,350.00	57,870.00
Nitrogen fertilizer (kg/ha)	1,104.50	773.84	0	3,226.50
Phosphorous fertilizer (kg/ha)	2,718.73	2,990.27	0	10,000.00
Potash fertilizer (kg/ha)	212.48	267.94	0	967.50
NPK fertilizer (kg/ha)	2,025.38	2,335.61	0	9,260.00
Animal fertilizer (kg/ha)	4,688.76	6,828.95	0	20,750.00
Pesticide (liter/ha)	67.43	58.39	0	216.00
Labor (man-day/ha)	1,647.50	855.32	332.00	3,554.50
Irrigation water (m^3/ha)	5,595.53	4,051.05	1,000.00	14,114.00
Other cost (thousand VND/ha)	4,776,16	6,671.50	0	17,640.00
Capital (thousand VND/ha)	4,404.04	4,027.85	0	13,261.50
Household head characteristics				
Age (years)				
Education (years)	10.09	2.28	5.00	18.00
Experience (years)	21.86	8.77	5.00	50.00
Tea farm characteristics				
Farm size (ha)	0.26	0.14	0.05	0.60
Tea age (years)	14.79	7.77	3.00	36.00
Farm value (thousand VND/ha)	77,193.16	36,960.03	4,500.00	352,000.00
Non-agricultural income share	0.08	0.13	0	0.59

Note: a man-day unit = 8 working hours of an adult
Source: Author's estimation

IV. Estimated Results

a) Stochastic frontier production model

In order to control for data reliability and validity, measurement and sampling errors and obtaining unbiased estimates, a number of tests were used. The Variance Inflation Factor (VIF)) procedure applied to detect multicollinearity and was preferred over the correlation coefficient method which fails to yield conclusive results (Pindyck and Rubinfield 1981). If the VIF is greater than 10, then there is a potential multicollinearity problem (Neter *et al.* 1989). No serious multicollinearity problem among variables in the sample were detected by the VIF test. All independent variables had VIF less than 10, and the mean VIF was 2.71.

Table 2 : OLS and stochastic frontier production estimates

Variables	OLS		Stochastic frontier	
	Coefficients	t- value	Coefficients	z-value
Nitrogen fertilizer	0.0950***	14.74	0.0936***	14.92
Phosphorous fertilizer	0.0074***	2.81	0.0077***	3.01
Potash fertilizer	-0.0012	-0.35	-0.0008	-0.25
NPK fertilizer	0.0724***	11.02	0.0688***	10.52
Animal fertilizer	0.0028	1.26	0.0034	1.58
Pesticide	-0.0345***	-3.36	-0.0355***	-3.85
Labor	-0.0865***	-4.06	-0.0946***	-4.41
Irrigation water	0.1883***	5.49	0.1944***	5.97
Capital	-0.0104***	-3.39	-0.0101***	-3.42
Other cost	-0.0036	-0.64	-0.0030	-0.55
Constant	8.5852***	31.63	8.7249***	33.04
Function of coefficient©	0.2297			
R^2	0.9494			
F-statistic***	463.2400			
F- critical value	2.3930			
σ_v			0.1216	
σ_u			0.1434	
σ^2			0.0354	
$\lambda = \sigma_u/\sigma_v$			1.1179	
$\gamma = \sigma_u^2/\sigma^2$			0.5809	
$se(\tilde{\lambda})$			0.0462	

*Note: *** indicate statistical significance of the 0.01 level, © indicate the sum of estimated coefficients*
Source: Author's estimation

The OLS estimate for choosing the relevant variables and stochastic frontier production for estimating technical efficiency are shown in Table 2. The coefficient R^2 is equal to 0.9494, showing that around 94.94 percent of the dependent variable is explained by independent variables in the OLS model.

The presence or absence of technical inefficiency was tested in the study using z test. The null hypothesis is that there is no inefficiency effect in the model. The estimation result from function (3) shows that $z_{statistic} = \frac{\tilde{\lambda}}{se(\tilde{\lambda})} = \frac{1.1179}{0.0462} = 24.20$. At the significance of 0.01 level, the critical value $z_{\alpha/2} = 2.58$. The calculated value $z_{statistic}$ is greater than $z_{critical\ value}$. Therefore, the null hypothesis was rejected at 0.01 level, suggesting the presence of technical inefficiency effect for tea farmers in the Northern mountainous region of Vietnam. Gamma (γ) is equal to 0.5809, which means that 58.09 %of the total variation of output levels is due to technical inefficiency.

A check for evidence of constant returns to scale among the sample implemented using F test. The restricted squares regression with the null hypothesis of constant return to scale was estimated. The computed F statistic of 581.44 was larger than the critical value F at the 1 percent level of significance. Thus, the null hypothesis is rejected and the study concluded that technology does not exhibit constant return to scale. In addition, the sum of the elasticity of all inputs was 0.2297. It shows that the possibility of Vietnamese farmers decrease returns to scale in tea production. Decreasing returns to scale suggests that increasing all inputs by a given proportion leads to a less than proportionate increase in output.

The results show that the coefficients estimated in models were statistically significant at 0.01 level. As this study used Cobb-Douglas production frontier function, the coefficient value of the variables can be used as direct elasticity of the function. The elasticity of independent variables represents how proportion changes in fresh tea yield if the inputs change in the production process. It can be seen from Table 2 that input variables such as: *Nitrogen fertilizer, Phosphorous fertilizer, NPK fertilizer,* and *Irrigation water* had significant positive impact on tea yield. The elasticity of *Irrigation water* (0.1883) was highest. This implies that for tea farmers 1 percent increase in irrigation water will lead to 0.1883 percent increase in fresh tea yield. The positive coefficients of *Nitrogen fertilizer* (0.0936), *Phosphorous fertilizer* (0.0077) and *NPK fertilizer* (0.0688) indicate that one percent increase in the amount of each kind of these fertilizers will lead to the increase in tea yield by 0.0936 percent, 0.0077 percent, and 0.0688 percent, respectively. Conversely, factors such as *Pesticide, Labor*, and *Capital* had negative effects on tea yield. The *Pesticide, Labor*, and *Capital* had partial output elasticity of about -0.0355, -0.0946, and -0.0104.This implies that 1 percent increase in *Pesticide, Labor*, and *Capital* will lead to a fall in tea yield by 0.0355 percent, 0.0946 percent, and 0.0104 percent.

b) Frequency distribution of Technical efficiency

Based on the estimation of the production frontier function, the frequency distribution of the technical efficiency of tea farming is presented in Table 3.

Table 3 : Frequency distribution of technical efficiency for tea farming

Efficiency level (%)	Frequency	Relative frequency (%)
≤50	0	0.00
>50≤60	0	0.00
>60≤70	2	0.78
>70≤80	5	1.94
>80≤90	107	41.47
>90≤ 100	144	55.81
Total	258	100
Minimum (%)	62.1	
Maximum(%)	97.2	
Mean (%)	89.6	

Source: Author's estimation

The technical efficieny (TE) of Vietnamese tea farmers ranges from 62.1 percent to 97.2 percent, with an average of 89.6 percent, suggesting that there was significant variation in technical efficiency among tea farmers. The highest frequency range of TE more than 90 percent comprises 144 farms, which is 55.81 percent of the total. None of farms have TE score lower than 60 percent, indicating that most tea farms in the North region achieve rather high technical efficiency in production. The results also show that the average technically efficienct farmers could reduce their cost by 8 percent [{1-(89.6/97.2)}*100] (Bravo-Ureta and Pinheiro 1997) if they could achieve maximum level of technical efficiency. Similarly, the most technically inefficient farmers could enjoy 36 percent cost savings [{1-(62.1/97.2)}*100] if they achieve the most technical efficient counterparts.

c) Efficiency effects model

To analyze which factors could have an impact on the tea production's technical efficiency, the Tobit model is applied with TE as a dependent variable and some key socio-economic independent variables presented in the equation (8), instead of the OLS estimate producing biased results, often toward to zero (Bravo-Ureta and Pinheiro 1997).

Table 4 : Two-limit Tobit estimates of the sources of technical efficiency

Variables	Explanation	Coefficient	t-value
Age	Household head age (years)	0.0001	0.58
Gender	Household head gender (1=male, 0=female)	0.0135***	2.70
Education	Household head education level (years)	0.0001	0.12
Experience	Household head experience in tea farming (years)	-0.0002	-0.92
Ethnicity	Household head ethnicity (1=Kinh, 0= otherwise)	0.0020	0.58
Household size	Number of member per household	-0.0016	-1.25
Farm size	ha	-0.0406	-1.13
Labor-land ratio	The ratio of labors and land	0.0003	1.53
Tea age	The age of tea tree in years	0.0002	1.11
Slope	Slope of tea field, degree	0.0021	0.89
Soil and water conservation	1=farmer employed SWC technology,0=otherwise	0.0267***	12.71
Farm value	Total value of agricultural product in natural logarithm	0.0240	3.16
Non-agricultural income share	Proportion of total income from non-agricultural sources	0.0148	1.27
Extension	1= farmer access to extension service, 0=otherwise	0.0105***	2.28
Cooperative	1= farmer join cooperative, 0=otherwise	0.0249***	3.76
Constant		0.6990***	16.99

*Note: *** indicate statistical significance of the 0.01 level*
Source: Author's estimation

The sign of the variables in the efficiency model is very important in explaining the observed level of technical efficiency of the farmers. A positive sign on the coefficient implies that variables had an effect in increasing technical efficiency, while a negative coefficient significant the effect of reducing technical efficiency. The parameter estimates of Tobit function are performed in the Table 4. Coefficients of *Soil and water conservation*, *Extension,* and *Cooperative* variables had positive significant effects on technical efficiency at the level of 1 percent. The coefficient of *Soil and water conservation* variable is statistically positive significant and biggest compared to other variables at the level of 1 percent. The more soil and water conservation methods applied in farm, the higher technical efficiency of households. The coefficient of *Extension* had positive effect to technical efficiency as expected. Farmers who access to extension services cultivate tea better and more efficiently than others. One of the variables most worth mentioning in relation to technical efficiency is *Cooperative.* Its estimation coefficient shows a significant positive effect to technical efficiency, signaling that famers participating in cooperative could produce tea more efficiently than others. Similarly, *Gender* had positive effect on technical efficiency, statistically significant at the level of 1 percent. The positive coefficient of *Gender* implies that male head households are relatively technically efficient than their female counterparts.

V. Discussion

Efficiency is an important factor of productivity growth as well as stability of production. This study estimated the technical efficiency of tea production in the Northern mountainous reion of Vietnam using stochastic frontier approach. The mean technical efficiency of tea production in this region was found to be 89.6 percent. It is clear that there are opportunities for tea growers to increase the productivity by 10.4 percent through using properly the available inputs and technology. In addition, this result indicates that Vietnamese tea farming is relatively efficient than some countries` tea production such as: Srilanka, Bangladesh and India. Basnayake *et al.* (2002) showed that the technical efficiency of small tea producers in Sri-Lanka was on average approximately 65 percent. For Bangladesh, the average technical efficiency was about 59 percent following by Baten *et al.* (2010). For India, Harisdas *et al.* (2012) found an average technical efficiency of 84.53 percent.

Agricultural production is a process of combining various inputs such as: seed, fertilizer, pesticide, labor, irrigation water, and machinery. These inputs are considered as important variables in production efficiency analysis. This study finds that irrigation water, fertilizer (nitrogen, phosphorous, npk), pesticde, labor and capital had significant impact on the efficiency of tea production.

The most important input having positive and siginificant effect on tea yield was *Irrigation water*. This indicates that the more irrigation water use, the higher tea yield. Although tea is an upland crop, it still favors warm and humid growing conditions. Irrigation becomes more esstential for tea production in the Northern region of Vietnam during the dry months (September to December) of the year (Do and Le 2000). Nghia (2008) using dummy variable in production frontier model showed that irrigated tea fields in the Northern mountainous region of Vietnam are more efficient production than non-irirgated fields. Finding of this study makes a strong case in favoring construction of proper irrigation system to all tea farms in Vietnam.

The use of chemical fertilizer is known to be a commonly used method in increasing productivity and in the intensification of agriculture production. Some of studies such as: Basnayake *et al.* (2002), Baten *et al.* (2010), and Harisdas *et al.* (2012) used the total amount of chemical fertilizer in prodcution frontier model to estimate the effect of this fertilizer on tea yield. In fact, tea plant need large amount of nitrogen, phosphorous and postasium for growth. The deficiency of these nutrients could adversely affect the yield of tea. The interesting of this study is that the impact of Nitrogen, Phophorous, Postasium, and NPK fertilizer on tea yield in stochastic production frontier model was analyzed independently. The positive coefficient of *Nitrogen fertilizer, Phosphorous fertilizer, NPK fertilizer* variable indicates that increasing productivity of tea are largely dependent on the type and amount of chemical fertilizer applied. This result will provide useful information for tea farmers to achieve proper balance of chemical fertilizer which is very essential to increase productivity and maintain soil fertility sustainability.

On the contrary, *Pesticide* variable had negative effect on tea yield. The negative and unexpected sign of pesticide signals that this chemical input has been over-utilized in tea disease control. Several factors may contribute to this overall pattern. Interviews with tea farmers show that they consider pesticides to be essential tools in avoiding crop failures and securing their income. 70 percent of farmers in the sample believe that the more frequently they apply pesticide the more effective pest control will be, proceed to, minimize economic risks and maximize yields. Besides, to attract the customers and motivate them to pay a higher price, tea farmers use chemical pesticides much to get more aesthetic appearances in tea buds. This excessive pesticide application of tea farmers will have strongly affect not only tea quality but also environment (through contaminating soil, air and water) and the life of plants and animals, including humans. Therefore, it is important to promote the implementation of integrated pest management (IPM) practices in order to reduce the dependence of tea farmers on chemical pesticides.

Similarly, *Labor* variable showed a negative and significant impact on tea yield. There are some studies related to agricultural sector (Battese and Broca 1997; Cuesta 2000; Zhu and Lensink 2010) with this non-normal sign of labor. This result implies that increasing labor is not critical way for increasing tea yield. This input is at macro level and we can observe decreasing returns to scale when adding more working days into tea production. The possibility of decreasing returns to scale in Vietnamese tea production was proved in the estimated results section. The *Capital* variable also had negative and significant effect on tea yield. This implies that there would be no significant increase in tea yield even if the investment in machinery would increase. Vietnamese tea farmers tend to excess current capital, which is either not used or not fully used in actual production. According to Pindyck (1991), when capital investment is often an irreversible decision, excess capital tends to persist. Therefore, these findingssuggest that tea farmers have wide chance to increase tea yield through properly utilizing their current labor and machineries.

For policy purposes, it is very useful to determine which factors of farmers' socio-economic and farm characteristics have impact on the technical efficiency of tea production. Using two-limit Tobit model, this study reveals that *Soil and water conservation, Extension, Cooperative,* and *Gender* variables had positive and significant effect on the technical efficiency of tea production.

The positive effect of *Soil and water conservation* implies that adoption of SWC technologies enhance productivity of tea production in the Northern mountainous region of Vietnam. This result is consistent with Dang (2002), Solis *et al.* (2006), and Mugonola (2013). In recent years, soil erosion resulting from bad farming practices on sloping lands, without attention to soil conservation, has been known to be a serious problem in the Northern mountainous areas of Vietnam. Soil erosion causes loss of productivity at all levels in this region (Thao 2011). In addition, there are constantly growing risks of severe droughts and water shortage for irrigation and changing climate in the North region of Vietnam (FAO 2011). Therefore, the promotion of soil and water conservation practices is very important measure to produce tea efficiently and sustainability.

This study also shows that tea farmers who access to extension services produce more efficiently than non- accsess farmers. Kalijaran (1991), Xu and Jeffrey (1998), Al-Hassan (2008), Saigenji and Zeller (2009), and Nyagaka *et al.* (2010) also found that agricultural extension services could help improving technical efficiency. Agricultural extension policy was designed in Vietnam to develop agriculure production in sustainable way. Tea production is one of the most important sectors implementing this policy. Extension service includes serveral features such as: training courses or technical instruction on tea cultivation (land preparation, planting etc.), training on modern techniques of application of fertilizer and pesticde, training on harvesting and conservation, provision of information on tea market and sale skills. Extension is essentially education and it could bring positive behavioral changes among farmers. Thus, it is important for Vietnamese tea farmers to have easy access to extension services in order to optimize on-farm technical efficiency and productivity, given the limited resources available.

The next findding of this study is that tea farmers joinning cooperatives could operate at higher level of technical efficiency. In recent years, Vietnamese tea cooperatives played an important role in increasing farmers' income through their improvement of production techniques and machines, knowledge about financial management, and market access capacity. Infact, farmers who joined or formed cooperatives in Vietnam are given priority to attend training courses about production technique and financial management which are funded by the government and other supporting organizations. In these courses, farmers were taught expenditure management, modern tea planting techinques, use of pesticide, integrated pest control and so on. These tea cooperatives also help members establish contracts with other chain actors i.e. supplier of farm inputs and other materials for tea farming; processors; wholesalers; distributors and retailers, develope policies and procedures for procurement; storing and packing as well as support members in equiping sieving machine; vacuum packaging machine and scenting machine. In addition, when participating in cooperatives, Vietnamese tea farmers have more opportunities to exchange information with other members on input markets and services. This enable farmers to adjust their production more effectively. Rahman (2003) also indicated that exchange information on input markets among cooperative members such as timely availability of fertilizers, pesticides and seed at competitive prices may positively affect to their production efficiency. This result is sufficient enough to encourage Vietnamese tea farmers join or form cooperatives.

The final result of this study is female household heads are relatively techncial inefficient than their male counterparts. This result is consistent with the findings of Due and Gladwin (1991) and Akinwuni and Djato (1997). Gender differences in agricultural productivity have been shown to be due to differences in the intensity of use of productive inputs such as: fertilizer, manure, land, credit, extension training, and education rather than differences in the management styles of men and women (Quisumbing 1996). Many factors explain the weakness of women's productivity. Women farmers lack access to cash or credit to acquire modern yield-increasing inputs of production, they tend to produce less (Gladwin 2002). The level of productivity of women is constraint because most agricultural technologies designed based on the assumption that farm mangers are men (Balakrishnan 2004). In reality, women farmers in the study site lack access to inputs, credit, and extension training because most of their time spends on doing housework like cooking, cleaning, washing, and caring children, apart from plucking and weeding possible during the lean season. Most of work in tea cultivation such as: buying inputs, fertilizing, pruning, spraying, managing fund, joining training courses are done by male farmers. Therefore, to improve women farmers' productivity in the region, women need to better support to increase access to factors of production such as: land, credit, inputs, information and technology.

VI. Conclusions and Policy Implications

This study sought to estimate tea production's technical efficiency and its determenants in the North mountainous region of Vietnam using stochastic frontier analysis. The estimated mean technical efficiency level is 89.6%, suggesting that increase output and decrease cost could be obtained by using the available technology. There was big difference in technical efficiency among farmers in the sample, suggesting the potential ability of output increase by using inputs more efficiently.

The study further shows that increasing tea yield depends on the quantity of irrigation water as well as the type and quantity of chemical fertilizers (nitrogen, phophorous, npk). Given the importance of farm inputs in raising tea productivity, further policies should be aimed at increasing investment in irrigation and increasing farmers' access to chemical fertilizers at affordable price. We suggest that the government should focus on stabilizing price of chemical fertilizers through intensifying quality control of chemical fertilizer circulated on the market, controlling the chemical fertilizers production activities; regulating and balancing the supply and demand of chemical fertilizers through reserving and regulating the chemical fertilizers import resources through tax policies and having support policies to improve the capacity of the distribution system. Moreover, the negative and significant impact of pesticide and capital on tea yield show that these resources are over-utilized or inefficiently used. Thus, the government should concentrate on technical assistances for tea farmers such as: effective pesticide application and capital management techniques and integerates pest management pratices.

The farmers' socio-economic and farm characteristics such as: applying soil and water conservation technology, accessing to extension services and participating in cooperative were found to be significant in increasing technical efficiency level of tea production in the region. To improve technical efficiency, the government should encourage farmers practice soil and water conservation technology, implement extension services widely, and promote farmers join cooperatives. The study also reveals that women tea farmers tend to produce less efficiently than their male counterparts. Policies which aim at increasing female farmers' accessing to production inputs as well as extension services will be useful for increasing technical efficiency of tea production.

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References Références Referencias

1. Al-Hassan, S. 2008. Technical efficiency of rice farmers in Northern Ghana. Discussion paper, AERC Research Paper 178 African Economic Research Consortium, Nairobi-4/2008.
2. Akinwuni, A and K.K.Djato. 1997. Relative efficiency of women as farm managers: Profit function analysis in Cote d"voire. Agric. Econ. Vol. 16, 74-53.
3. Aigner, D.J, C.A.K.Lovell, and P.Schmidt. 1977. Formulation and estimation of stochastic frontier production function models. *Journal of econometrics*. Vol. 6, No.1, 21-37.
4. Balakrishnan, R. 2004. Widening gaps in technology development and technology transfer to support rural
women. *Hills Lease held Forestry and for Age Development Project Nepal (GEPMEP/052 NET).*
5. Battese, G.E., and G.S. Corra. 1977. Estimation of frontier production model: With application to pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics*. Vol.21, No.3, 169-179.
6. Battese, G. E., and T. J. Coelli. 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical economics*. Vol. 20. No.2, 325-332.
7. Battese, G.E., S.S. Broca. 1997. Functional forms of stochastic frontier productions and models for technical inefficiency effects: A comparative study for wheat farmers in Pakistan. *Journal of Productivity Analysis.* Vol. 8, 395-414.
8. Baten, A., A. A. Kamil, and M. A. Haque. 2010. Productive efficiency of tea industry: A stochastic forntier approach. *African Journal of Biotechnoly*.Vol.9, No.25, 3808-3816.
9. Basnayake, B., and L. Gunaratne. 2002. Estimation of technical efficiency and its determinats in the tea small holding sector in the wet zone of Srilanka. *Srilankan Journal of Agricultural Economics*. Vol.4, 137-150.
10. Belbase, K and R. Grabowski. 1985. Technical efficiency in Nepalese agriculture. *The Journal of Developing Areas*. Vol.19, No 4, 515-525.
11. Binam, J.N., K.Sylla, I.Diarra, and G. Nyambi.2003. Factors affecting technical efficiency among coffee farmers in Cote d'Ivoire: Evidence from Centre West region. *African Development Review.* Vol 15, No.1, 66-76.
12. Bravo-Ureta, B. E., and A. E. Pinheiro. 1997. Technical, economic, and allocative efficiency in peasant farming: evidence from the Dominican Republic. *The Developing Economies*. Vol.35, No.1, 48-67.
13. Coelli, T.D.S.P.R and E. B. George. 2005. An introduction to efficiency and productivity analysis. *Springer Science, New York.*
14. Cuesta, R.A. 2000. A production model with firm-specific temporal variation in technical inefficiency: With application to Spanish dairy farms. *Journal of Productivity Analysis*. Vol.13, No.2, 139-158.

15. Dang, M. V. 2002. Effects of tea cultivation on soil quality in the northern mountainous zone, Vietnam. Ph. D thesis, University of Sasketchawan, Canada. 175 p.
16. Do, N.Q., and T.K. Le. 2000. Giaotrinh cay che: San xuat, Che Bien, va Tieu Thu (Textbook of Tea Plantation: Field Management, Process and Marketing Product. *Hanoi: Vietnam, NhaXuat Ban Nong Nghiep (Agriculture Publisher)*
17. Due, JM and CH. Gladwin. 1991. Impact of structural adjustment program African women farmers and female-headed households. Agric. Econ. Vol. 73(1991), 1431-1439.
18. Farrell, M. J. 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)*. Vol.120, No.3, 253-290.
19. FAO. 2011. Strengthening capacities to enhance coordinated and integrated disaster risk reduction actions and adaptation to climate change in agriculture in the Northern mountain regions of Vietnam. http://www.fao.org/climatechange/34068-0d42acdf5fb7c4d80f3013c038ab92ce6.pdf
20. Gladwin, C. 2002. Gender and soil fertility in an introduction. Afr. Stud. Quarterly, 6, 1-2.
21. Hayami, Y., and V.W.Ruttan.1971. Agricultural development: An international perspective. Baltimore, Md/London: *The Johns Hopkins Press*.
22. Hanley, N. and C.L.Spash. 1993. Farm management research for small farmer development. Food and Agriculture Organisation of the United Nations, Rome.
23. Haridas, N. S. A. Kumar, V. K. Nerella, M. Deepika, and A. Jyotishi. 2012. Measuring technical efficiency in tea plantations in India: A panel data analysis. Discussion paper, No.132/2012-Amrita School of Business and Vishwa Vidyapeertham University.
24. Jondrow, J., C. A. K. Lovell, I.S. Materov, and P.Schmidt.. 1982. On the estimation of technical inefficiency in the Stochastic Frontier Production function model. *Journal of Econometrics*. Vol.19:2/3 (August), 233-38.
25. Kalirajan, K. 1991. The importance of efficient use in the adoption of technology: A micro panel data analysis. *Journal of Productivity Analysis*. Vol.2, 113-126.
26. Kebede, T.A. 2001. Farm household technical efficiency: A stochastic frontier analysis: A study of rice producers in Mardi Watershed in Western development region of Nepal. Thesis/ Dissertation. The University of Bergen.
27. Khai, H.V., M.Yabe, H. Yokogawa and Sato, G. 2008. Analysis of productive efficiency of soybean production in Mekong River Delta of Vietnam. *Journal of Faculty of Agriculture, Kyushu University*. Vol. 53, No. 1, 271-279.
28. Meeusen, W., and J. V. D. Broeck. 1977. Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review*. Vol. 18, No. 2, 435-444.
29. Mugonola, B., Vranken, L., Maertens, M., Deckers, J., Taylor, D. B., Bonabana-Wabbi, J. and Mathijs, E.2013. Soil and water conservation technologies and technical efficiency in banana production in upper Rwizi micro-catchment, Uganda. *African Journal of Agricultural and Resource Economics*. Vol. 8, No.1, 13-29.
30. Neter, J., W. Wasserman, and M. H. Kutuer. 1989. Applied linear regression models (2nd ed.). *Homewood, Ill.: Irwin.*
31. Nghia, T.D. 2008. An analysis of economic and environmental impacts for the transition to organic tea production in Thai Nguyen Province of Vietnam. Ph.D. thesis, University of Hawaii at Manoa.
32. Nyagaka, D.O., G. A. Obare, J. M. Omiti, and W. Nuyo, 2010. Technical efficiency in resource use: Evidence from smallholder Irish potato farmers in Nyandarua North District, Kenya. *African Journal of Agricultural Research.* Vol. 5, No.11, 1179-1186.
33. Pindyck, R. S., and D. L. Rubinfeld. 1981. Econometric models and economic forecasts (2d ed.). *New York: McGraw-Hill.*
34. Pindyck, R.S. 1991. Irreversibility, uncertainty and investment. *Journal of Economic Literature*. Vol. 29, 1110-1148.
35. Quisumbing, A.R. 1996. Male-Female differences in agricultural productivity: Methodological issue and empirical evidence. *Economic Development and Cultural Change*, Vol 24, 1579-1596.
36. Rahman, S. 2003. Profit efficiency among bangladeshi rice farmers. *Food Policy*. Vol. 28(5-6): 487-503.
37. Saigenji, Y., and M. Zeller. 2009. Effect of contract farming on productivity and income of small holders: The case of tea production in north-western Vietnam. Discussion paper International Association of agricultural economists Conference, Beijing, China-9/2009.
38. Solis, D., B. E., Bravo-Ureta, and R. E. Quiroga. 2006. The effect of soil conservation on technical efficiency: evidence from Central America. *American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association*. In 2006 Annual meeting, July 23-26, Long Beach, CA (No. 21345).
39. Shapiro, K.H. 1977. Source of technical efficiency: the roles of modernization and information. *Economic Development and Cultural change.* Vol 25, No.2, 293-310.
40. Thao, T. D. 2001. On-Site costs and benefits of soil conservation in the mountainous regions of northern

Vietnam. *Economy and Environment Program for Southeast Asia (EEPSEA).*

41. Vietnam General Statistic Office. 2008, 2011, 2012. General report on agricultural product import and export. 24 p, 30p, 33p.
42. Vietnam Tea Association. 2012. General report on tea sector. 17 p.
43. Wenner, R. 2011. The deep roots of Vietnamese tea: Culture, Production and Prospects for Development. Indepent study project (ISP) collection. Paper 1159. http://digitalcollections.sit.edu/isp_collection/1159
45. Xu, X., and S. R. Jeffery. 1998. Efficiency and technical progress in traditional and modern agriculture: Evidence from rice production in China. *Journal of Agricultural Economics*. Vol. 18, 157–165.
46. Zhu, X. and A.Oude Lansink, 2010. Impact of CAP subsidies on technical efficiency of crop farms in Germany, the Netherlands and Sweden. *Journal of Agricultural Economics*. Vol.61, 545–564.
47. Zhang, Y.L. S.H. Luo, Y.H. Zeng and P.Y. Pengo 1997. Study nutrient scale of sufficiency or deficiency in tea soils in Hunan province and fertilizing recommendation. J. ofTea Soil 17 (2): 161-170.