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Profit efficiency of tea farmers: case study of safe and conventional farms in Northern Vietnam

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Abstract Safe tea production conducted under the standards of Vietnamese Good Agricultural Practices has been strongly encouraged by the Vietnam government. However, there is no study on profit efficiency of safe tea producers, which are therefore barriers for farmers and policymakers in terms of extending the safe tea production practice in Vietnam. Thus, this study investigated the profit efficiency of tea production practices using a stochastic profit frontier function. We applied propensity score matching to control for self-selection in assessing the profit efficiency of safe and conventional tea farming. Our results indicated that the average profit efficiency of tea farmers was around 74%, suggesting 26% of profit was lost due to inefficiency. Furthermore, significant different profit efficiency was observed between the two farmer groups. We further found that tea farmers with larger production scale, better irrigation system, accessing extension service are more likely to adopt safe tea practices than others are. Thus, public policies should focus on improving profit efficiency and facilitating adoption of eco-friendly production practice, and also supporting innovations to improve farmers' production conditions, including the access to extension service, irrigation system, enlarged farm size, and labor-saving machinery.

Keywords Profit efficiency · Propensity score matching · Safe tea · VietGAP · Vietnam

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1 Introduction

Tea plays an important role in Vietnam, in terms of the culture and economy. In Vietnam, tea plantation has a long history, dating back over 3000 years, and tea drinking is an integral part of Vietnamese culture (Tran 2008; Tran et al. 2004). From an economic point of view, tea is an important cash crop for farmers in the northern provinces of Vietnam. In 2012, about 146,700 tons of tea products were exported, valued about USD 224.6 million (FAO 2012). With a gross planting area over 130,000 ha, tea contributes significantly to job generation. According to the Centre for Research on Multinational Corporations (SOMO 2007), about 400,000 households are involved in tea production for their income and livelihood. The tea industry supplies about 1.5 million jobs for Vietnamese people.

Conventional tea production has been facing many challenges. Although the tea consumption and export volume have been increasing steadily since 1990s, tea has been mainly exported to the traditional markets with low requirements, such as China, Russia, Taiwan, and Iran (Tran et al. 2004). Besides, chemical components and pesticide have been widely used by tea farmers for protecting tea farms. Improper use of pesticides and chemical fertilizers has led to detrimental consequences for human health and the environment (Aktar et al. 2009; Tran et al. 2015; Hong and Yabe 2015). This, combined with domestic consumers' increasing concerns on food safety, led to the conversion from conventional to "safe or clean" tea production in Vietnam. Since 2008, the Vietnamese government has promoted the implementation of a voluntary standard package, called the Vietnamese Good Agricultural Practices (VietGAP), which is established on hazard analysis and critical control points, ASEAN Good Agricultural Practices, Global Good Agricultural Practices, and Freshcare. This standard package is designed to provide basic criteria for controlling agricultural production and must be applied in all stages including field selection, pre-plant field preparation, production, harvest, and post-harvest (MARD 2008). VietGAP tea production is certified by authorities for non-chemical residue. This is also considered as eco-friendly production practices due to maximal use of organic components in cultivation and protection (Ha 2014b).

Although there have been many studies on Good Agricultural Practices (GAPs) from various aspects, the findings are not consistent. For instance, the adoption of GAPs was identified as having a positive impact on the technical efficiency (Taraka et al. 2011; Ha 2014b), while some studies stated that farmers adopting GAPs do not receive a higher price (Calvin et al. 2004; Subervie and Vagneron 2012; Pongvinyoo et al. 2015), and others have found a positive impact on price, yield, or income (Kariuki et al. 2012; Islam et al. 2012). In Vietnam, data on the production efficiency of VietGAP adoption are limited due to the relatively late implementation of VietGAP. Reports on the production efficiency, advantages, and challenges of VietGAP tea production have appeared only in brief articles provided by the government or daily news agencies (Thuong 2016; Thao 2013; Tran 2016; Vietnam News Agency 2016). Ha (2014a) indicated that applying VietGAP in agricultural production would be a conversion period toward organic production, aiming to address relative challenges. Several works have focused on tea production. Tran (2008) estimated the economic efficiency of organic tea farmers in Thai Nguyen province. Saigenji (2011) determined the impact of contract farming on production efficiency and household income in the northwest region of Vietnam. Hong and Yabe (2015) investigated the profit efficiency of conventional tea farmers. According to Tran (2009), analyzing and comparing different tea production practices is an important element of understanding farmers' decision-making. Nguyen et al. (2015) concluded that tea production adopting VietGAP had achieved significantly higher yields than those using organic methods. Although the profit efficiency of tea farmers was also investigated by Hong and Yabe (2015), her study did not consider VietGAP tea practices. Tran (2008) confirmed that the production and profit efficiency of organic tea farming are higher than those of clean tea farming and conventional tea farming. This means that production practices can create different production efficiency, and thus, it is necessary that we study the production efficiency of VietGAP tea farmers.

There are several approaches of impact evaluation and various econometric methods have been used over the decade (Khandker et al. 2010). The choice of a particular method in a specific context is always argued for empirical economic analysis in the different fields (Wang et al. 2014). For instance, the effect of treatment can be estimated as the coefficients of covariates for treatment in the regression (Imbens 2004), while other studies also assessed the impact by including a dummy variable whether the farmer cultivated a certain crop or improved technology (Walker et al. 2004). In standard context, impact evaluation can provide most precise results if same farmers are compared with each others before and after the adoption takes place. This will ensure that there are not original differences in evaluation that may lead to bias results. In other words, baseline data on probable adopters would be needed before the adoption takes place. This might be possible in research trial with a small sample scale, but it is unfeasible at the regional scale. Imbens and Wooldridge (2009) found that better performance of some farmers might be the result of the characteristics of individuals rather than being an adopter or non-adopter. It is notable that in literature, the data is often obtained from non-randomized observational studies rather than from randomized trial (Becker and Ichino 2002). This implies that a selection bias among farmers might have a significant impact on their decisions and production performance. Thus, comparing the profit efficiency of tea practices could be biased if we do not control for these factors. To address this gap, this study investigated the profit efficiency of VietGAP and conventional tea farms. Then, we assessed the difference in profit efficiency between the two farmer groups, using propensity score matching to the control selection bias.

2 Methodology and data collection

2.1 Measurement of production and profit efficiency

Over last two decades, most of the empirical studies in agricultural production efficiency have focused on two major groups. One category of the literature estimated efficiency concerning price response of input demand. The other trend considered production inefficiency ignoring price responses (Arnade and Trueblood 2002). Of which cost minimization and profit maximization hypotheses are often considered in modeling production inefficiency. The difference here is that under cost minimization hypothesis, outputs are not included, and inputs are the endogenous variables, while both input and outputs are endogenous under profit maximization hypothesis. The estimation method using profit function was developed to deal with both production inefficiency and response price (Kumbhakar 1996). Production inefficiency is usually analyzed by its three components, namely technical, allocative, and scale inefficiency. In general context, if output level of a production unit lies below the maximum feasible output (the frontier output), then it is said to be technically inefficient, for a given set of inputs. Similarly, if a production unit is not using inputs in optimal proportion given the observed input prices and output level, then it cannot also be allocatively efficient. In a framework of profit maximization, a production unit cannot also be of scale efficiency if it is not producing an output level by utilizing the product price with the marginal cost (Kumbhakar et al. 1989). Recent developments of econometrics combined three measurements into one system, which enables more efficient estimation to be obtained by simultaneous estimates of the system using a profit function framework (Ali and Flinn 1989; Kumbhakar et al. 1989; Wang et al. 1996). A frontier production function is a widely used approach to measure efficiency, its components (Battese and Coelli 1995). However, measuring efficiency using a production function approach may be inappropriate when farmers face various prices and have different factor endowments (Ali and Flinn 1989). As a result, the stochastic profit function is directly applied to estimate a firm-specific efficiency (Kumbhakar et al. 1989; Ali and Flinn 1989; Wang et al. 1996). The profit function approach combines these three concepts (technical, allocative and scale inefficiency) into the profit relationship and any errors in the production decision are assumed to be lower profit for production units. According to the production analysis literature, two primary frontier methods are widely used to analyze production efficiency—the econometric approach and the mathematical programming approach (Lovell 1993). The stochastic frontier model is included two components. The first is a symmetric component that captures random variations of the frontier across firms and the effects of measurement errors. The second is a one-sided component that captures the effects of inefficiency relative to the stochastic frontier and incorporates an error term (Aigner et al. 1977). The stochastic frontier approach (SFA) is an econometric stochastic model that can separate the effects of noise from technical inefficiency.

The stochastic profit function is defined as follows:

$$\pi_i = f(P_i, Z_i) \cdot \exp(\xi_i), \tag{1}$$

where π is the normalized profit for the ith farm, defined as revenue less total variable costs, divided by firm-specific output price; P_i is a vector of the input price variables of ith farm, divided by the output price; Z_i is a vector of the fixed factors of the ith farm; i is the number of tea farms in the sample; and ξ_i is an error term, consisting of two components, v_i and μ_i (Ali and Flinn 1989). Then,

$$\xi_i = v_i - \mu_i, \tag{2}$$

where v_i is assumed to be independently and identically distributed $N(0, \sigma_v^2)$; μ_i denotes non-negative random variables associated with production inefficiency, and v_i and μ_i are independent of each other.

The profit efficiency (PE) of farm ith in the context of the stochastic frontier profit function is defined as

$$\mathrm{PE} = E[\exp(-\mu_i)|\xi_i], \tag{3}$$

where E is an expectation operator that can be estimated by obtaining the expressions for the conditional expectation μ_i upon the observed value of ξ_i ($0 \leq \mathrm{PE} \leq 1$).

2.2 Empirical model

Tea growers have many options for selecting inputs and selling their products as well. This leads to variations in the vector of actual prices faced by farmers. The price variation can be different in locations and product quality. Thus, a tea farmer can be assumed to allocate the inputs in optimal proportion by equating their ratios to the marginal productivity. In economic theory of profit efficiency analyses, a farm operation is assumed to maximize its profit in the given condition of perfectly competitive input and output markets, and a given output technology. Profit efficiency is defined as the ability of a farm to achieve the highest possible profit, with given the prices and fixed factors used. Then, profit inefficiency in this context is defined as the loss of profit resulting from not operating on the frontier (Ali and Flinn 1989). In other words, the profit efficiency of a tea farmer in this study is defined as the profit achieved from operating on the profit frontier, taking into consideration the variable input prices and quasi-fixed input quantities. According to Rahman (2003) and Kolawole (2006), the profit of a specific farm is equal to total revenue less total variable costs.

Taking the Cobb-douglas production form for production frontier, the production frontier function in an Eq. (1) can be written in logarithmic form as:

$$\ln vn/p = \alpha_0 + \Sigma\alpha_i \ln P_i/p + \Sigma\alpha_q \ln z_q + v_i - \mu_i, \tag{4}$$

where vn/p is a normalized variable of the profit frontier, P_i/p is a normalized variable of input prices, z_q denotes the quasi-fixed input quantities, and α_i and α_q are unknown parameters.

Then, P_i is the price of the ith input variable used by ith tea farm, normalized by dividing the tea price of the farm (p), including chemical fertilizers (equivalently converted to NPK), organic compounds, pesticide costs, labor costs, and the other costs. In addition, z_q is the quantity of fixed inputs used by a tea farm, including the tea farm size (ha), v_i is the statistical noise, μ_i is the effect of profit inefficiency, and α is the unknown parameter needs to be estimated.

The technique of maximum likelihood estimation is used to estimate the unknown parameters. The likelihood function is expressed in terms of variance parameters, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma_v^2$ (Battese and Coelli 1995). Then, the profit efficiency level of specific tea farms was predicted using specified statistic software. Finally, the regression model was deployed to determine the factors that affect the levels of profit efficiency of tea farmers. The regression model is given as follows:

$$\mathrm{PE} = \beta_o + \Sigma\beta_j Z_j + \omega, \tag{5}$$

where PE is the profit efficiency level of the ith tea farmer; Z_j denotes the variables of socioeconomic and farm characteristics that can affect the profit efficiency of a tea farmer, including gender, formal education, family labor, farming experience, irrigation access, credit access, ratio of tea income, membership of cooperatives, and machine status; and ω is an error term representing factors outside the model.

2.3 Propensity score matching

In case of randomized experiment context, the mean impact of a treatment on the treated group can be easily determined by measuring the difference between mean values of the outcome variable for both treatment and control groups. However, this approach could not be applied in the case because VietGAP tea farmers are not random. In other words, an appropriate method for impact evaluation in non-experimental case should be applied in the present case. Thus, we applied a propensity score matching (PSM) method to quantify the impact of VietGAP adoption on farmer using cross-sectional data.

The PSM was used to compare groups by matching individuals with similar characteristics or features. Theoretically, a PSM model attempts to create an experimental condition in which adopters and non-adopters are selected randomly. According to Becker and Ichino (2002), PSM is a two-step mathematical procedure. The first step estimated a farmer's propensity score using logit or probit models as follows:

$$Y(1,0) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \tag{6}$$

where Y is the dependent variable (1 = VietGAP farmer, 0 = conventional farmer), β denotes the estimated coefficients, and X_n denotes covariates. The choice of the covariates in X should be guided by economic theory, a sound knowledge of previous research (Sianesi 2004; Smith and Todd 2005). The omission of important variables can seriously increase bias in estimating results (Dehejia and Wahba 1999). In the study, we used the same covariates "number of family labors, formal education of household's head, credit access, extension access" as Noltze et al. (2012). We added the variables "irrigation status, machinery use" as indicators of mechanization in tea production (Tran 2008). The variables as gender, farming experience, farm size can also affect the adoption of agricultural innovations or production standards. Thus, they were also included in the model as Kersting and Wollni (2012). Finally, we incorporated a variable "ratio of tea income" to account for importance of tea income in the study area.

Then, the propensity score was estimated using the following equation:

$$P_{\text{score}} = 1/1 + e^{-(\beta_o + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n)} \tag{7}$$

In the second step, farmers with similar propensity scores between the groups were matched to estimate the average treatment effect for the treated (ATET), denoted as

$$\text{ATET} = E(Y_1 - Y_0)|x, D = 1) = E(Y_1|x, D = 1) - E(Y_0|x, D = 1), \tag{8}$$

where D is an indicator equal to one if the farmer applies VietGAP, and zero is otherwise, Y_1 is the outcome for a VietGAP adopter, Y_0 is the outcome for a non-adopter, and x is a vector of control variables. Then, single nearest neighbor matching (NNM) was used to match similar observations.

The estimator that provides the statistically identical variable means for treatment and control groups is preferable. Propensity score matching works under conditional independence assumption and common support. In fact, there might also be unobservable variables that affect both adoption of VietGAP production and its outcome variables. A hidden bias might arise if matching estimators are not robust (Rosenbaum 2002). These hidden biases may lead to both positive and negative unobserved adoption decision. As a result, the treatment effect would be overestimated if a farmer adopted the VietGAP production is also more likely to adopt VietGAP standards. Conversely, if negative unobserved selection exists, the treatment effect would be underestimated, because that the conditional independence assumption could not be directly tested. Thus, balancing test should be tested instead of first one. In previous studies, several indicators were used to check whether the matching procedure can balance the distribution of the relevant variables in both groups. Significant differences should not be systematically existed after conditioning on the propensity score (Caliendo and Kopeinig 2008). Adequate matching quality should create significantly lower standardized bias (Rosenbaum and Rubin 1985). They include statistically insignificant likelihood ratio test on the joint significance of all regressors (Smith and Todd 2005), and fairly low pseudo-R^2 (Sianesi 2004) after matching. Finally, common support should be accomplished by using visual inspection of the densities of propensity scores of treatment and control groups. Also, another way could be done via comparison test such as the Kolmogorov–Smirnov nonparametric test. If sizeable differences existed between the maxima and minima of the density distribution, cases lying outside the support of other distribution should be removed (Caliendo and Kopeinig 2008).

2.4 Description of used variables

All variables used in the model were selected on the basis of economic theory, the findings of previous studies, and the actual status of agricultural production in the study area. The dummy variable was used to assess the adoption of VietGAP among farmers instead of adoption index. This was derived from the fact that VietGAP certification is only certified for tea farmers who strictly follow all requirements of the organization as stipulated. Previous analysts have shown that a farmer's behavior can be affected by socioeconomic characteristics, such as education level and income, among others (Coady 1995; OECD 2008). Other dummy variables include machinery use, extension, credit access, as also used in recent studies (Hong and Yabe 2015; Coelli et al. 2002). At the same time, features of crops and agricultural products, such as input cost, output price, yield, irrigation pattern, and others, are also believed to have strong relationships with new crop management practices. The definitions of the variables are presented in Table 1.

2.5 Study site and data collection

The northern Vietnam is a major tea production region, accounting for 64.7% of total tea output and 71.6% of the country's tea production land. The field survey was conducted in Thai Nguyen province locating in the region that is very well known for tea production. According to GSO (2013), the province is the first position in tea production. We used a two-stage sampling technique for data collection. First, large number of farmers adopted VietGAP and conventional tea-producing districts in the region were sampled in three districts of the province, including Thai Nguyen city, Dai Tu and Dong Hy. Second, a random sampling technique was adopted to select representative VietGAP and conventional tea farmers belonging to the same study site. In other words, the survey did not make any prior stratification by gender, education level, assets marital status of household head or any other attribute of tea farmers in the study area, which is believed to have ensured equal chances of inclusion of VietGAP and conventional tea farmers. The farm-level data, essential to this study, was gathered by interviewing tea farmers using structured questionnaires constructed specifically for this purpose. The questionnaire set was designed with the support and aid of consultants and colleagues who have much experience in field surveys. Prior to the interviews, we translated the questionnaire, initially designed in English, into Vietnamese. Then, the questionnaire was pre-tested on 10 tea farmers in the study site. Based on the feedback, the questionnaire was updated and modified. Finally, the completed version was used to gather the data, including information on input use, costs, yields and output prices, farm-level characteristics as well as socioeconomic characteristics of the households. The data was collected through questionnaire interviews by enumerators who were trained prior to the exercise, between July and August 2016. After field survey, total dataset of 116 VietGAP and 210 tea farmers was used for analysis in this study. Besides, secondary data was also obtained from the General Statistic Office of Vietnam and communal reports during the field survey.

Table 1 Variable definition of used models

Variable	Definition	Unit
Used in the profit model		
Profit	Net return per hectare	K.vnd[a]/ha/year
Adop	Adoption of production practices (1-VietGAP; 0-CON)[b]	dummy
Pchem	Price of chemical fertilizer (converted NPK)	K.vnd/kg
Porg	Price of organic fertilizer	K.vnd/kg
Pescost	Cost for pest & disease control	K.vnd/ha/year
Plabor	Price of hired labor using in farm	K.vnd/day
Ocost	Other costs (fuel, fee…)	K.vnd/ha/year
Farm size	Tea farm size	ha
Used in the Tobit model		
PE score	Profit efficiency score of tea farmer	percent
Gender	Gender of household head (1-male; 0-female)	dummy
Formal education	Formal education (1-primary, 2-secondary, 3-high school, 4-upper)	category
Family labor	Number of family labors (aged 16-65 s) involving in tea production	number
Experience	Tea production experience of household head	year
Irrigation	Investing active irrigation system serving for tea farm (1-yes; 0-no)	dummy
Credit access	Accessing to credit loan invested for tea production (1-yes, 0-no)	dummy
Tea income ratio	Ratio of tea income over total family income	percent
Cooperative	Status of joining in tea production cooperative or group (1-yes; 0-no)	dummy
Extension access	Accessing trained service that meets farmer's demand (1-yes; 0-no)	dummy
Machinery use	Status of machinery application in tea processing (1-yes; 0-no)	dummy

[a]K.vnd: monetary unit of Vietnam measured in thousand dong; 1 usd ~ 21 K.vnd

[b]VietGAP farm: tea farm under Good Agricultural Practices

CON conventional tea farm

3 Results and discussion

3.1 Socioeconomic characteristics of tea farmers in study area

The descriptive statistic method was used to describe the current status of tea farms in the study area. Table 2 illustrates the descriptive features of important variables used in the model, as well as specific farm characteristics. A statistical index of VietGAP and conventional tea farmers were compared using *t* statistics. Moreover, as multicollinearity of variables may lead to an estimation bias in the regression model, an index of variance inflation factors (VIF) was used to test for collinearity. The estimated mean VIF index is 1.43, suggesting that there is no collinearity in the model. Besides, we also tested the relationship among variables using a correlation matrix. The coefficient of "age" and "experience" was high. Thus, only "experience" variable was retained in regression. The results indicated that the average tea yield is about 8100 kg per hectare. Tea farmers using VietGAP production obtained significantly higher yields compared with conventional tea farmers, at the 5% significance level. On average, a farmer earned about VND 147,500

Table 2 Result statistics of tea production comparing between two models. Source: author's surveyed data in 2016

Variables	All samples ($n = 326$)	VietGAP ($n = 116$)	CON ($n = 210$)	Diff.	t stat
Yield (kg/ha)	8116.8	8555.6	7874.4	681.17**	2.3935
Profit (K.vnd/ha)	147,588.4	172,683.8	133,726.2	38,957.59***	5.4041
Total cost (K.vnd/ha)	117,663.5	129,559.7	111,092.2	18,467.35**	2.1251
Chemical (kg/ha)	2628.6	2494.5	2702.6	− 208.16	− 1.3458
Organic (kg/ha)	2012.6	2557.3	1711.7	845.54***	3.8978
Pescost (l/ha)	176.5	157.2	187.1	− 29.97**	− 2.2390
Labor (man-day)	1105.1	1236.3	1032.6	203.74***	3.1915
Ocost (K.vnd)	26,193.3	24,839.7	26,941.1	− 2101.41	− 1.4385

Variables	Mean	SD	Min	Max
Input variables of profit function				
Pchem (K.vnd/kg)	6.88	1.72	4.5	13.5
Porg (K.vnd/kg)	4.89	1.94	2.4	15.6
Pescost (K.vnd/ha/year)	453.42	281.46	0	2650
Plabor (K.vnd/day)	135.73	36.80	50	210
Ocost (K.vnd/ha/year)	25,771.4	11,094.61	2364	81,538
Farm size (ha)	0.35	0.16	0.11	1.3

K.vnd: monetary unit of Vietnam measured in thousand dong; 1 usd ~ 21 K.vnd

*** and ** significance at the 1 and 5% levels, respectively

thousand per hectare. The VietGAP tea farmers also earned a higher profit than the conventional tea farmers, and the difference was statistically significant at 1% level.

Similarly, the VietGAP tea farmers spend more in terms of total cost per ha than do conventional farmers. Notably, tea farms under VietGAP production apply more organic fertilizer than do conventional tea farms. One of the reasons VietGAP tea farmers use more organic fertilizers is that they understand the sustainable benefits of using organic inputs for their tea products and farmland. In addition, VietGAP tea farmers have significantly lower pesticide costs than the conventional tea farmers. However, the variability might be the result of other factors, such as farm size, annual pest attacks, and the farmer's attitude and perception to the effects of pesticide. Technical training courses on pesticide use under the VietGAP program are largely considered as a major positive contributor to changing farmers' attitudes and perceptions on the use of pesticides and chemical compounds in tea farming. Furthermore, tea farms using VietGAP production require more labor-days than the conventional tea farms. This is largely the result of the strict control requirements for VietGAP tea products, in particular, following all the steps necessary for tea production. On average, the labor time required for tea production per hectare/year is around 1100 days, indicating that farming activities are highly labor intensive, particularly in the harvesting season when hand labor is still widely used. The tea production under VietGAP requires more working days than those under conventional practices. The estimation also indicated that the average size of a tea farm is around 0.35 ha per farmer, with no significant difference between VietGAP and conventional tea farms. This farm size is generally characterized as small-scale agricultural production in northern Vietnam.

Table 3 shows the comparative statistics of the major variables used in the regression model. The difference (diff.) between the groups is equal to the mean of VietGAP tea farmers less the mean of conventional tea farmers. The *t* statistic value indicates the significant level of difference between the groups.

Most of the tea farmers (85%) received a basic education at a secondary or high school level. A very small proportion of the tea farmers received a higher level of education, indicating that tea production has not yet attracted educated people, particularly among young labors. This may be a barrier to applying technology or using marketing to access high-value tea markets. The results also show that farmers have much experience in tea cultivation (about 22 years) and that they earn about 62% of total tea income, suggesting that the study area is dominated by tea production.

The comparative results indicated that farmers adopting VietGAP standards have more family labor available than do conventional tea farmers and that the difference was statistically significant at the 1% level. Although VietGAP farms are not intensive agriculture, they require more labor than conventional farming practices do. Labor time in tea cultivation is mostly spent during harvesting. Furthermore, the strict requirements of VietGAP certified tea farm means that farmers often invest more in production system including irrigation systems in order to control water quality. Water source and other input factors relevant to tea farms are regularly verified by certified organizations. Only when practices of the tea farmers meet all regulated standards, their tea products are certified with VietGAP trademark. In other words, availability of active irrigation system would be one of favorable factors for adopting new practices. Thus, VietGAP tea farms have been actively irrigated than conventional tea farms. Then, the results indicated a significant difference in

Table 3 Comparative statistics of model variables. Source: author's surveyed data in 2016

Variables	All samples (n = 326)	VietGAP (n = 116)	CON (n = 210)	Diff.	t stat
Gender	0.59	0.603	0.595	0.008	0.1443
Formal education					
Primary	0.075	0.060	0.090	0.030	0.9614
Secondary	0.475	0.465	0.481	0.015	0.2672
High school	0.377	0.379	0.376	0.003	0.0556
Upper level	0.064	0.094	0.048	0.047	1.6623
Family labor	2.90	3.078	2.800	0.278***	2.6291
Experience	22.30	21.293	22.862	− 1.569	− 1.5559
Irrigation	0.68	0.879	0.571	0.308***	6.0005
Tea income ratio	0.62	0.665	0.596	0.068***	3.4485
Credit access	0.15	0.163	0.142	0.021	0.5051
Cooperative	0.51	0.879	0.314	0.565***	9.770
Machinery use	0.62	0.810	0.509	0.301***	5.5822

Diff. is the difference between the adopter and non-adopter of VietGAP and equals the mean of the adopter minus the mean of the non-adopter

***Significance at 1% level

the tea income ratio between the two groups. A positive coefficient of the tea income ratio implied that farmers following VietGAP earned a higher income from tea production than the conventional tea farmers. In other words, conventional tea farmers are less dependent on tea production for their income than are VietGAP farmers. A significant difference between the VietGAP and conventional tea farms was also evidenced by the variables denoting the status of whether have joint any local agricultural cooperative and machinery application. Tea farmers adopted VietGAP tend to invest more capital in machinery and become members of a cooperative. Lastly, statistically insignificant differences were observed between the groups on other features, such as gender, formal education, farming experience, and credit access.

3.2 Estimated result of profit frontier function

Economic efficiency is of interest to both farmers and policymakers. The dual method was used to analyze the profit efficiency of tea farmers. The difference between VietGAP and conventional farms was assessed using the dummy variable "adop". The estimated results are presented in Table 4.

The positive and significant effect of the dummy variable "adop" in the profit frontier function reflected that tea farmers participated in the VietGAP program operate at higher profit efficiency than other tea farmers. The question here is whether the VietGAP program has a positive impact on profit efficiency. The higher profit efficiency of VietGAP tea farmers might be the result of better farm/farmer characteristics or the effect of participating in the VietGAP program. To answer this question, we conducted a more in-depth analysis in the next section, controlling for bias selection. The positive and significant effect of farm size implied that families with larger tea farms operate at a higher profit efficiency than do smaller tea farms. This finding was consistent with the results of Ali and Byerlee (1991), Kolawole (2006), Abdulai and Huffman (2000), and Tran et al. (2015). Tea-producing farms using the VietGAP standard are not organic farms. Thus, chemical fertilizers and pesticides are still applied. The difference is that VietGAP tea farmers minimize the use of such compounds, following strict harvesting intervals after spraying, and increase the adoption of organic fertilizers and biological compounds for pest and disease control. The tea products obtained from VietGAP production are free of pesticides

Table 4 Estimation result of profit efficiency among tea farmers. Source: author's surveyed data in 2016; sample size ($n = 326$)

Variables	Coefficient	SD	z stat	$p > \|z\|$
Adop	0.193***	0.046	4.12	0.000
Farm size	0.200***	0.059	3.36	0.001
Pchem	− 0.318***	0.110	− 2.89	0.004
Porg	− 0.344***	0.069	− 4.95	0.000
Pescost	− 0.013	0.388	− 0.33	0.740
Plabor	− 0.325***	0.076	− 4.19	0.000
Ocost	0.213***	0.044	4.82	0.000
Constant	8.151***	0.453	18.00	0.000
Log-likelihood	− 138.0769			
Lamda	1.478303			
Variance_u	0.4110226			
Variance_v	0.2780368			

***Significance at the 1% level

and chemical residues, and certified by authorized agencies in Vietnam. The estimated results showed that increasing prices of chemical and organic fertilizers have a negative and significant effect on profit efficiency. Thus, as the price of fertilizer inputs increase, the profit efficiency of tea production will decrease. These results were similar to those of Ali and Flinn (1989), Kolawole (2006), Tran et al. (2015), and Abdulai and Huffman (2000). The large coefficients of fertilizer prices implied a strong dependence on fertilizer inputs in both tea production practices. While the coefficient of pesticide cost was negative and statistically insignificant, the price of hired labor (man-days) was highly significant. The negative sign of the coefficient of labor price suggested that as the price of labor increases, the profit efficiency of tea farmers will decrease. This is reasonable, because labor is one of most important inputs of agricultural production such as tea. Thus, labor-related cost changes have a strong impact on profit efficiency. Note that other costs include hired irrigation, machine-related costs, and processing steps. The positive and significant coefficient of these costs implied that increasing these costs will increase profit efficiency. This result also suggested that farmers using machines during the production and post-harvest stages would obtain higher profit efficiency than other farmers.

3.3 Factors explaining the profit efficiency of tea farmers

Factors explaining the profit efficiency of tea farmers would be useful for policy purposes. Thus, we determine the factors affecting profit efficiency of tea farmers separately using a Tobit model, with a dependent variable of profit efficiency score. Then, important features of farms and farmers were used as explanatory variables in the model. The detailed results are shown in Table 5. Notably, joining cooperatives or production groups has a positive and significant impact on profit efficiency for both farmer groups, while other coefficients are relatively different. For farmers following the VietGAP standard, the coefficient of accessing an irrigation system is positive and significant. This suggests that tea farms irrigated by farmers achieve higher profit efficiency. Regular irrigation reduces loss of a tea yield, especially in the dry season and for high-yield tea varieties. This finding is consistent that of Hong and Yabe (2015). Participating in production cooperatives or groups contributes to increasing profit efficiency for tea farmers under the VietGAP program. In

Table 5 Factors affecting profit efficiency of tea farmers. Source: author's surveyed data in 2016; sample size ($n = 326$)

Variables	PE (VietGAP)	*t* stat	PE (CON)	*t* stat
Gender	0.014	1.24	0.026	1.58
Formal education				
Secondary	− 0.018	− 0.75	− 0.027	− 0.92
High school	− 0.002	− 0.07	− 0.029	− 0.93
Upper level	0.022	0.74	− 0.066	− 1.51
Family labor	− 0.004	− 0.58	− 0.006	− 0.70
Experience	0.0007	1.04	0.002	0.27
Irrigation	0.041**	2.25	0.003	0.12
Credit access	− 0.008	− 0.60	− 0.015	− 0.66
Tea income ratio	0.029	0.85	0.176***	3.68
Cooperative	0.089***	4.68	0.048***	2.68
Machinery use	0.011	− 0.76	0.006	0.22
Constant	0.633***	19.32	0.561***	14.60

*** and ** significance at the 1 and 5% levels, respectively general, farmers have a greater chance of accessing new information, technical training through experience exchange, and information sharing when they participate in production cooperatives or groups (Hong and Yabe 2015). Moreover, joining the cooperatives is more attractive to VietGAP tea farmers in terms of saving production costs on machinery investment for processing/packaging, trademark registration, and VietGAP certification. In addition, cooperatives make it easier to access credit facilities from agencies and to sign consumption contracts with collectors/distributors. In the case of individual tea producers, borrowing large amounts as loans from agencies and working with large wholesalers/companies seems to not be possible.

For conventional tea farmers, as in the case of VietGAP tea farmers, participating in production groups or cooperatives has a positive effect on profit efficiency, for much the same reason. Although these farmers do not incur higher production costs for VietGAP certification and product testing fees, they benefit from cooperatives or production groups through experience exchange, marketing information, and cost savings. Irrigation system is positive for profit efficiency improvement, but it is insignificant. The difference between two groups may be derived from the fact that various types of tea plantation have been growing in the study area. While most conventional farmers prefer local tea varieties to new ones that have often better resistant ability to dry weather condition, VietGAP farmers with better advantages of labor and investment capital often grow highly yield varieties. In turn, these new tea types also require strictly cared conditions including more regularly irrigated water, fertilizer input. The ratio of tea income “RItea” has a significant effect on profit efficiency. The positive sign of the estimated coefficient showed that farmers who are able to earn more income from tea farms pay more attention to their tea farms than do other tea farmers. Directly, this finding suggested that farmers show depend heavily on the income of tea production achieve greater profit efficiency. The underlying reason may be that this is the main source of income for the family. In this case, farmers often invest more of their time and attention. As a result, they achieve better performance than other farmers do. This result is similar to that of Ali and Flinn (1989), Wang et al. (1996), and Rahman (2003), who reported that farmers who earn a greater share of their income from off-farm activities operate at lower levels of efficiency. Other variables in the model do not have statistically significant impacts on profit efficiency. These variables include gender, education level, labor size, and farming experience. As expected, a higher level of education increases profit efficiency, but in the study area, most farmers have a basic education, with simple knowledge that is not relevant to farming. Thus, it is no surprise that formal education level does not have a significant effect on profit efficiency. This result did not differ from that of Coelli et al. (2002), who concluded that a higher level of education has not a large influence on efficiency levels. Similarly, the coefficients of credit access and machinery status have the same effects on profit efficiency for both types of farms. The negative sign of credit access seems to be irregular. However, it is not statistically significant. In the study area, a very small ratio of tea farmers borrowed funds from credit agencies (15%, on average). This may also lead to the statistically insignificant effect of the variable.

3.4 Distribution of profit efficiency and estimation of average treatment effect index

Table 6 compares the frequency distribution of the profit efficiency among tea farmers. Most farmers (72%) operate their tea farms with profit efficiency scores between 0.70 and 0.89. The average profit efficiency of tea farmers is about 74%, with a wide range, from 29

Table 6 Frequency distribution of profit efficiency (PE). Source: author's surveyed data in 2016, sample size ($n = 326$)

Profit efficiency (%)	Frequency			Percentage		
	All samples	VietGAP	CON	All samples	VietGAP	CON
≤ 50	13	1	12	3.98	0.86	5.71
50–59	21	3	18	6.44	2.58	8.57
60–69	51	13	38	15.64	11.21	18.10
70–79	135	63	72	41.41	54.32	34.28
80–89	99	35	64	30.37	30.17	30.48
90–99	7	1	6	2.16	0.86	2.86
Mean	74.38	76.3	73.4	–	–	–
Min	28.7	44.3	28.7			
Max	93.6	90.8	93.6			

to 94%. There is a slight difference in the average profit efficiency scores between VietGAP and conventional tea farmers. VietGAP tea farmers achieve higher mean profit efficiency (76.4%), whereas conventional tea farmers obtain an average profit efficiency of 73.4%. This result suggests there is still room to improve the profit efficiency of tea production (26%).

3.5 Propensity score for VietGAP tea adoption

The logit estimates for the VietGAP tea propensity equation are presented in Table 7.

Table 7 Logit estimates of the propensity to adopt VietGAP tea production. Source: author's surveyed data in 2016, sample size ($n = 326$)

Variables	Coefficient	Standard error
Gender	− 0.137	0.280
Formal education		
Secondary	− 0.378	0.543
High school	0.368	0.571
Upper level	− 0.321	0.571
Family labor	0.551	0.174***
Experience	− 0.062	0.018***
Farm size	1.215	0.770***
Irrigation	1.228	0.421***
Tea income ratio	2.036	0.866**
Credit access	0.467	0.367
Extension access	0.542	0.328***
Machinery use	0.797	0.358***
Constant	− 2.647	0.917***

*** and ** significance at the 1 and 5% levels, respectively

Several variables were statistically significantly associated with adopting VietGAP tea production. Farmers with more farming experience are less likely to adopt conventional tea farms. On the other hand, farmers with more family labor participating in farm activities are more likely to convert from conventional to VietGAP tea farms. As expected, farms that have access to better irrigation systems, extension services, and larger farm area are likely to be VietGAP tea farms. The use of machinery in farm activities has a positive impact on adopting VietGAP standards. Other variables, such as gender, formal education, and credit access, are not strongly associated with the choice of production method.

As discussed in Sect. 3.2, the higher profit efficiency of VietGAP tea farmers could be the result of adopting the new production method, but may also be the result of a selection bias. The estimated effect of the treatment may be biased by the existence of confounding factors. Using propensity score matching is a good way to "correct" for confounding factors, based on the idea that the bias is reduced when the outcomes are compared using treated and control subjects who are as similar as possible (Rosenbaum and Rubin 1983). Eliminating the effect of self-selection would be meaningful when comparing the profit efficiency of the two farmer groups. Thus, we use the average treatment effect on the treated (ATET) index here.

In the study, data analysis results in statistically insignificant likelihood ratio test on the joint significance of all regressors, and fairly low pseudo-R^2 after matching process. This suggested that there is no systematical and significant difference after matching. The matching quality was successful in the study (Smith and Todd 2005; Sianesi 2004). Besides, there is substantial overlap in the distribution of the estimated probability of tea farmers (of both VietGAP and conventional growers). Figure 1 indicates the presence of sufficient common support between two farm groups.

Before matching, a simple comparison indicates that the profit efficiency of VietGAP tea farmers was significantly higher than that of conventional tea farmers, at the 1% level. After matching, the estimated result of the ATET index indicates that the difference was also statistically significant (see Table 8). In other words, employing propensity score

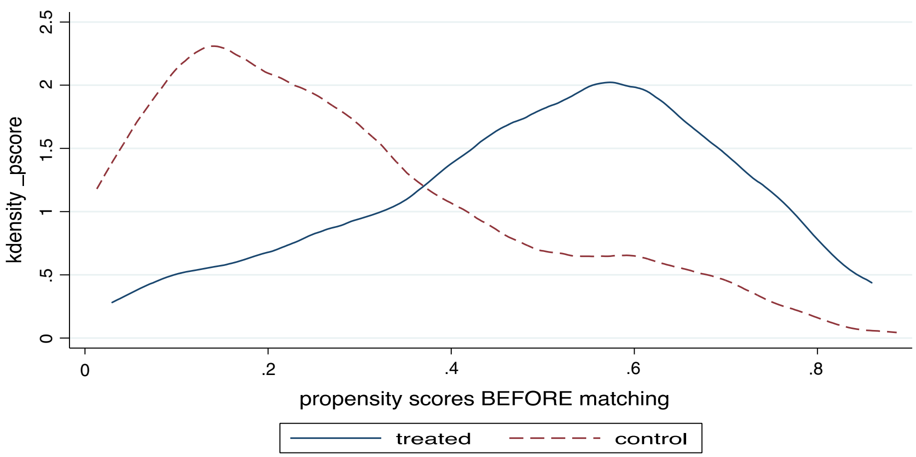

Fig. 1 Density distribution of propensity scores for treated and comparison groups

Table 8 Estimation of average treatment effects on the treated. Source: author's surveyed data in 2016

Index		Coeff.	AI robust SE		z stat
ATET (VietGAP and CON)		0.038*	0.020		1.91
Matching method	Pseudo R^2		LR χ^2 (p value)		
	Before	After	Before		After
Test of matching quality					
NNM	0.1876	0.0379	79.87***		6.88

ATET average treatment effects on the treated, *Coeff* coefficient, *NNM* nearest neighbor matching

*** and * significance at the 1 and 10% levels, respectively

matching approach reassures that safe tea production practice has positively been contributed to improve profit efficiency for tea farmers.

4 Conclusion

Tea production is generally characterized by small-scale agricultural production in northern Vietnam, with an average tea farm being 0.35 ha in size. Tea production plays an important role in generating household income and is a major income source of family income in the study area. This study investigated the profit efficiency of tea production in the northern mountainous region of Vietnam using a stochastic profit frontier function. Then, the propensity score matching approach was used to control for possible self-selection when assessing the difference between the profit efficiency of the two practices. The results showed that tea farmers are not operating at full profit efficiency. Safe-tea-producing farmers have the potential to improve their profit efficiency by about 24%, while conventional tea farmers could increase their profit efficiency by about 27%. The results also confirmed that tea farmers benefit higher profit efficiency from switching to safe tea production practice. Several policy implications are suggested by the findings of the study. The profit efficiency of tea farms can be improved significantly by supporting irrigation system development and the operational efficiency of cooperatives. Moreover, larger production scale is major important factor to promote the adoption of VietGAP standards among farmers because they can utilize machinery and other production tools. Thus, public policies aimed at diffusing adoption for eco-friendly production practices should support innovations that may minimize negative impact of small production scale. Lastly, supporting suitable labor-saving machinery, improvement of extension service might also be good incentives for the conversion in study area.

This paper has several limitations and additional studies are required. The issue of unobservable characteristics should be further investigated. Further studies should be sought as regards the relationship between yield and used labor, the information flow among actors, policy and institutions for VietGAP product marketing, market channel or value chain. Moreover, it is also worthwhile to do similar studies with larger samples which imply to extend the research to other regions of Vietnam. It would be very useful to carry out some researches on the direction of consumer's demand such as willing to pay for VietGAP product. Besides, it would be more useful to do further studies using time-series data and different methods for checking results. Finally, more indicators for impact evaluation, such as household income, household consumption expenditure, and yield, should be investigated.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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