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Agricultural extension and technical efficiency of tea production in northeastern Vietnam

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Abstract

This study uses the stochastic production frontier to analyze technical efficiency of tea production in northeastern Vietnam. Our study estimated that the average technical efficiency of tea production is very low, only about 32%. Technical efficiency can be improved by having a training on sale skills whereas it can be negatively affected by access to information on tea market. The results indicated that there are a big potential for improving technical efficiency in tea production by using the available inputs and technology. For the purpose of improving efficiency, efforts should be made on agricultural extension (keeping the current form of training on sale skills, modifying the provision of information on tea market). Producers are also recommended to be more careful on the adoption of tea variety for their cultivation.

Keywords: Agriculture extension; technical efficiency; stochastic frontier; translog; tea production

JEL Classification: C21; D24; Q12; Q18

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1 Introduction

Tea is globally one of the most popular and lowest cost beverages, next only to water. The major tea producers include India, China, Kenya, Sri Lanka, Turkey and Vietnam (Shah, 2013). In 2011, total tea production in the world exceeded 4 million tons while Vietnam produced about 0.23 million tons (FAO, 2012). The tea sector was ranked as 7th over 20 main agricultural exporting sectors in Vietnam and it accounts about 200 million dollars in total export value in 2011. There are about 400,000 households taking part in the tea cultivation and the tea sector has created over 1,5 million jobs per year (GSO, 2011).

Tea is known as one of the most economically efficient crops in Vietnam after coffee (Tran et al. 2004). Vietnam has potential to increase the share of tea values as it has a great domestic market with about 90 millions inhabitants on the one hand, and an important land surface able to be converted to tea cultivation on the other hand. However, the tea sector surprisingly represents a small part in the Vietnamese economy. Indeed, tea was not included in the list of five strategic agricultural products due to a decrease in its total export value (Van Der Wal, 2008). The tea sector is known as relatively small compared to other agricultural sectors (0.2% of GDP and 7% of total agriculture sector, much lower than other crops).

Some main weakness of the Vietnamese tea sector have been identified: low and unstable quality of tea products, low productivity, preponderance of small producers, fragmentation of cultivation surface, irrational use of pesticides and fertilizers. Another important weakness is the tea variety used in cultivation. Indeed, most of tea cultivation surface correspond to the variety "Trung-Du" which gives a low quality, small leaves, and a low productivity (see Tran et al. 2004).

Agricultural extension policy was designed in Vietnam in order to develop in a sustainable way the agricultural sector by increasing its added value in a sustainable way. The tea sector is also in heart of this agricultural extension. Extension policy encompasses several features: (i) training courses or technical instruction on tea cultivation (land preparation, planting, etc.), (ii) training on modern techniques of application of fertilizer and pesticide, (iii) training on harvesting and conservation, (iv) provision of information on tea market and sale skills. Another measure has been the incitation to adopt new tea varieties such as "PH_1", "LDP_1", and "Bat-Tien", which are thought to have a better productivity and higher quality than the old variety "Trung-Du". These measures of agricultural extension and the adoption of new tea varieties are then expected to have improving effects on technical efficiency (Xiaosong and Jeffrey (1998), Seyoum et al. (1998), Ahmad et al. (2002), Tran et al. (2004), Lindara et al. (2006), Idiong (2007), Al-Hassan (2008), Solis et al. (2009), Nyagaka et al. (2010)).

Our study aims to provide an assessment of technical efficiency relative to tea production in northeastern Vietnam by applying the stochastic production frontier analysis to a data survey collected by ourselves. We particularly try to identify the role of agricultural extension, which is an important policy for agricultural development in Vietnam, and the heterogeneity linked to different tea varieties. Our results are twofold. One the one hand, we observe that tea production in this region suffers from a strong technical inefficiency. On the other hand, the implementation of existing agriculture extension and the adoption of new varieties so far do not have the expected results on technical efficiency, i.e. these measures do not help to reduce technical inefficiency observed in our data.

The remaining of the paper is organized as follows. Section 2 discusses the determinants of technical efficiency, including factors which are related to other crops but appear relevant to tea. Section 3 describes the data we collected ourselves in northeastern Vietnam. Section 4 presents the stochastic production frontier model applied to our data. Section 5 reports estimation results and interpretation. Finally, Section 6 concludes the study.

2 Determinants of technical efficiency

The literature on stochastic frontier production is abundant. Researches on tea production are however relatively scarce and results obtained from existing studies are very heterogeneous. We will limit our attention on studies concerning agriculture and, in particular, the tea sector. We think that results obtained for other crops can be reasonably applied to tea.

Reviews of technical efficiency estimation in agriculture using stochastic frontier production can be found in Battese and Coelli (1992) and Bravo-Ureta and Pinheiro (1993). In particular, Bravo-Ureta and Pinheiro (1993) reviewed the frontier works applied to farm level data collected in developing countries. About 30 studies from 14 different countries were examined. India was the country that has received most attention and rice was the most studied agricultural product. The average technical efficiency computed from all the studies reviewed is about 72%. These findings underline that there is considerable room to rise agricultural output without additional inputs and given existing production technology. The variables frequently used in these works are farmer's education and experience, contacts with agricultural extension, access to credit, and farm size. These variables except for farm size appear to have a positive and significant effect on technical efficiency.

Cuesta (2000) introduced a stochastic frontier model accommodating firm specific temporal variation in technical inefficiency in Spanish dairy farms. Mean technical efficiency is decreasing over time from 0.8574 in 1987 to 0.7755 in 1991, whereas the mean for the entire period is 0.8271. Results from the Battese and Coelli (1992) model (with a common pattern of efficiency change) indicate a decreasing technical efficiency of Spanish dairy farms as well, from 0.8423 in 1987 to 0.8140 in 1991.

Wadud and White (2000) applied a translog model using survey data on rice farmers in Bangladesh. Variables included in modeling technical efficiency are age of farmers, land fragmentation, year of schooling, irrigation infrastructure, environmental degradation. Thiam et al. (2001) used the Cobb-Douglas function and found that crop variety does not seem to significantly affect technical efficiency. Raphael (2008) obtained that technical efficiency of cassava farmers in South Eastern Nigeria is on average about 77%. The study also found that education, farmer's experience, membership of farmers association, credit, household size, improved cassava variety and farm size were found to be significantly related to technical efficiency while age and extension contact were not significantly related to technical efficiency. Khai et al. (2008, 2011) analyzed efficiency of soybean and rice productions in Vietnam and found that the average technical efficiency is around 82%. These studies showed that the most important factors having positive impacts on technical efficiency are intensive labour in rice cultivation, irrigation, and education. The authors observed that agricultural policies did not help farmers cultivate rice more efficiently.

Chirwa (2007) estimated technical efficiency for small maize farmers in Malawi and found that maize production was inefficient, i.e. the average efficiency is only 46.23%. The results of the study reveal that inefficiency diminishes for hybrid varieties and farmers who belong to a farmer club or association. The author also considered farmer's education, fertilizer and agricultural extension as additional determinants of efficiency. However, they effects are no statistically significant.

Regarding tea production, Basnayake et al. (2002) showed that technical efficiency of small tea producers in Sri-Lanka is on average approximately 65%. The authors indicated that farmer's age, education level, occupation, crop variety, and farmer's experience can have significant impacts on efficiency. For Bangladesh, the average technical efficiency was about 59% following Baten et al. (2010). For India, Haridas et al. (2012) found an average technical efficiency of 84.53%. Concerning tea production in Vietnam, Nghia (2008) showed that organic tea production has a very high technical efficiency, about 99%. In their work, Saigenji et al. (2009) showed that the mean technical efficiency is 60%. They also observed that contracted farming gained significantly higher technical efficiency compared to non-contracted farming. More precisely, technical efficiency of farms having a contract with a state-owned firm, farms having a contract with a private firm or a cooperative, and those having no contract is on average 69%, 58%, and 47%, respectively. Other variables affecting technical efficiency were also included, such as total land owned by the household, number of plots, age of tea tree weighted by area, number of extension usage, distance to the collecting point of tea leaves, use of motorbike to collecting point, poverty index. Karki et al. (2012) investigated factors determining the conversion to organic tea producing in Nepal. The research found that farmers who are better trained and have larger farm areas were more likely to adopt organic production. Results suggest that farmers located in a distance from regional markets, older in age, better trained, affiliated with institutions and having larger farms are more likely to adopt organic production. Similarly, a factor analysis shows that environmental awareness, bright market prospects, observable economic benefit and health consciousness are the major factors influencing farmers' decisions on the conversion to organic production. Maity (2012) estimated technical efficiency for tea production in West Bengal, India and found that efficiency increases with the size of tea gardens.

Regarding the variable of interest, agricultural extension, although its effect is expected to have an intuitive sign, i.e. negative effect on technical inefficiency (or positive effect on technical efficiency), confronting with real data gives a contrasted result. For example, Xiaosong and Jeffrey (1998), Seyoum et al. (1998), Ahmad et al. (2002), Lindara et al. (2006), Idiong (2007), Al-Hassan (2008), Solis et al. (2009) and Nyagaka et al. (2010) found that various measures of agricultural extension (access to extension services, training, number of contacts with agricultural extension officers, etc.) can help improving technical efficiency. On the contrary, Khai et al. (2008, 2011), Oladeebo et al. (2007) obtained that agricultural extension features can worsen technical inefficiency. Finally, Hussain (2007) found no significant relationship between agricultural extension and wheat production efficiency.

3 Data

The data used in the research are collected from the field survey in three northeastern provinces (Tuyen-Quang, Phu-Tho, Thai-Nguyen) of Vietnam by the authors from January to May 2013. Tuyen-Quang and Phu-Tho are two provinces which mainly produce black tea whereas Thai-Nguyen is renowned for its green tea. Figure 1 indicates the geographical location of these provinces on the map of northern Vietnam. The survey corresponds to a broad research project on "Welfare, sustainable development, and tea cultivation in northeastern Vietnam" that we currently conduct in Vietnam.

The survey has been done randomly from the household lists of the villages. It consisted of a quantitative household survey of 244 tea farmers including 130 green tea producers and of 114 black tea producers. The households are asked to provide information on tea production in 2012. The main questions are related to important household characteristics such as: assets, social capital, income sources, fertilizers, household head's education, cultivation surface, labor, etc.

Agricultural extension is represented by 7 dummy variables indicating different types of

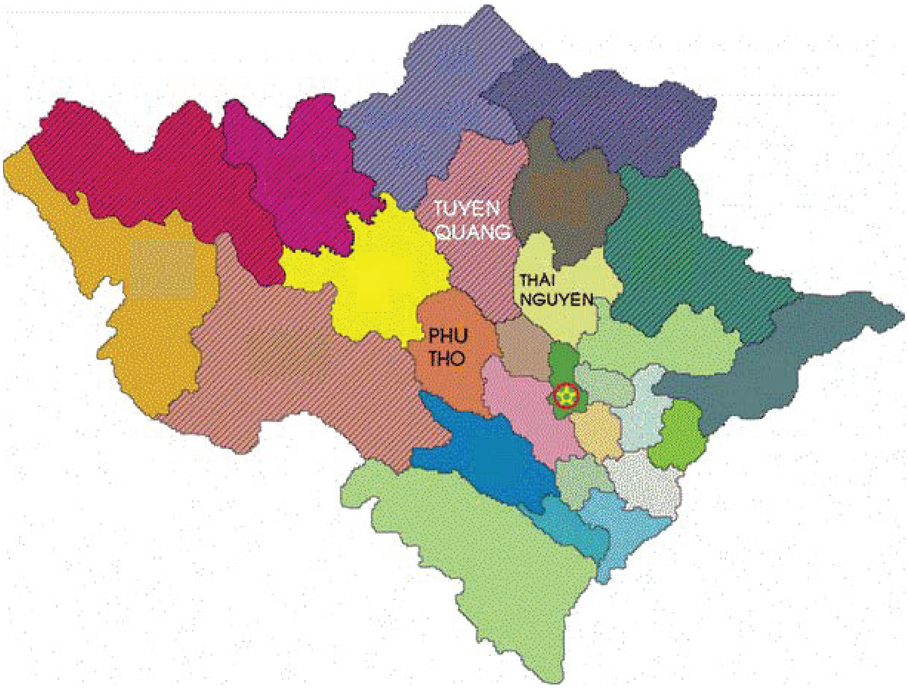

Figure 1: Geographical location of the survey

training and information the producers can receive from officers (training on cultivation techniques, application of fertilizers, application of pesticides, training on harvesting, training on conservation, information on tea market, training of sale). Tea varieties are classified following any types: Trung-Du (the oldest variety), PH_1, LDP_1, Bat-Tien, and other types. As a tea tree only starts giving a significant production if it has at least 5 year old, these varieties are consequently defined over tea trees with 5 year old or higher.

A definition of variables is given in Appendix. The summary statistics of the variables are reported in Table 1. Table 2 gives the distribution of the data following different tea varieties. We observe that the average productivity is about 4.9 tons/year, with a standard deviation of 8.43 which indicates the large variability in productivity among the farmers. Average land area for tea is 0.58 ha per household. The mean of labor participating in tea production (planting, harvesting, etc.) is about 225 person-days/ha.

Table 1: Summary statistics the characteristic for the tea producers

Variable	Mean	Std. Dev.	Min.	Max.
Production (tons)	4.9	8.4	0.02	60
Land (ha)	0.58	0.59	0	4.5
Labor (per-days/hh)	224.63	542.591	5	7863
Fertilizer				
Chemical	0.725	0.447	0	1
Leaf	0.041	0.199	0	1
Organic	0.486	0.501	0	1
Tea variety				
"Trung-Du"	0.455	0.499	0	1
"PH_1"	0.180	0.385	0	1
"LDP_1"	0.213	0.410	0	1
"Bat-Tien"	0.193	0.395	0	1
"Other"	0.176	0.382	0	1
Agricultural extension				
Cultivation	0.717	0.451	0	1
Pesticide	0.590	0.493	0	1
Fertilizer	0.512	0.501	0	1
Harvesting	0.557	0.498	0	1
Conservation	0.320	0.467	0	1
Information	0.254	0.436	0	1
Sale	0.221	0.416	0	1
High-income	0.332	0.472	0	1
High-education	0.328	0.470	0	1
Minority	0.107	0.309	0	1
Black-tea	0.467	0.499	0	1

Table 2: Distribution following tea varieties

Variables	Freq.		Percent	
	No:0	Yes:1	No:0	Yes:1
"Trung-Du"	133	111	54.51	45.49
"PH_1"	200	44	81.97	18.03
"LDP_1"	192	52	78.69	21.31
"Bat-Tien"	197	47	80.74	19.26
"Other"	201	43	82.38	17.62

4 A stochastic production frontier for tea production in northeastern Vietnam

The purpose of this section is to describe a model of stochastic production frontier (SPF) that can be applied to our Vietnamese data. The concept of SPF was introduced by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977).

The stochastic frontier production function has been altered and extended in a number of directions. For example, Stevenson (1980) suggest more general distributions for the u_i; Pitt and Lee (1981) incorporate panel data; Schmidt and Lovell (1979) consider stochastic cost frontiers; and the list goes on. Recent reviews of the frontier literature are provided by Bauer (1990). These many extensions of the stochastic frontier provide a range of tools for the applied economist to choose from.

Afterward, stochastic frontier models get a well liked domain in econometric (see Kumbhakar and Lovell (2003) for an introduction). We assume that output y_i of producer i, $i = 1, 2, ..., n$ is subject to random shocks v_i and a degree of technical efficiency $\xi_i \in (0, 1]$:

$$y_i = f(x_i; \beta)\xi_i \exp(v_i), \ i = 1, 2, ..., n, \tag{1}$$

where x_i is a $K \times 1$ vector of inputs, β a $K \times 1$ vector of parameters to be estimated. By assuming $\xi_i = \exp(-u_i)$ with $u_i \geq 0$, we obtain[1]

$$y_i = f(x_i; \beta) \exp(\theta_i), \ i = 1, 2, ..., n, \tag{2}$$

where $\theta_i \equiv v_i - u_i$. Applying log-transformation to (2), we get

$$\ln y_i = \ln f(x_i; \beta) + v_i - u_i. \tag{3}$$

[1]It should be noted that by definition ξ_i and u_i move in the opposite directions: ξ_i represents a measure of technical efficiency while u_i corresponds to the technical inefficiency. The producer achieves the optimal output when ξ_i reaches the highest value ($\xi_i = 1$) while u_i is at its lowest value ($u = 0$). On the contrary, when u_i tends to infinity, ξ_i tends to 0, the production is totally inefficient.

We observe that v_i corresponds to the usual regression error term, i.e. independently and identically distributed $N(0, \sigma_v^2)$, which captures random variation in output due to factors beyond the control of producers. The error term corresponding to technical inefficiency in production, u_i, is assumed to be independently distributed $N^+(\mu, \sigma_u^2)$ with truncation point at 0.[2] Condition $u_i \geq 0$ ensures that all observations lie on or beneath the production frontier.

An estimation for u_i is given by (see Jondrow et al., 1982)

$$E\{u_i|v_i - u_i\} = \tilde{\mu}_i + \tilde{\sigma}\left\{\frac{\phi(-\tilde{\mu}_i/\tilde{\sigma})}{\Phi(\tilde{\mu}_i/\tilde{\sigma})}\right\}, \tag{4}$$

where $\tilde{\mu}_i = [-(v_i - u_i)\sigma_u^2 + \mu\sigma_v^2]/\sigma^2$, $\tilde{\sigma} = \sigma_v\sigma_u/\sigma$, $\sigma = (\sigma_v^2 + \sigma_u^2)^{1/2}$, and $\phi(.)$ and $\Phi(.)$ are respectively the density and the cumulative distribution function of the standard normal distribution. A $(1-\alpha)\%$ confidence interval of the conditional distribution $u_i|(v_i - u_i)$ is given by

$$\begin{aligned} LB_i &= \tilde{\mu}_i + \tilde{\sigma}\Phi^{-1}\left[1 - (1-\alpha/2)\Phi(\tilde{\mu}_i/\tilde{\sigma})\right] \quad (5) \\ UB_i &= \tilde{\mu}_i + \tilde{\sigma}\Phi^{-1}\left[1 - (\alpha/2)\Phi(\tilde{\mu}_i/\tilde{\sigma})\right] \quad (6) \end{aligned}$$

where LB_i and UB_i correspond to the lower bound and the upper bound, respectively (see Horrace and Schmidt, 1996, 2000, and Greene, 2008).

The degree of technical efficiency can be estimated by the following conditional expectation

$$\hat{TE}_i \equiv E\{\exp(-u_i)|v_i - u_i\} = \left\{\frac{\Phi(\tilde{\mu}_i/\tilde{\sigma}) - \tilde{\sigma}}{\Phi(\tilde{\mu}_i/\tilde{\sigma})}\right\}\exp\left\{-\tilde{\mu}_i + \frac{1}{2}\tilde{\sigma}^2\right\} \tag{7}$$

where $v_i - u_i = y_i - \ln f(x_i; \beta)$ from equation (3). The $(1-\alpha)\%$ confidence interval for technical efficiency $\hat{\xi}_i$ can be computed as $\{\exp(-UB_i), \exp(-LB_i)\}$.

In order to compute technical efficiency, we need to estimate parameters from model (3) which can be performed by maximum likelihood. The log-likelihood of this model is

$$\begin{aligned} \ln L = & \sum_{i=1}^{n}\Big\{-\frac{1}{2}\ln(2\pi) - \ln\sigma - \ln\Phi\big(\frac{\mu}{\sigma\sqrt{\rho}}\big) \\ & + \ln\Phi\Big\{\frac{(1-\rho)\mu - \rho(v_i - u_i)}{\{\sigma^2\rho(1-\rho)\}^{1/2}}\Big\} - \frac{1}{2}\Big\{\frac{(v_i - u_i) + \mu}{\sigma}\Big\}^2\Big\}, \quad (8) \end{aligned}$$

where $\rho = \sigma_u^2/\sigma^2$.

For the estimation, we need to specify the functional form for $f(x_i; \beta)$. Usually, it may correspond to the Cobb-Douglas and translog function. Moreover, as in Battese and Coelli (1995) and Kompas (2004), instead of the homogeneity in the distribution of technical efficiency ($u_i \sim N^+(\mu, \sigma_u^2)$) we can specify a conditional mean model for u_i as

$$u_i = z_i'\delta + \eta_i, \tag{9}$$

[2]We can also assume that u_i follows an exponential or a half-normal distribution.

where z_i' is a $L \times 1$ vector of explanatory variables, δ is the associated vector of unknown coefficients, and η_i is $N^+(0, \sigma_u^2)$ with truncation point at 0. In this case, we replace μ in the above expressions by $z_i'\delta$. We observe that some input variables may be included in both x_i and z_i (Battese and Coelli 1995, Kompas (2004)). The absence of technical inefficiency is characterized by $\rho = \delta = 0$. This test may be implemented by a likelihood ratio test with correct critical values provided by Kodde and Palm (1986).[3]

5 Estimation results

Using the stochastic production frontier presented in the previous section, we firstly use the likelihood-ratio test in order to choose which production function is the most suitable for modeling tea production. The two competing production functions are Cobb-Douglas (null hypothesis) and translog (alternative). The test statistic is 18.59, which is higher than the critical value of the $\chi^2(10)$ distribution at the 5% level (18.307), leading to the rejection of the Cobb-Douglas function in favor of the translog one.

By using the translog model, we test for absence of technical inefficiency, which corresponds to the null hypothesis $H_0 : \rho = \delta = 0$. We observe that the distribution of the likelihood-ratio test statistic is not standard under the null hypothesis. We can however use the non standard critical values provided by Kodde and Palm (1986). As the computed value of the test statistic is 337.041, much higher than the 5% critical value 28.268, we can reject the null hypothesis and therefore conclude that there may be inefficiency in tea production.

The final test is related to the joint significant of determinants of inefficiency. The likelihood-ratio statistic follows a $\chi^2(16)$ distribution under the null hypothesis $H_0 : \delta = 0$ (except the intercept). The computed value of the statistic is 161.53, strongly higher than the 5% critical value 26.296, implying that the determinants included in the model are jointly significant. In other words, the factors used here can provide an explanation for technical efficiency in tea production.

In the following, we report the results on the translog production function and the determinants of technical inefficiency. Table 3 shows the coefficients of the translog frontier production model with bootstrap standard errors. All the direct effects of production inputs (fertilizers, labor, and land) appear statistically insignificant. Certain joint effects of these factors are significant. Indeed, the interaction term between chemical fertilizer and labor has a significantly negative effect (-0.207), representing a substitution between these two factors, i.e. an increase in labor can help compensate a diminution in the use of chemical fertilizer.

[3] The usual critical values of the likelihood-ratio statistic cannot be used here because the distribution of the test statistic under the null hypothesis ($H_0 : \rho = \delta = 0$) is not well defined.

In other words, labor effect on production is lower when chemical fertilizer is used during the production process than when there is no chemical fertilizer. Moreover, the result shows that chemical fertilizer and leaf fertilizer are substitutes (the coefficient of the interaction term is -1.513), i.e. using both chemical fertilizer and leaf fertilizer will lower the production.

Table 3: Production function for tea production, translog model

Variables	Coef.	(Boots. Std. Err.)
Intercept	-3.743	(2.497)
Leaf fertilizer	1.086	(2.660)
Organic fertilizer	0.795	(0.871)
Chemical fertilizer	0.579	(0.682)
lnLand	0.502	(0.342)
lnLabor	-0.000	(0.440)
lnLand×lnLabor	0.042	(0.060)
Chemical×lnLand	0.67	(0.108)
Chemical×lnLabor	-0.207*	(0.110)
Chemical×Organic	0.119	(0.181)
Chemical×Leaf	-1.513**	(0.693)
Leaf×lnLand	-0.044	(0.635)
Leaf×lnLabor	0.114	(0.701)
Leaf×Organic	0.269	(0.726)
Organic×lnLand	-0.108	(0.103)
Organic×lnLabor	-0.010	(0.083)

Notes: ** and * mean for significance at the 5% level and 10% level, respectively.

Table 4 reports estimation results on determinants of technical inefficiency associated to the translog production function. Among variables on agricultural extension, information on tea market and training on sale skills are the only two significant factors. However, their impacts on technical inefficiency are of opposite direction. In particular, contrary to sale skills which has a decreasing effect on inefficiency (-0.236), information on tea market has an unexpected effect (0.243). This finding means that the current state of information can disrupt technical efficiency rather than improve it. This results is consistent with Khai et al. (2008, 2011), Oladeebo et al. (2007).

There is a heterogeneity relative to tea varieties. Indeed, among five groups of tea varieties, only variety “Trung-Du” and “Other” varieties group have significant impacts. The result shows the efficiency of the production of these varieties. The effects of “Trung-Du” and

"Other" varieties group are -0.260 and -0.308, respectively.

We also observe that black tea production proves to be more efficient (the estimated effect is -2.302) than green tea production. This finding seems contradict the results of Nghia (2008) who found that green tea has a very high technical efficiency (the computed technical efficiency of green tea is 99.8%). Finally, other variables such as high income, high education of the head of the household and minority appurtenance have no significant effect on technical efficiency.[4]

We also compute the distribution of technical efficiency for our data as described in the previous section. Table 5 provides a summary of the distribution of technical efficiency. The computation points out that the technical efficiency is very low for our data. The average value of TE is about 0.323, and the range is very large, varying from 0.005 to 0.915. The distribution of TE can be clearly observed in Figure 2. Many tea producers have a low technical efficiency. In particular, approximately a half of them have a technical efficiency below 40%.

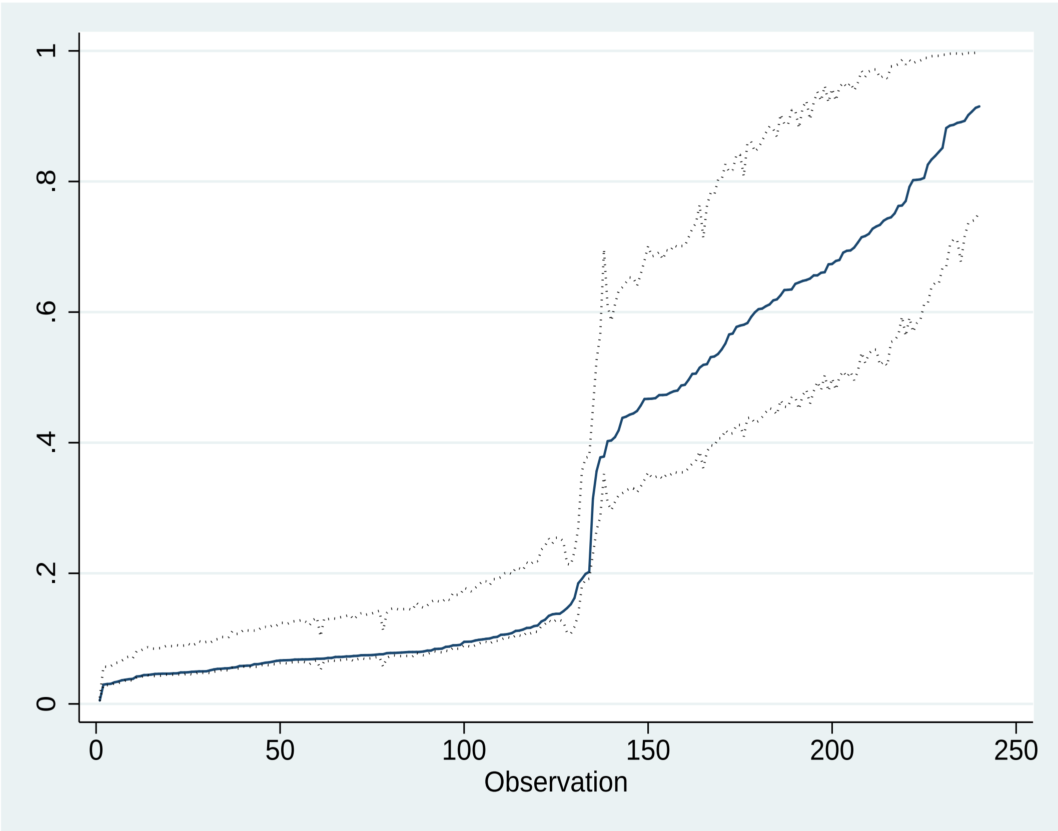

Figure 2: Estimation of technical efficiency and its confidence interval. Observations are ranked in increasing order of efficiency. The solid line represents technical efficiency $\hat{TE}_i \equiv E(\exp(-u_i)|v_i - u_i)$. The dashed lines correspond to the 95% confidence interval.

[4]We also included other variables like number of members per household, age of the head of the household, gender, etc. However, the results do not change as the coefficients of these additional variables are insignificant.

Table 4: Determinants of technical inefficiency in tea production, translog model

Variables	Coef.	(Boots. Std. Err.)
Agricultural extension		
Cultivation	0.116	(0.164)
Pesticide	-0.146	(0.142)
Fertilizer	-0.103	(0.179)
Harvesting	-0.023	(0.182)
Conservation	0.213	(0.146)
Information	0.243**	(0.123)
Sale	-0.236*	(0.127)
Tea variety		
"Trung-Du"	-0.260*	(0.151)
"PH_1"	-0.147	(0.325)
"LDP_1"	-0.176	(0.127)
"Bat-Tien"	-0.140	(0.144)
"Other"	-0.308*	(0.180)
Black tea	-2.302**	(0.354)
High income	-0.028	(0.134)
High education	-0.004	(0.102)
Minority	0.109	(0.117)
Intercept	2.911**	(0.380)
$\ln(\sigma^2)$	-1.183**	(0.253)
$\text{logit}(\rho)$	2.079	(11.935)
σ_u^2	0.272	(0.365)
σ_v^2	0.034	(0.362)
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.306	(0.078)
$\rho = \sigma_u^2/\sigma^2$	0.888	(1.179)

Notes: ** and * mean for significance at the 5% level and 10% level, respectively.

Table 5: Summary statistics for technical efficiency

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Technical efficiency	0.32260	0.29375	0.00521	0.91496	240
u_i	1.86051	1.02825	0.28020	5.30831	240

6 Conclusions

This paper studies the determinants of technical efficiency in tea production in the northeastern Vietnam using the stochastic production frontier. The research underlines that tea production in this region suffers a strong inefficiency (technical efficiency is on average approximately equal to 32.2%). This result shows that there exists a high potential for improving technical efficiency. Hence, the main concern remains to identify the factors which could decrease production inefficiency.

As we observed that among different factors included in our model, agriculture extension and tea varieties can influence technical efficiency. Concerning agriculture extension, we should pay attention on market information and training on sale skills. Training on sale skills can be provided in its present form to tea producers as it can help reducing technical inefficiency. However, given the positive effect of information on inefficiency, we can say that information on tea market provided to producers during the period of survey was of low quality and that this "bad" information was harmful to tea production. Hence, action should be taken in order to modify information provision accordingly in order to reverse the sign of its effect.

Regarding tea varieties, our finding suggest that tea producers should be careful about adopting new tea varieties. In particular, they would choose either "Trung-Du" or "Other" because they can help to improve technical efficiency. This result contradicts the current recommendation about the non-adoption of the "Trung-Du" variety.[5]

Moreover, our analysis shows that black tea production is more technically efficient than green tea production. This adds another dimension to the problem of choosing between green tea production and black tea production. We think that the decision about the conversion from black tea production to green tea one or vice versa should not only base on economic value (green tea has a higher economic value than black tea), but also on technical efficiency (green tea is technically less efficient than black tea).

An interesting extension we can develop in future is to address the issue of choosing green tea production versus black tea production, by accounting for these elements, i.e. high economic value of green tea and high technical efficiency of black tea.

[5]We can refer to some websites of Vietnamese newspapers or institutions, for example `http://www.hoinongdan.org.vn/index.php/phong-trao-nong-dan/nong-dan-sxkd-gioi/8297` (Association of farmers), `http://thuvienphapluat.vn/archive/Quyet-dinh-4184-QD-UBND-nam-2013-De-an-phat-trien-che-Nghe-An-2011-2015-vb210411.aspx` (Legal documents), `http://baophutho.vn/kinh-te/cong-nghiep/201311/nang-cao-chat-luong-de-phat-trien-che-ben-vung-2284001/` (Phu Tho's newspaper).

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Appendix

Table A1: Definition of variables

Variable name	Definition	Nature
lnLand (m^2)	log of land which a household use planting the tea	continous
lnLabor (person-days/hh)	log of total the number person-days per household	continous
Tea variety		
"Trung-Du"	tea variety, $\geq$ 5 year old	dummy
"PH_1"	tea variety, $\geq$ 5 year old	dummy
"LDP_1"	tea variety, $\geq$ 5 year old	dummy
"Bat-Tien"	tea variety, $\geq$ 5 year old	dummy
"Other"	other tea varieties, $\geq$ 5 year old	dummy
Pesticide	use of pesticide	dummy
Fertilizer		
Chemical	use of chemical fertilizer	dummy
Leaf	use of fertilizer for leaves	dummy
Organic	use of organic fertilizer	dummy
Agricultural extension		
Cultivation	training on tea cultivation	dummy
Pesticide	training on pesticide	dummy
Fertilizer	training on fertilizer	dummy
Harvesting	training on harvesting	dummy
Conservation	training on conservation	dummy
Information	information on tea market	dummy
Sale	training on sale skills	dummy
High income	subjective perception of high income	dummy
High education	high level of education (high school or above)	dummy
Minority	household corresponds to a minority	dummy
Black tea	black tea production	dummy