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THESIS

Doctor of Philosophy in Economics

ECONOMIC ANALYSIS OF FARMERS' DECISIONS: APPLICATIONS TO THE VIETNAM'S TEA PRODUCTION

presented by

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Résumé de la thèse

Dans cette thèse, nous nous intéressons aux décisions de production des agriculteurs et plus particulièrement aux producteurs de thé au Vietnam. Nous développons dans ce cadre une analyse à la fois empirique et théorique pour cerner le comportement d'agriculteurs lors de leurs décisions de production de thé. Pourquoi ils choisissent un certain type de produits plutôt qu'un autre? Pourquoi décident-ils de produire le thé noir ou le thé vert, le thé biologique ou le thé classique? Qu'est ce qui les pousse à participer à un certain nombre d'actions collectives qui peuvent être formelles ou informelles?

Pour y répondre, nous avons commencé par identifier les principales caractéristiques du secteur du thé vietnamien : prépondérance des petits producteurs, utilisation irrationnelle des intrants, etc. De plus il existe de nombreuses variétés de thé au Vietnam (Trung-Du, PH1, Bat Tien, LDP1, etc.). Tandis que certaines anciennes variétés comme le Trung-Du, moins performantes, demeurent les plus cultivés, la stratégie actuelle au Vietnam consiste à remplacer progressivement ces anciennes variétés par des nouvelles plus performantes. Par conséquent, Notre étude vise à explorer les facteurs susceptibles d'influer sur l'efficacité technique dans la production de thé au Vietnam. À cette fin, nous mobilisons l'analyse de frontière de production stochastique (SPF). Nous essayons notamment d'expliciter les liens entre les formes de politique agricole l'hétérogénéité des comportements et le choix des différentes variétés de thé.

Observant l'intérêt grandissant des consommateurs pour les produits issus de l'agriculture biologique, le gouvernement vietnamien a par exemple initié récemment un programme visant à développer la production de thé biologique. Le programme ne s'appuie pas toutefois sur des études scientifiques sérieuses et il s'agit donc d'évaluer sa pertinence. Notre étude vise

également à fournir quelques explications au sujet des conditions qui pourraient favoriser le choix de produire le thé biologique ; autrement dit le basculement vers une nouvelle technologie de production.

Il existe en effet de plus en plus de travaux portant sur les formes de comportements et la perception du risque, dans le secteur agricole tout particulièrement. Il en ressort que dans le cas du thé par exemple, la décision d'adopter un type de variété de thé est non seulement déterminée par l'aversion au risque des agriculteurs, mais aussi par leurs préférences concernant différents attributs du produit. Même quand il est avéré qu'une variété de thé a une meilleure productivité, les agriculteurs peuvent continuer à produire d'autres types de variétés moins performantes mais qui possèdent des attributs liés au marché de la consommation. Notre étude analyse les déterminants du choix des agriculteurs concernant les variétés de thé en regards aux différents attributs qui leurs sont associés.

Finalement, au Vietnam, il existe des organisations importantes telles que l'Union des agriculteurs, Union de la jeunesse, le Parti communiste et l'Union des anciens combattants, etc. Ces organisations sont très puissantes, car elles sont considéreés comme les composants solides formant le Parti communiste qui est un parti politique unique au Vietnam. En conséquence, ils ont des liens étroits avec l'Etat et l'adhésion à ces organisations pourrait présenter des avantages dans les affaires, la recherche d'emploi, l'éducation, la promotion sociale, etc. Notre étude montre que les relations politiques ont quelques impacts sur le revenu des agriculteurs.

Principales contributions

Cette thèse est structurée autour de cinq chapitres dont les paragraphes suivants fournissent des résumés. Le chapitre 1 donne un aperçu rapide de l'évolution observée dans le monde et au Vietnam au cours des dernières années, ainsi qu'une brève analyse des caractéristiques de la culture et de l'industrie du thé au Vietnam.

Le chapitre 2 porte sur l'analyse de l'efficacité technique de la production de thé au Vietnam. Notre étude permet de conclure que l'efficacité technique moyenne de la production de thé est très faible (seulement 41%). Parmi les possibilités d'actions s'offrant aux agriculteurs, il apparaît que seule une meilleure utilisation des intrants (engrais et pesticides en particulier) a un impact allant dans le sens d'une amélioration de l'efficacité technique. Le chapitre montre également une certaine hétérogénéité dans le choix des variétés de thé. De plus, l'adoption de variété plus ancienne comme le "Trung-Du" ne semble pas constituer une source d'inefficacité tandis que les effets liées aux choix d'autres nouvelles variétés paraissent insignifiants. Au final, les résultats du chapitre indiquent que pour améliorer l'efficacité de la production dans la région de l'étude, la plupart des éléments de politiques agricoles existants doivent être révisée. Ils devraient conduire à rendre les agriculteurs plus attentifs au choix du type de variétés qu'ils adoptent pour la production.

Le chapitre 3 présente un modèle théorique analysant les décisions d'agriculteurs dans le cadre d'une conversion à la production biologique. Nous cherchons ici à réunir les conditions optimales pour la conversion compte tenu des contraintes concernant l'allocation des terres pour les types de production classique et biologique. Nous montrons notamment l'importance de (i) la quantité disponible de terres consacrées aux plantations, (ii) la productivité de la technologie de production biologique, (iii) les mécanismes d'incitation et enfin (iv) les contraintes inhérentes à la production biologiques.

Dans le chapitre 4, nous utilisons un modèle logit multinomial afin d'examiner les déterminants du choix des agriculteurs pour les différentes variétés de thé. Nous comparons à cette occasion, un modèle avec hétérogénéité non observable et le modèle sans aucune hétérogénéité. Sur la base des tests statistiques nous constatons que l'hypothèse d'un modèle sans hétérogénéité est préférée. Les résultats obtenus révèlent certains facteurs importants qui influent sur l'adoption de variétés de thé. Il s'agit du revenu, de l'existence de personnes âgées dans le ménage, de la taille du ménage et l'usage d'engrais biologiques.

Dans le chapitre 5, dernière chapitre de la thèse, nous nous intéressons aux impacts des relations politiques sur le revenu total et le revenu issu de la production de thé des ménages. Nos résultats soulignent le rôle important des relations politiques sur l'amélioration des revenus des agriculteurs. Dans la mesure où le temps consacré à la production diminue cela entraine la réduction des surfaces cultiveés. Cette réduction et la baisse des revenues engendrée sont compenseés par les informations fournies, grâce à l'appartenance aux organisations profesionnelles et politiques concernant l'évolution des prix et des circuits de commercialisation.

Publications

To-The N., Le-Van C. (2015) “Farmers’ adoption of organic production", *BETA Working Paper,* n° 2015-23.

Nguyen-Van P., To-The N. (2016), “Efficacité technique des producteurs de thé au Nord-Est du Vietnam : Le rôle de la politique de promotion agricole", *Cahiers d’Etudes Vietnamiennes,* numéro 24, à paraître.

To-The N., Tran-Nam Q. (2015) “Impact of political connection on farming households’ performance of tea production in Vietnam", *Journal of Agricultural Science,* Vol. 7, No. 12.

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General Introduction

Motivation

Nowadays, understanding the producer's behavior is helpful for designing an appropriate argicultural policy, especially in the context of developing countries. In this thesis we focus on the behavior of farmers in the decision making process. We consider that farmers provide a particularly interesting opportunity for the study of economic behaviors.

Indeed, we find many researches on farmer's behavior in decision making (see Antle and Crissman, 1990; Lynne et al., 1988; Kurosaki and Fafchamps, 2002 and Prokopy et al., 2008). Moreover, the farmer's behavior is usually investigated in respect to specific topics. Some studies showed that farmers are likely to be interested in maximizing production and making profits (Herath et al., 1982; Gasson et al., 1988 and Westhead, 2003). In addition, under an increasing demand for environmentally friendly products, farmers' production behaviors will be changed (Gasson, 1973; Fairweather and Keating, 1994 and Defrancesco et al., 2008). Besides, the majority of economic literature focusing on behavior aims at increasing production and farmer's behavior for adopting new methods, new policies, crop varieties, or new technologies (Austin et al., 2001; Howley and Dillon, 2012 and McDonald et al., 2015).

The main purpose of the thesis is to develop both empirical and theoretical analysis under a special focus on farmer's behavior in tea production in Vietnam. More specifically, this thesis will examine several research questions: **(i) Why do farmers choose a certain kind of goods rather than another? (ii) Why do farmers decide to produce black tea or green tea, organic tea or conventional tea? and (iii) Why do farmers participate in some kinds of collective actions which can be formal or informal?**

Vietnam has been ranked fifth in the world in terms of tea output. Indeed, tea has become an important crop in recent years; the tea sector presents several advantages, particularly as it may help fighting erosion and runoff in the mountainous regions. It also helps to alleviate poverty in rural areas by increasing the farmers' daily income. However, some main weaknesses of the Vietnamese tea sector have been identified including preponderance of small producers, irrational use of inputs and old varieties. For instance, size of the tea production remains relatively small, about 70% of households owning an area less than 0.2 hectares; Actually, some old varieties such as Trung-Du still account for the majority, and hence the strategy of Vietnam is to gradually replace these old varieties. Most of the tea cultivation surface corresponds to these varieties which give a low quality, small leaves. The tea productivity in Vietnam is about 8.2 tons per hectare compared to 10.2 tons per hectare of the world's average productivity. Therefore, our study aims to explore the factors impacting on technical efficiency in tea production. For this purpose, the stochastic production frontier analysis will be applied; we also try to identify the role of agricultural policy and the heterogeneity linked to different tea varieties.

Currently, consumers tend to use organic products, tea products which are also located in that trend. Therefore, Vietnam government encourages farmers to produce organic. However, these policies are an impulsive action and are not based on a scientific basis. Thus, in this study, we want to examine the relevance of these policies. The research aims to provide explanations regarding certain conditions which could help the farmers moving toward an organic production. In this case, organic production is defined as a new technology. Moreover, some studies have not fully addressed the factors that changed technology, and the result is inconsistent. Especially, they do not consider elements of productivity that may affect the decision of choosing this new technology. To address these limitations, we mention some elements as land and labor in our models. Then, we will investigate these factors effects on the adaptation of organic production.

Recently, studies concerning behavior and perception have been emphasized, especially in the agricultural sector. Despite all the developments regarding decision theories by economists or sociologists, farmers at present still largely rely on perception and intuition in decision-making. For instance, adopting one type of tea variety is not only determined by the farmer's risk attitude but also by his preference regarding different product attributes. Farmers may continue growing types of tea variety that possess the preferred consumption or market related attributes, regardless of other ones from which it may result a better production. Hence, this study will apply the multinomial logit and examines the determinants of the farmers' choice concerning different varieties. This model has an advantage that can help in analyzing the decisions across more than two categories, or in the estimation of choice probabilities for different categories. This part presents insights into the determinants of the adoption choice of varieties by analyzing tea producers' assessment in Vietnam.

In addition, forming a consistent definition of political connection is almost impossible as it depends on several social and cultural backgrounds in a specific nation or even a region. Particularly, in Vietnam, there are some important organizations such as Farmers' Union, Youth Union, Communist Party, Women' Union and Veteran's Union, etc. These organizations are very powerful because they are considered as the solid components forming the Communist Party which is unique political party in Vietnam. As a result, they have strong links with the state and their membership that could help them in some advantages in business, looking for a job, education, promotion, etc. Therefore, in this research, a household will be considered as having a political connection if one or more of its members participate into these organizations. We find the interesting result that the relationship between political connection and tea producers' income. This is likely to imply a certain significance for political link on economic behaviors.

Contribution of the thesis

The thesis contributes to highlight some theoretical points of view which are discussed above. Theoretically, we provide an interesting analysis of the farmers' behavior in adopting new technology under some optimal conditions. On the empirical side, we investigate the technical efficiency of tea production; adoption of tea varieties and the role of political connection in improving farming households' income. This dissertation is made of five chapters. The following paragraphs provides the abstracts of each chapter.

Chapter 1 gives a general view about the tea sector in the world and in Vietnam. This chapter helps the reader getting a quick overview of the field of tea in recent years. It also provides some brief analysis of the world tea production's situation, and characteristics of the tea industry in Vietnam.

For agricultural production in general, and in particular tea producers, the assessment of the technical efficiency is essential. It indicates the level of input used by farmers and their level of efficiency. Basing on empirical results, we give some recommendations to help the farmers to improve their production efficiency.

Chapter 2 analyses the technical efficiency of the tea production in Vietnam. Our analysis is based on the model introduced by Aigner et al. (1977); Meeusen and van Den Broeck (1977) and Kumbhakar and Lovell (2003). It will apply the stochastic production frontier methodology using a survey database collected in Vietnam. This study found that the average technical efficiency of tea production is about 41%. Among available practices for farmers, only training on production inputs (especially fertilizers and pesticides) has an improving impact on technical efficiency. Other features of policy are not effective as expected. The chapter also shows heterogeneity of tea varieties. More precisely, the adoption of the oldest variety 'Trung-Du' does not constitute an inefficiency while the effects of other new varieties are insignificant.

Government over the last years, has conducted some policies aiming to encourage farmers to move towards organic production. However, there were doubts about the effectiveness of those policies, hence Chapter 3 will clarify the appropriateness of these policies. Indeed, Chapter 3 discusses a theoretical model in order to figure out farmers' decisions concerning organic production adaptation. Particularly, we will focus on finding the optimal conditions for the case of organic production, given the constraints concerning the allocation of lands for conventional and organic production. This chapter suggests that an entirely theoretical exercise can point out parts of this complex issue which the empirical work cannot reach. This result is considered as a good example for a new technology. We show the importance of (i) the available quantity of land devoted for agricultural plants, (ii) the productivity of the organic products, (iii) the incentive mechanisms and finally (iv) the constraints on output of organic products. Our results might give some advice to policy makers when contemplating regulations in the agricultural sector.

Actually, in tea production, there is a wide range of choices of varieties, but it is not clear which factors influence the selection of different tea varieties. In Chapter 4, we apply the multinomial logit (MNL) and examine the determinants of the farmers' choice regarding different tea varieties. This general model is based on Nerlove and Press (1973) and Greene (2012). We first compare the models with and without unobservable heterogeneity. We also produce a LR test of the model with heterogeneity against a model without heterogeneity. We also make predictions implying that the quality of predictions does not vary widely across the model. Regression results revealed some important factors which influence the adoption of tea varieties including income, elderly, household size and organic fertilizer. Furthermore, it also indicates influence of the Tea Association, Farmer's Union, Youth Union and Contract.

In addition, results presented in Chapter 5 provide more detail about the role of political connections on farming households' performance; and some definitions of political connections will be clarified. In this chapter, we pay attention to investigating the impacts of political connections on farming households' performance, especially in the context of tea production in Vietnam. However, to avoid dropping observations of the independent variable, the Box-Cox method has been applied (see Box and Cox, 1964). The findings indicate the significant role of political connection on improving farming households' income. First, both estimations show that land, labor, member of household, household head's education, household head's experience and gender variables are statistically significant. As expected, the coefficient of land is significantly positive. This suggest that an increase in the production surface increases both farmer's total income and tea income. Second, for total income estimation, our findings indicate that being a members of Farmer's Union or Youth Union has a positive effect on total income of household are positive. However, the interaction effects of Farmer's/Youth Unions and land on total income are negative. This means that if a farmer has a political connection the positive effect of augmenting the surface of land on total income is reduced. Alternatively, having more land reduces the positive impact of being in Farmer's Union. Third, for tea income estimation, we find that being part of a Union has no significant impact on household's revenue. Nevertheless, we find that the interaction coefficient are still significantly negative for Veteran/Communist Party.

Chapter 1

Overview on tea production in the world and in Vietnam

1.1 Production of tea products

The majority of tea production in the world is mainly concentrated in a small number of countries, such as China, India, Kenya, SriLanka, Vietnam, Indonesia, etc. According to FAOSTAT and based on our calculations, during period 1961-2012, we observe that the world production of tea has increased significantly.[1] Actually, the world's tea area has reached about 1.3 millions hectares in 1961, it has reached about 3.5 millions hectares in 2012. Besides, the world's tea production has reached about 0.9 millions tons in 1961, and it reaches about 5 million tons in 2012 (Figure 1.1(a)). Meanwhile, production of tea in Vietnam has significantly increased in the 60s, mainly due to the expansion of tea area and growth of tea productivity. In the 60s, the tea area in Vietnam had just about 19 thousands hectares. However, it has been multiplied by 6.1 times until 2012. The total tea production was about 7.5 thousands tons in 1961 and reached about 216 thousands tons in 2012 (Figure 1.1(b)).

Accordingly, the FAO (2012) report indicates that world's black tea production is about 75% while green tea is about 25%.[2] To be more specific, black tea production in Kenya increases by 2.3%, while production of black tea in India increases by 2.5% and it increased by 1.7% over the same period in Sri Lanka. Meanwhile, world's green tea is produced mainly in China (representing 73% of world's green tea production), followed by Japan (13%), Vietnam

[1] http://faostat3.fao.org/home

[2] Black tea: tea raw materials, withering, pitcher, fermentation, drying, sieving and sorting. Water brown red, sweet flavored, scented. Green tea: tea raw materials, kill yeast, cooling, pitcher, drying, sieving and sorting. Water yellow green, bright, strong tannin, happy, scented nuggets (http://www.asiatea.com.vn).

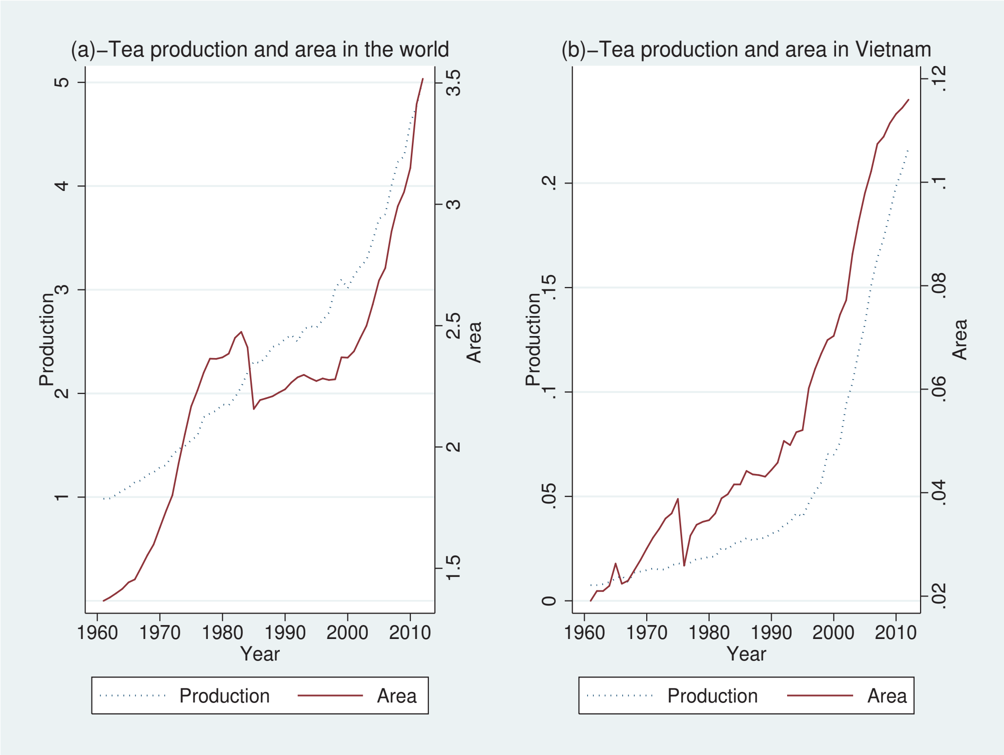

Figure 1.1: Production (million tons) and area (million hectare) in the world and in Vietnam (1961-2012)

(6%) and Indonesia (6%). However, the majority of green tea is mainly produced for domestic consumption (e.g., China, Japan and Vietnam).

Coffee, tea and pepper are the main industrial crops in Vietnam. Tea has become an important crop in recent years. Indeed it offers certain advantages, particularly it may help to fight against erosion and runoff in the mountains. It helps to further combat poverty in the rural region, because it may bring a daily income to farmers. Following Vitas (2009), Vietnam has about 400 thousands tea producers, mostly concentrated in major producing regions such as the North Mountain (about 60%) and the Central Highlands (about 20%). Furthermore, the tea sector in Vietnam is occupied by six millions rural workers. However, the size of the tea production remains relatively small, about 70% of households producing tea with an area less than 0.2 hectares.

Tea production is generally present in six regions such as Northwest, Northeast, North Mountain, North Central, Central Highlands and Central Coast. Tea production is concentrated in some provinces such as Phu Tho, Thai Nguyen, Yen Bai, Lam Dong and Gia Lai, etc. The North Mountain includes provinces Phu Tho, Thai Nguyen, Yen Bai and accounts for about

60% of the total area of tea plantations in Vietnam. The Central Highlands includes provinces Lam Dong and Gia Lai and represents more than 20% of the total tea area in Vietnam (Table 1.1).

Table 1.1: Distribution of tea area in Vietnam (%)

Regions \ Year	2002	2003	2004	2005	2006	2007	2008
North Mountain	57.98	58.21	58.14	57.13	56.99	56.87	57.05
Central Highlands	23.78	22.62	22.07	21.41	20.83	20.84	21.07
Northwest	7.27	7.47	7.68	9.25	9.75	9.72	9.54
North Central	7.25	7.93	7.29	8.06	8.08	8.17	8.02
Northeast	2.32	2.50	2.57	1.98	2.24	2.32	2.27
Central Coast	1.40	1.27	2.25	2.17	2.11	2.08	2.05

Source: Vitas (2009) and our calculations.

As shown Figure 1.2, the world tea productivity also increases significantly in this period. In 1961, world tea productivity is about being about 7.2 tons per hectare, it reaches about 14.3 tons per hectare in 2012. Similarly, tea productivity in Vietnam has significantly increased the recent years, mainly due to the expansion of new tea varieties and application of new technologies, etc. In the 60s, tea productivity in Vietnam was about 3.9 tons per hectare. It has reached around 18 tons per hectare in 2012.

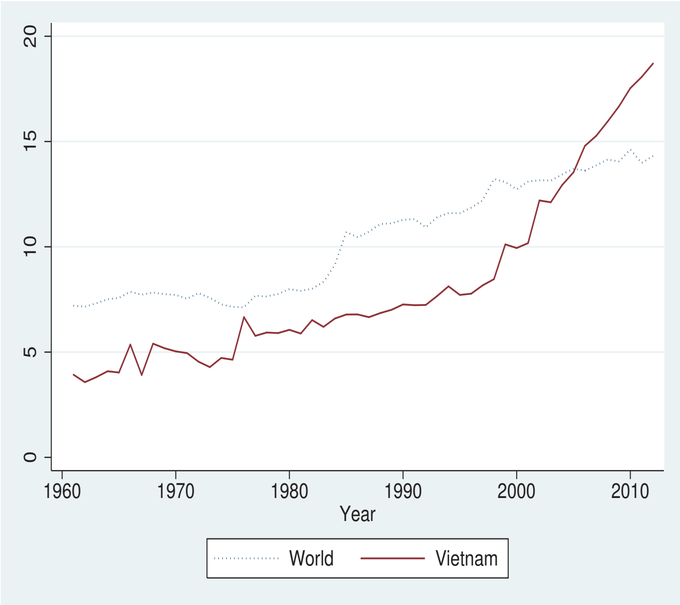

Figure 1.2: Tea productivity in the world and in Vietnam (tons/hectare) (1961-2012)

1.2 Trade of tea products

The export price of tea in the world increases overall by 2.20% during the period from 1961 till 2012. In 1961, the price was about USD 1153 per ton while in 2012, it was about USD 3499. The average world price in this period is USD 1855 per ton (see Figure 1.3(a)). The average exporting prices of Vietnamese tea was lower than exporting prices in other countries, that is about USD 1199 per ton, and around 55% of the world's prices. The explanation for the low export price is probably the use of inconsistent inputs and the use of low processing technology, which decrease the quality of tea. Another explanation is that 90% of Vietnamese tea is exported in raw forms, and very few Vietnamese companies invest in packaging and marketing. This also explains that at present time none of Vietnamese tea trademark is present on the world's market.

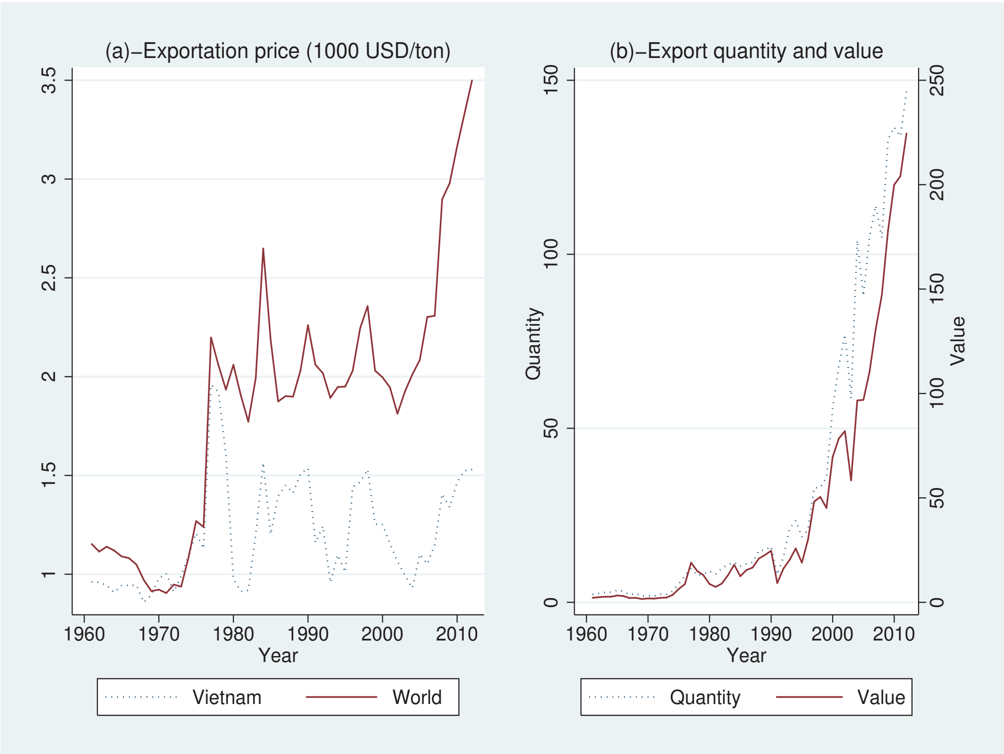

Figure 1.3: Exportation quantity (thousand tons), value (million USD) and price (1000 USD) of tea (1961-2012)

Figure 1.3(b) also shows that quantity of the export in Vietnam had just about 2.3 thousands tons in the 60s. However, it was about 146.7 thousands tons until 2012. Similarly, the value of exported tea tends to significantly increase more than the quantity of the exported tea. To be more precise, as shown Figure 1.3(b), it had just about 2.1 million dollars in the 60s. However, it was about 224.5 million dollars until 2012.

About 70% of tea production of Vietnam is mainly earmarked for exportation. In particular, the tea exported through three main ways: i) State enterprises; ii) joint ventures and foreign companies; iii) private companies. About 98% of the amounts of tea exports are under the form of raw materials, which can explain that tea exporters do not have a high added value.

Table 1.2: The main export markets of Vietnamese tea (millions USD)

Countries	Market share (%)	Exports value	Growth (%)
Pakistan	20.85	26.88	16.4
Taiwan	14.48	18.66	10.8
Russia	9.99	12.88	21.1
Iraq	8.08	10.42	-23.3
China	6.10	7.86	42.4
India	3.59	4.62	-6.0
Indonesia	3.07	3.96	27.3
Germany	2.90	3.73	12.6
UAE	2.52	3.25	34.4
US America	2.30	2.96	29.1
Poland	2.21	2.85	7.6
Saudi Arabia	2.18	2.81	25.1

Source: UNCTSD (2000-2012) and our calculations.

Regarding tea export, Vietnamese exports tea in more than one hundred countries around the world, although tea export is mainly concentrated on countries like Pakistan, Russia, Taiwan, Iraq, China and India, etc. According to the UNCTSD and our calculations, Taiwan and Pakistan are the two largest importers of Vietnamese tea.[3] They roughly accounted for 35% of the total quantity of tea exports in the period of 2000 to 2012. Russia is the third largest importer of Vietnamese tea; the exportation value also reaches 12.88 millions dollars. Equivalent to about 10% of total export of Vietnam's tea. Moreover, the growth rate of export value has increased by 21% per year in this period. Iraq is also one of the largest importers of Vietnam's tea since it represents around 8% of Vietnam's total exports. The average tea export value reaches 10.42 millions dollars, nevertheless the growth rate of export value has decreased by 23% per year in the same period. Similarly, China is also an important tea market for Vietnam. The average export value of tea reaches around 6 millions dollars. Despite this, it holds just 7.8% of the market share of Vietnam's tea exports. However the growth rate of export value significantly

[3]United Nations Commodity Trade Statistics Database (UNCTSD) (http://comtrade.un.org/)

increases. It increases on average by 42% per year in the recent year. Beside, the growth rate of tea export value into in India decreases by 6% per year (Table 1.2).

Chapter 2

Technical efficiency and agricultural policy[1]

2.1 Introduction

Tea is globally one of the most popular and lowest cost beverages, next only to water. In recent year, tea has become an important crop in Vietnam. Tea production shows modest growth before in the 1990s and more rapid thereafter. Vietnam ranks fifth in the world in terms of tea output. Furthermore, the tea sector in Vietnam offers certain advantages, particularly it may help to fight against erosion and runoff in the mountains. It helps to further combat poverty in the region rural, because it may bring a daily income to farmers.

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. There are about 400,000 households taking part in tea cultivation and the tea sector has employed about 1.5 million jobs per year. 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. The tea sector is known as relatively small compared to other agricultural sectors (only 0.2% of GDP and 7% of total agriculture sector, much lower than other crops) (GSO, 2011).

Tran et al. (2004) argues that the Vietnamese tea sector have some main weaknesses such as low and unstable quality of tea products, low productivity, preponderance of small producers,

[1]This chapter is drawn from Nguyen-Van P., To-The N. (2014) "Agricultural extension and technical efficiency of tea production in northeastern Vietnam", *BETA Working Paper,* n° 2014-11. A shorter version of it is published in Cahiers d'Etudes Vietnamiennes: Nguyen-Van P., To-The N. (2016), "Efficacité technique des producteurs de thé au Nord-Est du Vietnam : Le rôle de la politique de promotion agricole", n° 24, forthcoming.

fragmentation of cultivation surface, irrational use of pesticides and fertilizers. Most of tea cultivation surface correspond to the variety ‘Trung-Du’ which gives a low quality, small leaves, and a low productivity. Therefore, we want to check the accuracy of this argument.

Tea productivity depends on tea varieties, farming techniques, surface and environmental conditions specific to the geographical position of plantations. Actually, there are many varieties of tea in Vietnam such as Trung-Du, PH1, Bat Tien, LDP1, etc. However, some old varieties of tea such as Trung-Du still represent the majority, and the strategy of Vietnam is to gradually replace these old varieties. In general, a common view is that old varieties give a lower low than productivity new varieties. For instance, the productivity of traditional tea variety, Trung-Du, has about 4 tons per hectare, while that of PH1 is about 6.5 tons per hectare (Cuong, 2006). Meanwhile, in other regions, tea producers which applied some new varieties of tea have higher productivity. Concerning province Son La, the average productivity reaches 12 tons per hectare (Tran et al., 2004).

Agricultural policy is an activity which aims to improve the utilization of existing technologies and to develop the managerial skill of farmers. It also aims to provide farmers with information on new technologies, new varieties, more efficient farming practices, links to markets and other players in the agricultural value chain, etc. (Owens et al., 2003; Dinar et al., 2007; Birner et al., 2009; Davis et al., 2012; Ragasa et al., 2013). Agricultural policy is an important policy for agricultural development in Vietnam. It was designed in Vietnam in order to develop the agricultural sector by increasing its added value in a sustainable way. The tea sector can take advantage of this agricultural policy. Agricultural 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 (v) training on sale skills.

Another measure is the incentive to adopt new tea varieties such as ‘PH1’, ‘LDP1’, and ‘Bat-Tien’, which are thought to have a higher productivity and better quality than the old variety ‘Trung-Du’. These measures of agricultural policy and the adoption of new tea varieties are then expected to have improving effects on technical efficiency.

Our study aims to provide a reassessment of the impacts of these factors on technical efficiency in tea production in Vietnam. For this purpose, we apply the stochastic production frontier analysis to a survey data collected by ourselves. We particularly try to identify the role of agricultural policy and the heterogeneity linked to different tea varieties. Our results are twofold. On the one hand, we observe that tea production in this region suffers from a strong technical inefficiency. On the other hand, the implementation of some agricultural policy activities and the adoption of certain new tea varieties so far do not seem to have the expected results on technical efficiency.

The remaining of the chapter is organized as follows. Section 2.2 discuss the determinants of technical efficiency, including factors which are related to other crops but appear to be relevant to tea. Section 2.3 describes the data we collected ourselves in Vietnam. Section 2.4 presents the stochastic production frontier model applied to our data. Section 2.5 reports estimation results and interpretation. Finally, Section 2.6 concludes the study.

2.2 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 Bravo-Ureta and Pinheiro (1993). In particular, this study 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 studies are farmer's education and experience, access to credit, and farm size, etc. 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 85,7% in 1987 to 77,5% in 1991, whereas the mean for the entire period is

82,7%. Beside, result of Dey et al. (2010) depicts the frequency distribution of the estimated technical efficiency on small scale farms in Southern Malawi. The technical efficiency of the integrated aquaculture agriculture farmers is 90%, while it is only 65% for non integrated aquaculture agriculture farmers.

Wadud and White (2000) used a translog function for 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 was not significantly related to technical efficiency. Khai et al. (2008) analyzed efficiency of soybean 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 labor in rice cultivation, irrigation, and education.

Regarding tea production, Basnayake and Gunaratne (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 and Kamil, 2010). Concerning tea production in Vietnam, Nghia (2008) showed that organic tea production has a very high technical efficiency, about 99%. In their work, Saigenji and Zeller (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, distance to the collecting point of tea leaves, use of motorbike to collecting point, poverty index.

Concerning the variable of interest, agricultural policy, 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 contrasted results. Seyoum et al. (1998), Ahmad et al. (2002), and Lindara et al. (2006) found that various measures of agricultural policy (access to policy services, training, number of contacts with agricultural policy officers, etc.) can help improving technical efficiency. More precisely, Seyoum et al. (1998) investigated technical efficiency in maize producers in eastern Ethiopia, by comparing farmers within the Sasakawa-Global 2000 project (which involves better farming practices) and other farmers outside this project. The authors found that advice of policy workers is beneficial for farmers within the project whereas they do not help farmers outside the project to reduce technical inefficiency. Ahmad et al. (2002) studied the technical efficiency of wheat producers in Pakistan and showed that having contact with agricultural policy agents can help farmers to raise their technical efficiency. Regarding the study of Lindara et al. (2006) on the spice based agroforestry sector in Matale District, Sri Lanka, technical efficiency is shown to be increased with the number of farm visits by policy officers and the farmer's participation to a training class.

On the contrary, some studies showed that agricultural policy features do not have any significant impact on technical efficiency and that, in some cases, they can worsen technical inefficiency. For example, Raphael (2008) obtained that policy contact variable does not have any significant effect on technical efficiency in cassava production in Nigeria. Khai et al. (2008) found that training and supports from the government (on fertilizers, pesticides, and seeds) have no significant effect on soybean production efficiency in Vietnam. This variable can be thought to encompass features of policy in Vietnam aiming to increase the performance of the agricultural system. The authors observed that agricultural policy did not help farmers cultivate rice more efficiently.

2.3 Data

The data used in the research were collected from the field survey in three 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. The survey corresponds to a broad research project on 'Welfare, sustainable development, and tea cultivation in Vietnam' that we currently conduct in Vietnam.[2]

The survey has been carried on randomly from a household lists of 10 different villages. Face to face interviews have been conducted. The average duration for the whole questionnaire has been 1 hour and 13 minutes with a maximum of 2 hours. It consists of a quantitative household survey of 244 tea farmers. The households were asked to provide information on tea production in 2012 (tea varieties, quantity of production, use of fertilizers, use of pesticides, cultivation surface, labor, and types of agricultural policy they followed). The main questions are also related to important household characteristics such as: assets, social capital, income sources, education, etc.

A summary of definition of variables is given in Appendix A6. The summary statistics of the variables are reported in Table 2.1. We observe that the average quantity of tea is about 4.96 tons/household, with a standard deviation of 8.42, and the rang of production varies from about 0.02 tons (or 20 kg) to 60 tons (or 60000kg). These figures indicate the large variability in production among the farmers. Average land area for tea is about 5866 m^2 per household. The average quantity of labor employed in tea production (planting, harvesting, etc.) is about 225 person-days. These details on tea production show that our data include both small and large producers.

The collected data include 139 green tea producers and 105 black tea producers. A dummy variable for black tea is then defined to check whether there exists a difference between black tea production and green tea production. Information of the use of fertilizers and pesticides are also reported. Two groups of fertilizers, organic and chemical fertilizers, are considered. The latter, including chemical substances for tea trees and leaves, can degrade soil quality contrary to organic fertilizers. The data show that most of the producers in our sample (178 households) employ chemical fertilizers while, in a lesser extend, about a half of the sample (118 households) used organic fertilizers. Moreover, as all the producers in our survey have recourse to pesticides, it is not informative to consider this variable in the analysis.

Agricultural policy is represented by 5 dummy variables indicating different types of training and information given to the producers: (i) training on cultivation techniques, (ii) training on the use of pesticides and fertilizers, (iii) training on harvesting and conservation, (iv) information on the tea market, and (v) training of sale skills. A producer can then follow different

[2] Data and the survey questionnaire are available from the authors upon request.

Table 2.1: Descriptive statistics

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Production (tons)	4.962	8.429	0.024	60	244
Land (m^2)	5866.47	5997.24	130	45000	241
Labor (person-days)	224.63	542.59	5	7863	244
Organic fertilizers	0.486	0.501	0	1	243
Chemical fertilizers	0.730	0.445	0	1	244
Black tea	0.430	0.496	0	1	244
Tea varieties					
'Trung-Du'	0.455	0.499	0	1	244
'PH1'	0.180	0.385	0	1	244
'LDP1'	0.213	0.410	0	1	244
'Bat-Tien'	0.193	0.395	0	1	244
'Other'	0.176	0.382	0	1	244
Agricultural policy					
Cultivation	0.717	0.451	0	1	244
Inputs	0.668	0.472	0	1	244
Harvesting & conservation	0.570	0.496	0	1	244
Information	0.254	0.436	0	1	244
Sale skill	0.221	0.416	0	1	244
High income	0.332	0.472	0	1	244
High education	0.328	0.470	0	1	244
Minority	0.107	0.309	0	1	244

types of training. Training on cultivation techniques is the most followed activity (175 producers) and training on sale skills is the least one (54 producers). Training on the use of pesticides and fertilizers (or inputs), training on harvesting and conservation, and information on the tea market are followed by 163, 139, and 62 producers, respectively. We finally remark that our study does not cover other aspects of policy such as contact with policy officers, credit access, agricultural policy, etc.

Tea varieties are classified following 5 categories: 'Trung-Du' (the oldest variety), 'PH1', 'LDP1', 'Bat-Tien', and the remaining types (category Other). 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. Table 2.2 gives the distribution of the data following tea varieties. We note that farmers can cultivate several tea varieties at the same time. The oldest variety 'Trung-Du' is cultivated by 111 households, about 45% of the data sample. Other varieties are adopted in a much lower extend, less than a half of the 'Trung-Du' proportion.

Table 2.2: Data distribution following tea varieties

Tea varieties	Freq.		Percent	
	No: 0	Yes: 1	No: 0	Yes: 1
'Trung-Du'	133	111	54.51	45.49
'PH1'	200	44	81.97	18.03
'LDP1'	192	52	78.69	21.31
'Bat-Tien'	197	47	80.74	19.26
'Other'	201	43	82.38	17.62

Our analysis also includes dummies corresponding to household characteristics like high income (= 1 if the household's head thinks that (s)he belongs to the high-income group, 0 otherwise), high education (= 1 if the household's head has a high school degree or above, 0 otherwise), and minority (= 1 if the household belongs to a minority, 0 otherwise). The data contain 81 (self-perceived) high-income households, 80 households with high education, and 26 households belonging to a minority ethnic group. The purpose of considering these factors is to check whether they can impact the technical efficiency of tea production. Indeed, we might think that a higher economic condition and a high level of education can favor the access to new production technology and to any information that can improve the production. On the contrary, being part of a minority ethnic group can represent a lack of advantage comparing to the majority group.

2.4 A stochastic production frontier for tea production

The purpose of this section is to briefly describe a model of stochastic production frontier (SPF) that can be applied to our Vietnamese data. The concept of SPF was introduced by Aigner et al. (1977) and Meeusen and van Den Broeck (1977). The stochastic frontier production function has been extended in a number of directions. For example, Stevenson (1980) suggested more general distributions for the u_i; Pitt and Lee (1981) incorporate panel data; Schmidt and Lovell (1979) considered stochastic cost frontiers; and the list goes on. Recent reviews of the frontier literature can be found in Bauer (1990), Kumbhakar and Lovell (2003), Ozkan et al. (2009), Kompas et al. (2012) and Jiang and Sharp (2015).

We assume that output y_i of producer i, $i = 1, 2, \ldots, n$ is subject to random shocks v_i and a degree of technical efficiency $\omega_i \in (0,1]$:

$$y_i = f(x_i;\beta)\omega_i \exp(v_i),\ i = 1,2,...,n, \tag{2.1}$$

where x_i is a $K \times 1$ vector of inputs, β a $K \times 1$ vector of parameters to be estimated. By assuming $\omega_i = \exp(-u_i)$ with $u_i \geqslant 0$, we obtain[3]

$$y_i = f(x_i;\beta)\exp(v_i - u_i),\ i = 1,2,...,n, \tag{2.2}$$

Applying log-transformation to (2.2), we get

$$\ln y_i = \ln f(x_i;\beta) + v_i - u_i. \tag{2.3}$$

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.[4] Condition $u_i \geqslant 0$ ensures that all observations lie on or beneath the production frontier.

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

$$E\{u_i|v_i - u_i\} = \tilde{\mu}_i + \tilde{\sigma}\left\{\frac{\phi(-\tilde{\mu}_i/\tilde{\sigma})}{\Phi(\tilde{\mu}_i/\tilde{\sigma})}\right\}, \tag{2.4}$$

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

$$\begin{aligned} LB_i &= \tilde{\mu}_i + \tilde{\sigma}\Phi^{-1}\left[1-(1-\alpha/2)\Phi(\tilde{\mu}_i/\tilde{\sigma})\right], & (2.5)\\ UB_i &= \tilde{\mu}_i + \tilde{\sigma}\Phi^{-1}\left[1-(\alpha/2)\Phi(\tilde{\mu}_i/\tilde{\sigma})\right], & (2.6)\end{aligned}$$

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

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

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

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

$$\widehat{TE}_i \equiv E\{\exp(-u_i)|v_i - u_i\} = \left\{\frac{\Phi(\tilde{\mu}_i/\tilde{\sigma}) - \tilde{\sigma}}{\Phi(\tilde{\mu}_i/\tilde{\sigma})}\right\}\exp\left\{-\tilde{\mu}_i + \frac{1}{2}\tilde{\sigma}^2\right\}, \tag{2.7}$$

where $v_i - u_i = \ln y_i - \ln f(x_i;\beta)$ from equation (2.3). The $(1-\alpha)\%$ confidence interval for technical efficiency $\widehat{TE}_i$ can be computed as $\{\exp(-UB_i), \exp(-LB_i)\}$.

In order to compute technical efficiency, we need to estimate parameters from model (2.3) which can be performed by maximum likelihood. The log-likelihood of this model is

$$\begin{aligned} \ln L &= \sum_{i=1}^{n}\left\{-\frac{1}{2}\ln(2\pi) - \ln\sigma - \ln\Phi\left(\frac{\mu}{\sigma\sqrt{\rho}}\right)\right. \\ &\quad \left. + \ln\Phi\left\{\frac{(1-\rho)\mu - \rho(v_i - u_i)}{\{\sigma^2\rho(1-\rho)\}^{1/2}}\right\} - \frac{1}{2}\left\{\frac{(v_i - u_i) + \mu}{\sigma}\right\}^2\right\}, \end{aligned} \tag{2.8}$$

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 afterwards in Kompas et al. (2012), 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

$$u_i = z_i'\delta + \eta_i, \tag{2.9}$$

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 previous expressions by $z_i'\delta$. The absence of technical inefficiency is characterized by $\rho = \delta = 0$. This test may be implemented by a likelihood ratio test whose the correct critical values can be found in Kodde and Palm (1987).[5]

[5]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.

2.5 Estimation results

In this section, we report estimation results and tests on the production function and the determinants of technical inefficiency. Estimation is performed by maximum likelihood. As the sample size is moderate, we use the bootstrap standard errors instead of the usual ones in order to obtain a more robust inference.

We firstly use the likelihood-ratio test 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 20.99, which is higher than the critical value of the $\chi^2(6)$ distribution at the 5% level (12.592), leading to the rejection of the Cobb-Douglas function in favor of the translog specification.

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 correct critical values provided by Kodde and Palm (1987). As the computed value of the test statistic is 424.757, much higher than the 5% critical value of the $\chi^2(16)$ distribution under the null (25.689), we can therefore reject the null hypothesis and conclude that inefficiency exists in the tea production.

The final test is related to the joint significant of determinants of inefficiency. The likelihood-ratio statistic follows a $\chi^2(14)$ distribution under the null hypothesis $H_0 : \delta = 0$ (except the intercept). The computed value of the statistic is 122.82, strongly higher than the 5% critical value 23.685, implying that the determinants included in the model are jointly significant. In other words, the factors used here can provide a good explanation for technical efficiency in tea production.

Table 2.3 shows the coefficients of the translog frontier production model. Land and organic fertilizers have significant positive effects on the production. The elasticity of land is 0.430. This result is also compatible with that of Kompas et al. (2012). Besides, the elasticity of organic fertilizers is quite high, 1.463. This finding is also in contrast to the results of Dey et al. (2010). This result is not surprising, because other than short-term crops are rice, maize, wheat, etc. Tea is the long-term cycle plants, hence producer would use more organic fertilizer to get a good outputs for the next years, if producer use many chemical fertilizers, then the next years, the output will is not good. Labor and all the interaction terms are statistically insignificant.[6]

Table 2.3: Estimation of the production function for tea production, translog model

Variables	Coefficient	Boot. Std. Err.
lnLand	0.430*	0.247
lnLabor	-0.302	0.352
Organic fertilizers	1.463**	0.692
Chemical fertilizers	-1.209	0.802
lnLand × lnLabor	0.054	0.047
Organic × lnLand	-0.099	0.094
Organic × lnLabor	-0.119	0.088
Chemical × Organic	-0.079	0.156
Chemical × lnLabor	0.094	0.086
Chemical × lnLand	0.095	0.079
Intercept	-2.394	2.153

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

Table 2.4 reports estimation results relative to the determinants of technical inefficiency associated to the translog production function. Among five categories of agricultural policy, training on the use of inputs (fertilizers and pesticides) is the only significant factor (its effect is -0.242). The existing literature, which does not distinguish various training activities and information provision as the 5-category scheme in our analysis, provides contradictory results as reported in Section 2.2. Here, we observe that only training on the use fertilizers and pesticides can help to reduce inefficiency while other policy variables have no significant role. This finding is different from that obtained by Khai et al. (2008) who showed that government's support (on pesticides, fertilizers, and seeds) does not have any significant impact on soybean production efficiency. Moreover, in a study of Dey et al. (2010) who also mentioned that extension service does not have significant effect on farm output.

There is a heterogeneity concerning the cultivated varieties. Indeed, among five groups of tea varieties, varieties 'Trung-Du', 'Bat-Tien' and 'Other' have significant impacts on technical efficiency. The effects of 'Trung-Du', 'Bat-Tien' and 'Other' varieties group are -0.261, -0.214 and -0.369, respectively. These figures show that adopting the oldest variety ('Trund-Du') is not really a disadvantage and that only some of new varieties can lead to increase efficiency ('Bat-Tien' and 'Other'). Two other new varieties, 'PH1' and 'LDP1', have no effect on tea

[6] We observe that although the interaction terms are individually not significant, their joint effect are statistically significant as shown above by the likelihood ratio test, leading to the choice of the translog production specification to the detriment of the Cobb-Douglas one.

Table 2.4: Determinants of technical inefficiency in tea production, translog model

Variables	Coefficient	Boot. Std. Err.
Agricultural policy		
Cultivation	0.122	0.153
Inputs	-0.242*	0.142
Harvesting & conservation	0.114	0.108
Information	0.130	0.147
Sale	-0.047	0.120
Tea varieties		
'Trung-Du'	-0.261**	0.107
'PH1'	-0.002	0.366
'LDP1'	-0.144	0.112
'Bat-Tien'	-0.214*	0.112
'Other'	-0.369**	0.176
Black tea	-2.805	3.422
High income	-0.016	0.110
High education	-0.009	0.083
Minority	0.093	0.115
Intercept	2.663**	0.397
$\ln(\sigma^2)$	-1.493**	0.329
inverse logit of (ρ)	0.622	9.192
σ_u^2	0.146	0.472
σ_v^2	0.079	0.470
σ^2	0.225	0.074
ρ	0.651	2.089

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

production efficiency.

We also observe that there is no statistical difference between black tea production and green tea production as the coefficient of this variable is insignificant. This finding does not confirm the results of Nghia (2008) who found that green tea production in Vietnam has a very high technical efficiency (the computed technical efficiency of green tea is 99.8%).

Finally, household's characteristics such as (self-perceived) high income, high education of the household's head, and being part of a minority group have no significant effect on technical efficiency.[7] We also compute the distribution of technical efficiency for our data as described in the previous section. Table 2.5 provides a summary of the distribution of technical efficiency. The computation points out that technical efficiency is very low for our data. The average value

[7] 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.

of technical efficiency is about 0.412, and the range is very large, varying from 0.014 to 0.929.

Table 2.5: Summary statistics for technical efficiency

Variables	Mean	Std. Dev.	Min.	Max.	Obs.
Technical efficiency	0.412	0.362	0.014	0.929	240
u_i	1.445	1.114	0.076	4.301	240

In summary, our results are not quite comparable to those estimated by previous frontier studies in tea sector. For example, the overall average level of technical efficiency computed from the study of Madau (2007) are on average 90,2% for conventional and 83,1% for organic practices.

The distribution of technical efficiency can be clearly observed in Figure 2.1.[8] Many tea producers have a low technical efficiency: approximately a half of them have a technical efficiency lower than 50%.

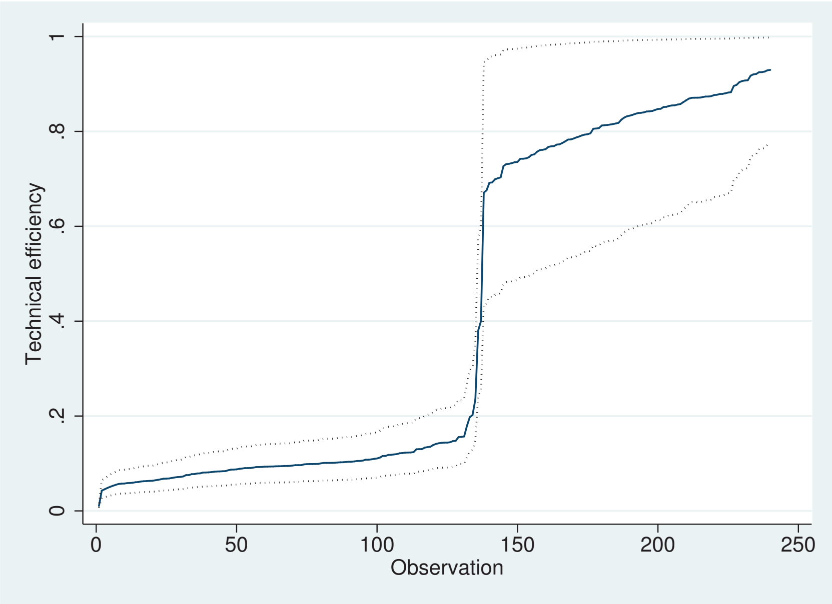

Figure 2.1: Estimation of technical efficiency and its confidence interval

2.6 Conclusion

This chapter studies the determinants of technical efficiency in tea production in Vietnam using the stochastic production frontier.

[8]Observations are ranked in increasing order of efficiency. The solid line represents technical efficiency $\widehat{TE}_i \equiv E(\exp(-u_i)|v_i - u_i)$. The dashed lines correspond to the 95% confidence interval.

Our research underlines that tea production in this region suffers a strong inefficiency (technical efficiency is on average about 41%, much lower than previous findings). This result shows that there exists a huge potential for improving technical efficiency in Vietnam. Hence, the main concern remains to identify the factors which could help to reduce production inefficiency.

As we observed that among different factors included in our model, agricultural policy and tea varieties can influence technical efficiency. Concerning agricultural policy, we should focus on training relative to the use of inputs. Training on these inputs can be provided in its existing form to tea producers as it can help reducing technical inefficiency. Other kinds of training and information under their current state (training on cultivation techniques, harvesting and conservation, sale skills, and information on the tea market) have no significant role. Hence, they should be modified in order to get expected effects on production efficiency.

Regarding tea varieties, our finding about the heterogeneity of their effects on technical efficiency suggests that tea producers should be careful about adopting new varieties. In particular, the oldest variety ‘Trung-Du’ still remains efficient. This results is normal because the productivity reaches maximum when the tea tree is 30 years old. We observe the oldest variety ‘Trung-Du’ still at the highest productivity. Although there are some limitations above discussion in Section 2.1, however it has a positively significant impact on technical efficiency is consistent. This result seems contradict the current recommendation about the non-adoption of the ‘Trung-Du’ variety by some actors of the profession and Vietnamese institutions (Tran et al., 2004).Among new tea varieties, farmers should not choose ‘PH1’ and ‘LDP1’ but they can adopt ‘Bat-Tien’ or other new types because they can have a higher efficiency.

Chapter 2

Efficacité technique et le rôle de la politique de promotion agricole

2.1 Introduction

Le thé est une des boissons les plus populaires et les moins chères, juste après l'eau. Les principaux producteurs de thé dans le monde sont l'Inde, la Chine, le Kenya, le Sri Lanka, la Turquie et le Vietnam. La production mondiale de thé en 2011 totalise plus de quatre millions de tonnes alors que le Vietnam en a produit 0,23 millions de tonnes (FAO, 2012). Le secteur de thé est en 7ème position parmi les 20 secteurs agricoles exportateurs au Vietnam, la valeur des exportations de thé avoisinant 200 million de dollars en 2011. Le secteur de thé implique environ 400000 ménages producteurs et emploie plus de 1,5 millions de personnes (GSO, 2011). Alors que le thé est reconnu comme une des cultures les plus économiques au Vietnam après le café, le secteur du thé ne représente qu'une petite part de l'économie vietnamienne. En effet, il ne correspond qu'à 0,2% du PIB national et 7% de l'ensemble du secteur agricole en 2011. Certaines faiblesses du secteur du thé ont été identifiées : qualité insuffisante et fluctuante des produits de thé, faible productivité, prépondérance des petits producteurs, fragmentation des surfaces cultivées, utilisation irrationnelle des pesticides et d'engrais. Une autre faiblesse soulignée par les études existantes concerne le type de thé adopté par les producteurs, en particulier la variété « Trung-Du ». En effet, la plupart des surface de la culture correspondent à cette variété, parmi les plus anciennes, qui donne de petites feuilles de thé et d'une qualité assez limitée (Tran et al., 2004). Pour cette raison, les producteurs sont incités à adopter les nouvelles variétés de thé comme « PH1 », « LPD1 », et « Bat-Tiên » pour lesquelles on pense pouvoir obtenir une meilleure productivité et une qualité supérieure.

Dans ce contexte, la promotion agricole au Vietnam joue un rôle important dans le développement du secteur agricole en général et de la production de thé en particulier. La politique de promotion agricole vise à améliorer l'utilisation des technologies existantes et à développer les compétences des agriculteurs. Elle fournit aux fermiers des informations sur les nouvelles techniques de production, les nouvelles variétés, de nouvelles pratiques agricoles, le marché et des autres acteurs de la filière, etc. Elle comporte plusieurs facettes : (i) formation sur les techniques de culture (préparation de la terre, plantation,. . .), (ii) formation sur l'utilisation des engrais et des pesticides, (iii) information sur la récolte et la conservation, (iv) information sur le marché de débouchés, (v) techniques de commercialisation. Notre étude a l'ambition d'évaluer les impacts des pratiques de promotion agricole sur l'efficacité technique dans le processus de production de thé au nord-est du Vietnam. Nous distinguons également les effets de différentes variétés de thé afin de voir si l'incitation à adopter de nouvelles variétés de thé porte ses fruits. Nous estimons une frontière de production stochastique à l'aide d'une base de données d'enquête de ménages producteurs que nous avons collectée dans la région. Nous calculons ensuite l'efficacité technique pour les producteurs de thé. Cette dernière correspond à l'écart entre la production effectivement observée et la frontière de production qui représente la meilleure production possible étant donné les quantités observées d'inputs. Plus cet écart est faible, plus la production est efficace. Inversement, un grand écart correspond à une plus faible efficacité technique (ou, de manière équivalent, une plus grande inefficacité). Nos résultats sont doubles. D'une part, nous montrons que la production de thé dans la région est fortement inefficace, reflétant ainsi une utilisation sous optimale des facteurs de production. D'autre part, les pratiques de promotion agricole et l'incitation à adopter de nouvelles variétés de thé ne semblent pas produire les effets escomptés sur l'efficacité technique. La suite de cet article est organisée comme suit. La section 2 présente un survol des études existantes sur l'efficacité technique relative au thé. La section 3 fournit une description des données d'enquête que nous avons collectées nous-même au Vietnam. La section 4 discute la méthodologie, les résultats d'estimation et les interprétations qui en résultent. Enfin, la dernière section présente quelques remarques de conclusion.

2.2 Efficacité technique et politique de promotion agricole

Des survols de littérature sur l'estimation de l'efficacité technique se trouvent dans Battese et Coelli (1992), Bravo-Ureta et Pinheiro (1993) et Greene (2008), etc. Les recherches sur la frontière de production et l'efficacité technique sont abondantes. Cependant, celles sur le thé le sont beaucoup moins. Basnayake et Gunaratne (2002) ont trouvé que l'efficacité technique des petits producteurs de thé au Sri Lanka est en moyenne de 65%. Les auteurs ont souligné que l'âge, le niveau d'instruction, le type de variété, l'expérience du fermier ont des effets significatifs sur l'efficacité. Pour le Bangladesh, l'efficacité technique est de 59% selon Baten et al. (2010) alors que ce chiffre remonte à 84,53% pour l'Inde selon Haridas et al. (2012). Maity (2012) a trouvé que l'efficacité technique de la production de thé en Bangalie ouest (Inde) augmente avec la surface cultivée. En ce qui concerne le Vietnam, Nghia (2008) a obtenu que ce chiffre est très élevé pour la production de thé biologique, environ 99%. Dans l'étude de Saigenji et Zeller (2009) ont, quant à eux, obtenu une valeur de 60%. Ils ont également observé que les fermiers ayant signé un contrat de vente avec des acheteurs ont une efficacité technique plus grande que ceux n'ayant pas signé un contrat. Plus précisément, les producteurs ayant un contrat avec une entreprise d'Etat a une efficacité de 69%, ceux ayant un contrat avec une entreprise privée ou une coopérative a une efficacité de 58% alors que ceux n'ayant aucun contrat ne donne qu'un niveau d'efficacité de 47%. Des facteurs déterminant l'efficacité technique ont été également analysés, comme la surface de terre détenue par les ménages, le nombre de pieds de théier, l'âge moyen des plantes, la distance par rapport aux points de collecte des feuilles de thé, l'utilisation des moyens motorisés de transport, l'indice de pauvreté, etc. Quant à la variable d'intérêt, politique de promotion agricole, les études existantes dégagent des conclusions contrastées. Dans les études de Seyoum et al. (1998), Ahmad et al. (2002), and Lindara et al. (2006), qui ne sont pas sur la production de thé, les politiques de promotion agricole peuvent améliorer l'efficacité. En particulier, Seyoum et al. (1998) ont étudié l'efficacité technique des producteurs de maïs à l'est de l'Ethiopie, en comparant les fermiers impliqués dans un programme consistant à adopter des meilleures techniques de culture et ceux qui sont en dehors de ce programme. Les auteurs ont montré que les conseils des travailleurs de promotion agricole sont bénéfiques aux fermiers participant à ce programme alors qu'ils n'ont aucun effet sur les autres fermiers. Ahmad et al. (2002) ont souligné que les contacts avec les travailleurs de promotion agricole accroissent l'efficacité technique des producteurs de blé au Pakistan. Enfin, selon Lindara et al. (2006), les visites des travailleurs de promotion agricole et la participation des fermiers aux programmes de formation améliorent l'efficacité technique dans le secteur d'agroforesterie d'épices dans le district Matale au Sri Lanka. A l'opposé, certains travaux ont remarqué que les pratiques de promotion agricole peuvent avoir aucun impact, voire un effet néfaste, sur l'efficacité technique. Plus précisément, Idiong (2007) n'a obtenu aucun effet significatif de la variable de promotion agricole sur l'efficacité technique de la production de riz de marécage au Nigeria. Pour Raphael (2008), le même résultat est observé pour la production de manioc dans le même pays. Chirwa (2007) n'a trouvé aucun effet significatif des pratiques de promotion agricole sur la production de maïs eu Malawi. Pour le cas du Vietnam, Khai et al. (2008) ont trouvé que les programmes de formation et le soutien de l'Etat (sur l'utilisation des engrais, des pesticides et de grains) n'ont pas d'effet significatif sur l'efficacité de la production de soja. Dans leur étude, Khai et al. (2011) ont utilisé une variable correspondant à trois politiques principales du gouvernement (crédit à taux favorables, mise à disposition de terrain, promotion agricole), dont le but vise à améliorer la performance du secteur agricole au Vietnam. Ils ont conclu avec leurs données sur la production de riz que ces politiques n'ont pas aidé aux fermiers à produire plus efficacement.

2.3 Données

Les données proviennent de notre enquête réalisée dans trois provinces au nord-est du Vietnam (Tuyên-Quang, Phu-Tho et Thai-Nguyên) de janvier à mai 2013. Tuyên-Quang et Phu-Tho sont deux provinces qui produisent principalement le thé noir tandis que Thai-Nguyên est renommée pour son thé vert. Cette enquête est réalisée de manière aléatoire sur les listes de ménages des villages. Au total, nous avons un échantillon de 244 ménages producteurs de thé. L'enquête porte sur les informations sur la production de thé en 2012 (variétés de thé, quantité de production, utilisation des engrais, utilisation des pesticides, surface cultivée, quantité de travail et pratiques de promotion agricole suivies par les producteurs). Les données collectées concernent également les caractéristiques importantes des ménages comme le revenu, la composition du ménage (présence des personnes âgées, des enfants), le niveau d'instruction du chef de ménage, etc. Le tableau A6 dans Appendix donne la liste des variables utilisées dans cette étude ainsi que leur définition. Le tableau 2.1 présente des statistiques descriptives des variables utilisées dans notre analyse. Une description plus détaillée des données se trouve dans Nguyen-Van et To (2014). Nous remarquons que la production moyenne de thé dans notre échantillon est de 4,96 tonnes et la production des ménages-producteurs varie de 0,02 tonnes (20 kg) à 60 tonnes (60000 kg) montrant ainsi une grande variabilité de la taille des exploitations. La surface cultivée est de 5866m2 par ménage en moyenne. La quantité moyenne de travail utilisée est de 225 personnes-jours. Toutes ces informations montrent que notre échantillon couvre à la fois des petits et moyens producteurs.

Table 2.1: Descriptive statistics

Variable	Moyenne	Ecart-type	Min.	Max.	Obs.
Production	4.96	8.43	0.02	60	244
Terre	5866.48	5997.24	130	45000	241
Travail	224.63	542.59	5	7863	244
Engrais organiques	0.49	0.50	0	1	243
Engrais chimiques	0.73	0.44	0	1	244
Thé noir	0.43	0.50	0	1	244
Variétiés					
‘Trung-Du’	0.45	0.50	0	1	244
‘PH1’	0.18	0.38	0	1	244
‘LDP1’	0.21	0.41	0	1	244
‘Bat-Tien’	0.19	0.40	0	1	244
‘Autres’	0.17	0.38	0	1	244
Promotion agricole					
Cultivation	0.72	0.45	0	1	244
Inputs	0.67	0.47	0	1	244
Récolte & conservation	0.57	0.50	0	1	244
Information	0.25	0.44	0	1	244
Vente	0.22	0.42	0	1	244
Revenue élevé	0.33	0.47	0	1	244
Instruction élevé	0.32	0.47	0	1	244
Minorités	0.11	0.31	0	1	244

Par ailleurs, les données incluent 139 producteurs de thé vert et 105 producteurs de thé noir. Une variable indicatrice est définie pour tenir compte de la différence entre ces deux types de thé. L’information sur l’utilisation des engrais (organique et chimique) est également disponible. Nous introduisons deux indicatrices pour indiquer la présence de ces deux engrais dans le processus de production. Notons que les engrais chimiques peuvent dégrader le sol, contrairement aux engrais organiques. Les données montrent que la plupart des producteurs (178 ménages) utilisent des engrais chimiques alors que, dans une plus faible proportion, environ la moitié de l'échantillon (118 producteurs) utilisent des engrais organiques. Comme tous les producteurs utilisent les pesticides, la prise en compte de cette variable dans notre analyse n'est pas vraiment intéressante. En ce qui concerne la promotion agricole, cinq variables indicatrices sont définies pour représenter les activités suivantes : (i) formation sur les techniques de culture, (ii) formation sur les engrais et les pesticides, (iii) formation sur la récolte et la conservation, (iv) information sur le marché de produits de thé et (v) formation sur les techniques de vente et de commercialisation. Les variétés de thé sont classifiées dans cinq catégories : « Trung-Du » (variété ancienne, la plus répandue), « PH1 », « LDP1 », « Bat-Tiên » et « Autres ». Le tableau 2.2 montre le nombre de producteurs qui ont choisi ces différentes variétés pour leur production de thé. Notons qu'un producteur peut cultiver plusieurs variétés de thé en même temps. Nous observons que la catégorie « Trung-Du » est adoptée par 111 ménages. Les autres variétés sont moins répandues, environ deux fois moins nombreux de « Trung-Du ».

Table 2.2: Distribution selon variétés de thé

Variétés de thé	Fréquence		Pourcentage	
	Non: 0	Oui: 1	Non: 0	Oui: 1
'Trung-Du'	133	111	54.51	45.49
'PH1'	200	44	81.97	18.03
'LDP1'	192	52	78.69	21.31
'Bat-Tien'	197	47	80.74	19.26
'Autres'	201	43	82.38	17.62

Enfin, notre analyse inclut une variable indicatrice pour un niveau de revenu élevé, une indicatrice pour un niveau d'instruction élevé du chef de ménage (lycée ou supérieur), et une indicatrice d'appartenance à des minorités. Nous pensons que ces facteurs peuvent influencer le processus de production. En effet, des conditions matérielles favorables ou un niveau d'instruction suffisant s'avèrent nécessaires pour favoriser l'accès à de nouvelles technologies de production et à des informations permettant améliorer la production de thé. A l'opposé, l'appartenance à un groupe ethnique minoritaire pourrait constituer un handicap par rapport au groupe majoritaire.

2.4 Méthodologie et résultats d'estimation

Pour étudier l'efficacité technique de la production de thé au nord-est du Vietnam, nous appliquons le modèle de frontière de production stochastique proposé par Aigner et al. (1977) et Meeusen et van den Broeck (1977). Nous calculons ensuite l'efficacité technique qui mesure l'écart entre la production effectivement observée et la frontière de production qui représente la meilleure production possible étant donné les quantités observées d'inputs. Un survol de littérature peut se trouver dans Bauer (1990), Kumbhakar et Lovell (2003), et Greene (2008). Le modèle correspond à la fonction de production translog et est estimé par la méthode du maximum de vraisemblance. Les détails relatifs à l'estimation de ce modèle sont présentés dans Nguyen-Van et To (2014). Les résultats d'estimation du modèle sont reportés dans les tableaux 2.3 et 2.4. Le tableau 2.3 représente l'estimation de la fonction de production. On y lit notamment les effets de différents inputs sur la production de thé. Nous remarquons que seuls la surface de terre et l'utilisation des engrais organiques ont un effet significatif et positif sur la production. Ceci signifie que ce sont deux facteurs les plus importants dans le processus de production de thé dans la région étudiée. Le tableau 2.4 quantifie les impacts de différents déterminants de l'inefficacité technique. Nous observons que parmi les cinq types de promotion agricole, seule la formation sur l'utilisation des inputs (engrais et pesticides) a un effet significatif. Cet effet négatif (-0,24) signifie que cette pratique de promotion agricole peut aider aux producteurs de réduire l'inefficacité technique. Autrement dit, la participation à la formation sur l'utilisation des inputs peut améliorer l'efficacité technique du processus de production. Ce résultat est différent de celui de Khai et al. (2008) qui ont trouvé que cette politique de promotion agricole n'a aucun impact sur l'efficacité technique de la production de soja au Vietnam.

Quant aux variétés de thé, les variétés de type « Trund-Du », « Bat-Tiên » et « Autres » ont un impact significatif sur l'inefficacité technique (donc sur l'efficacité). Ces effets sont respectivement -0,26, -0,21 et -0,37, tous indiquant une réduction de l'inefficacité technique (ou de manière équivalente, une amélioration de l'efficacité technique). Les deux autres catégories, « PH1 », « LDP1 », n'ont aucun impact significatif sur l'efficacité technique. Ce résultat souligne que la production de thé avec la variété ancienne « Trung-Du » ne constitue pas forcément une faiblesse. En revanche, les nouvelles variétés « PH1 » et « LDP1 » n'ont pas d'effet espéré, ce qui va à l'encontre des recommandations actuelle de certains acteurs de la filière visant à rem-

Table 2.3: Estimation de la function production

Variables	Coefficient	Ecart-type
Log Terre	0.43*	0.25
Log Travail	-0.30	0.35
Engrais organiques	1.46**	0.69
Engrais chemiques	-1.21	0.80
Log Terre × Log Travail	0.05	0.05
Engrais organiques × Log Terre	-0.10	0.09
Engrais organiques × Log Travail	-0.12	0.09
Engrais chemiques × Organiques	-0.08	0.16
Engrais chemiques × Log Travail	0.09	0.09
Engrais chemiques × Log Terre	0.09	0.08
Constante	-2.39	2.15

Note: * et ** représentent respectivement la significativité au seuil de 10% et 5%.

Table 2.4: Déterminants de l'inefficacité technique

Variable	Coefficient	Ecart-type
Promotion agricole		
Cultivation	0.12	0.15
Inputs	-0.24*	0.14
Récolte & conservation	0.11	0.11
Information	0.13	0.15
Vente	-0.05	0.12
Variétés de thé		
'Trung-Du'	-0.26**	0.11
'PH1'	-0.00	0.37
'LDP1'	-0.14	0.11
'Bat-Tien'	-0.21*	0.11
'Autres'	-0.37**	0.18
Thé noir	-2.80	3.42
Revenu élevé	-0.02	0.11
Instruction élevé	-0.01	0.08
Minorités	0.09	0.12
Constante	2.66**	0.40

Note: * et ** représentent respectivement la significativité au seuil de 10% et 5%.

placer la variété « Trung-Du » par de nouvelles variétés (Tran et al., 2004). L'analyse montre également qu'il n'y a pas de différence notable entre le thé noir et le thé vert. Ceci ne confirme pas les résultats de Nghia (2008), qui a souligné que le thé vert au Vietnam a une très forte efficacité technique (environ 99,8%). Nous observons finalement que les facteurs comme le revenu élevé, le niveau élevé d'instruction et l'appartenance à des minorités n'ont aucun impact statistiquement significatif sur l'efficacité technique.

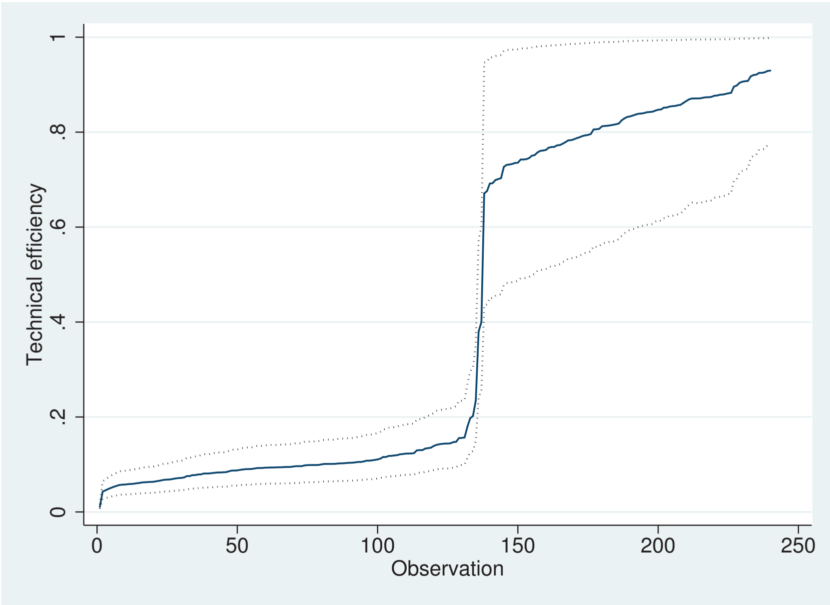

Figure 2.1: Efficacité technique dans la production de thé. L'ordonnée correspond à l'efficacité technique.

Pour avoir une idée précise sur l'efficacité technique de la production de thé, nous avons donc calculé cette quantité sur la base des paramètres estimés. La figure 2.1 présente la distribution de l'efficacité technique au sein de notre échantillon, les ménages sont classés selon l'ordre croissant concernant cette mesure. La courbe en trait continue représente l'efficacité technique, les courbes en pointillé correspondent à l'intervalle de confiance de 95%. Notons qu'une valeur proche de l'unité représente une production fortement efficace (l'efficacité technique maximale égale à 1) alors qu'une valeur proche de zéro indique une très faible efficacité (valeur minimale égale à 0). Nous observons qu'il y a une très grande hétérogénéité au sein de notre échantillon concernant l'efficacité technique. Cette dernière varie de 0,01 à 0,93. Notre résultat montre que la production de thé dans la région étudiée est largement inefficace, l'efficacité technique moyenne de notre échantillon est seulement de 0,41, inférieure à 50%.

2.5 Conclusion

Cette étude se consacre aux déterminants de l'efficacité technique de la production de thé au nord-est du Vietnam. Nous avons trouvé que la production de thé dans cette région est très peu efficace. L'efficacité technique atteigne seulement une valeur de 41% en moyenne, indiquant ainsi que la production actuelle se trouve très loin de la frontière de production. Autrement dit, ce résultat signifie que les ressources sont largement sous utilisés dans la production de thé. Il implique que les acteurs de la filière thé au Vietnam (gouvernements central et local, producteurs) devraient faire beaucoup d'effort afin de réduire l'inefficacité de production. Nous avons observé que parmi les variables analysées, certaines pratiques de promotion agricole et certains types de variétés de thé peuvent aider à améliorer l'efficacité technique. Il en résulte qu'il faudrait se focaliser sur la formation sur l'utilisation des engrais et des pesticides. D'autres pratiques de promotion agricole, étant donné leur impact négligeable, devraient être repensées et modifiées afin de les rendre plus effectives. Par ailleurs, notre résultat suggère une prudence sur le choix de variétés de thé. En particulier, il ne faudrait pas se précipiter sur n'importe quelle nouvelle variété pour remplacer l'ancienne variété « Trung-Du » qui reste encore relativement efficace. S'il fallait choisir une nouvelle variété, notre résultat suggèrerait « Bat-Tiên » plutôt que « PH1 » et « LDP1 ».

Chapter 3

Farmers' adoption of organic production[1]

3.1 Introduction

Recently, numerous empirical studies have considered the effects of adopting new technologies. Some authors used the logit and probit models for their research (Nerlove and Press, 1973; Schmidt and Strauss, 1975; Kebede et al., 1990; Maddala, 1991; Ayuk, 1997; Negatu and Parikh, 1999; Adesina et al., 2000; Adesina and Chianu, 2002; Adebayo and Oladele, 2013; Ouma and De Groote, 2011; Abebe et al., 2013; Läpple and Kelley, 2015, etc.). These empirical studies measure the factors' effect on probability adaptation new technology or new variety in agricultural sector. For example, Adesina et al. (2000) applied a logit model in their study. Their result showed that the negatively significant age variable suggested that younger farmers are more likely to adopt improved production technologies. The positively significant variable on possession of full rights over trees suggested that it has a positive influence on the likelihood to adopt improved production technologies. Besides, they put on some other variables such as gender, age, education, etc. However, they turned out to be insignificant. Ouma and De Groote (2011) computed the factors affecting adoption of improved corn varieties and fertilizer by farmers in Kenya. They used some variables such as education, access to credit, hired labor, extension contacts, distance to market, fertilizer. The result concerning the education variable is significantly positive, revealing its association with adoption of improved maize varieties. However, it did not show significant as related to adoption of fertilizer. Distance to market was negatively associated with adoption of fertilizer, although it was positively associated with the

[1]This chapter is drawn from To-The N., Le-Van C. (2015) "Farmers' adoption of organic production", *BETA Working Paper,* forthcoming.

intensity of fertilizer's use. Use of fertilizer and improved maize seed were significantly positive at 1% level, respectively. It means that it is strongly associated with adoption of improved maize seed and fertilizer. Abebe et al. (2013) determined the adoption of improved potato varieties in Ethiopia. The result indicated that higher education of the household head, gender, access to credit, family size, stew quality of local variety and the presence of a radio and/or television also have a significant positive effect on adoption.

Meanwhile, a few studies considered the theoretical aspects. Some of them considered the effects of risk on technology change at the firm level. Stoneman (1981) developed a dynamic version of a single innovation model to prove the inter-firm diffusion of the new technology. This research showed that the expected level of use of the new technology is positively related to profitability but also influenced by uncertainty, attitudes to risk and adjustment costs. After that, Just and Zilberman (1983) developed a model that explains land allocation and technology adoption. The results suggested that risk attitudes play a large role in determining the farm size in technology adoption. Furthermore, Feder et al. (1985) offered an excellent survey of this literature. The major result of this line of work is that the level of modern inputs used in product to depends on whether these inputs are risk reducing or risk increasing and on whether relative risk aversion is increasing or decreasing. Kim et al. (1992) examined the role of output price as a factor of influence on technological change. The results indicated that a reduction in the variance of output prices will increase the rate of adoption new technologies. However, besides referring to the risks of application of new technology, these studies did not mention the other conditions of firm with adaption of new technology.

An alternative approach, namely Duration Analysis, explored by some authors (Hannan and McDowell, 1984; Levin et al., 1987). This method has been used widely in labor economics, with examples in technology literature, but fewer in agricultural economics (Burton et al., 2003). Especially, the dearth of applications to agricultural adoption literature is rather surprising as Duration Analysis has a great advantage of dealing with both cross-section and time series data.

In this study we mainly focus on the agricultural sector. There is evidence indicating which factors influence the farmers' decision to change their technology. Here, it should be understood more holistically as new fertilizer and new adaptation can modify the technology, etc. Kebede et al. (1990) examined the impact of factors such as income, wealth, family size, farm size, access to outside information, education, experience influence on the adoption of new fertilizer and pesticide technologies in Tegulet-Bulga district, Ethiopia. Strauss et al. (1991) explored the determinants of technology adoption by upland rice and soybean of farmers in Brazil. They used some factors for this study, such as infrastructure to the farm level data containing information on farmer human capital as well as land quantity and quality. The result showed a positive impact of the farmers' education on the decision to accept new technology.

Other studies considered the situation of small farms regarding their technology adoption behavior. In particular, Rauniyar and Goode (1992) showed that farmers differ from one another in their adoption frequency and pointed out that a technology adoption study should address adoption behavior as a continuum rather than as an adopter/non-adopter type of discrete phenomenon. Huang and Rozelle (1996) focused on measuring the relative importance of the role of technology versus the one of institutional innovation in China's rural economy. This analysis identified technology adoption as the most important determinant of rice yield growth, accounting for nearly 40%; institutional reform accounted for 35%. Ayuk (1997) indicated that water availability and the profitability of the technology itself enhance the probability of adopting live hedges. The results provided an insight on the conditions that should be taken into consideration when targeting farmers for this agro-forestry technology. Adesina et al. (2000) showed that the farmer characteristics which influence decisions of adoption include farmer's gender, contact with extension agents, years of experience with agro-forestry and tenancy status in the village. The model results showed the human capital variables to be significant in explaining the farmers' decisions to adapt and modify the technology.

In addition, some studies are related to the organic agricultural sector (Burton et al., 2003; Koesling et al., 2008; Läpple, 2010; Läpple and Van Rensburg, 2011; Läpple and Kelley, 2015). These works aimed to determine factors affect alternative farming practices. The empirical results highlight the importance of gender, age, training, risk attitudes, farming experience, attitudes to the environment, and information networks in determining the adoption of organic farming practices.

Generally, these studies do not fully address the factors that change the technology, each study gives a different variable, and the result is inconsistent each other, especially as they do not consider elements of new technology productivity affecting the adoption. To address these limitations, in this study, we mention some elements as land, labor and productivity in our models. We investigate the effects of these factors on the adoption of organic production or new technology.

Government can encourage farmers to produce organic product. However, this policy is an impulsive action and without any scientific basis. Thus, in this study, we want to examine the relevance of these policies. Our study aims to provide explanations regarding the conditions which could help farmers to move towards an organic production. Three scenario for policies and perception of farmer are illustrated in Section 3.2. Some recommendations also be drawn about appropriate policies enhancing organic production.

The remaining of the chapter is organized as follows. Section 3.2 presents our theoretical model and three scenarios which can be derived from it. For each scenario, we give conditions to have farmers changing towards organic production. Section 3.3 reviews on the principal results. Section 3.4 concludes the study. Finally, all the proofs are given in Appendix 3.5.

3.2 Theoretical model

The technological adoption is a hotly debated topic. We want to focus on the agricultural economic sector, specifically on agriculture production in which farmers would like to switch to organic product in their farming. We would like to examine under which conditions farmers adopt an organic product (new technology).

Furthermore, the definition of new technology is quite large. Although organic product is not an innovation, it requires the adoption of a different farming practice. In our context, new technology is defined as organic production. In general, in order to make decision on converting from conventional production to organic production, farmers have to select either keeping the farm as a conventional practice or converting it into organic product.

We assume that a producer wants to use a new technology, T_2, to produce some output, Y_2, of organic product with price P_2. The price of conventional product is P_1. Let S_1 be the quantity of land for conventional product, S_2 be the quantity of land needed for the organic product and V be the total quantity of land for the farmer. Let $C(S_1)$ be the cost function for conventional product. When a producer uses the new technology, her/his productivity is expected to gain or lose A. The cost becomes $\Phi(A)C(S_2)$, where the function $\Phi(\cdot)$ is concave, differentiable, increasing, with $\Phi(A) > 0$, $\Phi(0) = 0$. We want to investigate under which conditions a farmer accepts to adopt the organic product.

Let w denote the wage, L_1, L_2 be the quantities of labor used for producing conventional and organic product. The production function is $F(S,L) = S^{\alpha}L^{1-\alpha}$, $0 < \alpha < 1$. We assume the cost function is $C(S) = \gamma\frac{S^2}{2}$, $\gamma > 0$. We suppose there is no constraint on labor but the total quantity of land used in production is limited by an amount V. We will present three scenarios, namely three cases that can arise.

Scenario 3.2.1. ***Each farmer has two kinds of technologies, an old technology (conventional product) which is called*** T_1 ***and a new technology (organic product) called*** T_2***. The production function which corresponds to the conventional product,*** T_1***, is*** $F_1(S_1,L_1) = S_1^{\alpha}L_1^{1-\alpha}$ ***while the technology corresponding to the organic product,*** T_2***, is*** $F_2(S_2,L_2) = AS_2^{\alpha}L_2^{1-\alpha}$ ***with*** $A > 0$***.*** A ***define as productivity. The empirical result of Huang et al. (2002) and Ali and Abdulai (2010) tells us that productivity is influenced by the adoption of technology. The farmer has only the constraint that the supply of land is limited by an quantity*** V***.***

Then, the producer optimization problem $(\mathbb{P}_1)$ is

$$\left.\begin{array}{l} \max\left\{P_1S_1^{\alpha}L_1^{1-\alpha} - wL_1 - C(S_1) + P_2AS_2^{\alpha}L_2^{1-\alpha} - wL_2 - \Phi(A)C(S_2)\right\} \\ \text{subject to}\left\{\begin{array}{l} S_1 + S_2 \leqslant V, \\ S_1 \geqslant 0,\ S_2 \geqslant 0,\ L_1 \geqslant 0,\ L_2 \geqslant 0. \end{array}\right. \end{array}\right\} (\mathbb{P}_1)$$

Lemma 3.2.1. *Consider* $(\mathbb{P}_1)$*. Let* S_1^*, S_2^*, L_1^*, L_2^* *denote the optimal values of lands and labors for conventional product and organic product; then*

$$(a)\ S_1^* > 0 \quad \Leftrightarrow \quad L_1^* > 0,$$
$$(b)\ S_2^* > 0 \quad \Leftrightarrow \quad L_2^* > 0.$$

The proof of this Lemma 3.2.1 is given in Appendix 3.5.1. Lemma 3.2.1 helps us understanding the relationship between land and labor. This result implies that when the farmer uses the land for cultivating conventional product (old technology) S_1^*, then, at the same time, their use of labor is L_1^*. Similarly, producers also use the land for planting the organic product (new technology) S_2^* and their use of labor is L_2^*.

Proposition 3.2.1. *Under Scenario 3.2.1, consider the problem* $(\mathbb{P}_1)$*. Let* $A_1 = \frac{P_1}{P_2}$ *and*

$$
\begin{aligned}
Q(P_1,P_2,\alpha,w,\Phi,\gamma,A) &= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{1-\alpha}{\alpha}} + \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{1-\alpha}{\alpha}} \\
&= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{1-\alpha}{\alpha}}\left[1+\frac{1}{\Phi(A)}\left(\frac{A}{A_1}\right)^{\frac{1}{\alpha}}\right].
\end{aligned}
$$

(i) If $V \geqslant Q(P_1,P_2,\alpha,w,\Phi,\gamma,A)$ *then the optimal lands and labors are the following*

$$
\begin{aligned}
\textit{land of conventional product, } S_{1a}^{*} &= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}, \\
\textit{labor of conventional product } L_{1a}^{*} &= \frac{\alpha}{\gamma}P_1^{\frac{2}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}}, \\
\textit{land of organic product, } S_{2a}^{*} &= \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}, \\
\textit{labor of organic product } L_{2a}^{*} &= \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{2}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}}, \\
\textit{and total land } V &> S_{1a}^{*}+S_{2a}^{*}.
\end{aligned}
$$

(ii) If $V < Q(P_1,P_2,\alpha,w,\Phi,\gamma,A)$*, let*

$$
R = (P_2A)^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} - P_1^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}},
$$

then the optimal lands and labors will be given in the following sequel.

(ii.a) $R \geqslant 0$ *is equivalent to* $A \geqslant \frac{P_1}{P_2}$*,*

(ii.a1) If $\frac{R}{\gamma\Phi(A)} < V < Q(P_1,P_2,\alpha,w,\Phi,\gamma,A)$*, then*

$$
\begin{aligned}
\textit{land of conventional product, } S_{1a}^{**} &= \frac{\gamma\Phi(A)V-R}{\gamma(1+\Phi(A))} > 0, \\
\textit{labor of conventional product } L_{1a}^{**} &= \left[\frac{\gamma\Phi(A)V-R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0, \\
\textit{land of organic product, } S_{2a}^{**} &= \frac{\gamma V+R}{\gamma(1+\Phi(A))}, \\
\textit{labor of organic product } L_{2a}^{**} &= \left[\frac{\gamma V+R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_2A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.
\end{aligned}
$$

(ii.a2) If $V \leqslant \frac{R}{\gamma\Phi(A)}$, then the optimal lands and labors are the following

$$S_{1a}^{**} = 0,\ S_{2a}^{**} = V,\ L_{1a}^{**} = 0,\ L_{2a}^{**} = V\left\{\frac{P_2 A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

(ii.b) $R < 0$ is equivalent to $A < \frac{P_1}{P_2}$.

(ii.b1) If $-\frac{R}{\gamma} < V < Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$, then

$$\begin{aligned}
S_{1a}^{**} &= \frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))} > 0, \\
L_{1a}^{**} &= \left[\frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0, \\
S_{2a}^{**} &= \frac{\gamma V + R}{\gamma(1+\Phi(A))} > 0, \\
L_{2a}^{**} &= \left[\frac{\gamma V + R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_2 A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.
\end{aligned}$$

(ii.b2) If $V \leqslant -\frac{R}{\gamma}$ the optimal lands and labors are the following

$$S_{2a}^{**} = 0,\ S_{1a}^{**} = V,\ L_{2a}^{**} = 0,\ L_{1a}^{**} = V\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

The proof of Proposition 3.2.1 is given in Appendix 3.5.2.

Observe that $Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$ is the total land required by the producer when there is no constraint on land supply. Statement (*i*) tells us that, if land supply V is more than $Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$, the producer will behave as if she/he does not face the supply constraint. She shares her lands following conventional product (old technology) S_{1a}^*, organic product (new technology) S_{2a}^* and she will allocate labors following the conventional product L_{1a}^* and the organic product L_{2a}^*.

Statement (*i*) is consistent with the study of Strauss et al. (1991), as their result indicates that the total area of land owned by the farmer is unrelated to the adoption of new technology. But statement (*i*) is more precise: the empirical results in Strauss et al. (1991) are true when the total area is large enough.

Statement (*ii*) indicates that, if land supply V is less than $Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$, the land constraint will bind. However, we observe two cases. The first case corresponds to a productivity A larger than $\frac{P_1}{P_2}$. We determine a threshold value $\frac{R}{\gamma\Phi(A)}$. If the land is beyond this threshold value $\frac{R}{\gamma\Phi(A)}$ and is less than the total land $Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$, then the farmer will use his land following S_{1a}^{**}, S_{2a}^{**} and assigns his labor following L_{1a}^{**}, L_{2a}^{**} (Proposition 3.2.1($ii.a1$)). In the statement ($ii.a2$), if land V is less than the threshold value $\frac{R}{\gamma\Phi(A)}$, then the farmer prefers to plant only the organic product (new technology) S_{2a}^{**} and to use labor L_{2a}^{**}.

The second case corresponds to a productivity A lower than $\frac{P_1}{P_2}$. Again, there is a threshold value $-\frac{R}{\gamma}$. If the farmer land is beyond the threshold value $-\frac{R}{\gamma}$ and is less than the total land $Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$, then the farmer will distribute its land following the conventional product (old technology) S_{1a}^{**}, the organic product (new technology) S_{2a}^{**} and will share out his labor following L_{1a}^{**}, L_{2a}^{**} (Statement ($ii.b1$)). In statement ($ii.b2$), if land V is beyond the threshold value $-\frac{R}{\gamma}$, then the farmer will plant only conventional product, S_{1a}^{**} and use all labor L_{1a}^{**} for planting this product. Here the productivity A is too low to incite farmers to adopt it.

Finally, when A is very large, case ($ii.a2$) of Proposition 3.2.1 shows that total land will be devoted to organic production. And when A is very small, case ($ii.b2$) of Proposition 3.2.1 shows that total land will be used for conventional product.

Proposition 3.2.2. *If we have (ii.a1) or (ii.b1) then there exist values $\widehat{A}$ and $\tilde{A}$ such that if $A > \widehat{A}$ then S_{2a}^{**} is an increasing function of A, and if $A < \tilde{A}$ then S_{2a}^{**} is a decreasing function of A.*

Proof.

From the case ($ii.a1, ii.b1$) in Proposition 3.2.1, we have

$$S_{2a}^{**} = \frac{\gamma V + R}{\gamma(1 + \Phi(A))}, \; R = (P_2 A)^{\frac{1}{\alpha}} \alpha \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}} - P_1^{\frac{1}{\alpha}} \alpha \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}}.$$

Then, we get $S_{2a}^{**} = \frac{V(1+\frac{R}{\gamma V})}{1+\Phi(A)}$.

We first prove for ($ii.a1$).

We observe that $\frac{R}{\gamma V} - \Phi(A) < 0$.

We obtain

$$\begin{aligned}
\text{Log}S_{2a}^{**} &= \text{Log}V + \text{Log}(1+\frac{R}{\gamma V}) - \text{Log}(1+\Phi(A)) \\
\frac{d}{dA}\text{Log}S_{2a}^{**} &= \frac{1}{(1+\frac{R}{\gamma V})} \times \frac{1}{\gamma V}\left[P_2^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} A^{\frac{(1-\alpha)}{\alpha}}\right] - \frac{1}{1+\Phi(A)}\Phi'(A) \\
&= \frac{1}{\gamma V+R}P_2^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} A^{\frac{(1-\alpha)}{\alpha}} - \frac{\Phi'(A)}{1+\Phi(A)}.
\end{aligned}$$

Observe that $\frac{1}{\gamma V+R} > \frac{1}{\gamma V(1+\Phi(A))}$. Hence,

$$\frac{d}{dA}\text{Log}S_{2a}^{**} > \frac{1}{1+\Phi(A)}\left[\frac{1}{\gamma V} \times P_2^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} A^{\frac{(1-\alpha)}{\alpha}} - \Phi'(A)\right].$$

Let

$$\phi(A) = \frac{1}{\gamma V} \times P_2^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} A^{\frac{(1-\alpha)}{\alpha}} - \Phi'(A).$$

Function ϕ is increasing. It takes a negative value $-\Phi'(0)$ when $A = 0$ and equals $+\infty$ when $A = +\infty$. Hence there exists a value $\hat{A}$ such that if $A > \hat{A}$ then $\phi(A) > 0$ implying $\frac{d}{dA}\text{Log}S_{2a}^{**} > 0$. When $A \to 0$,

$$\frac{1}{\gamma V+R}P_2^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} A^{\frac{(1-\alpha)}{\alpha}} - \frac{\Phi'(A)}{1+\Phi(A)} \to -\Phi'(0) < 0.$$

Hence there exists $\tilde{A}$ such that, if $A < \tilde{A}$ then $\frac{d}{dA}\text{Log}S_{2a}^{**} < 0$. The proof for the case $(ii.b1)$ is similar. □

In the study of Langyintuo and Mungoma (2008), there is a significant and negative relationship between land size and adoption. They assert that for a unit increase in land size, the intensity of use of high yielding maize varieties decreases by 0.4 percent. Similarly, in the study of Akinola et al. (2010), land size has negative and insignificant effect on adoption of balance nutrient management systems-rotation in the northern Guinea savanna of Nigeria. The second statement of Proposition 3.2.2 explains these empirical results: the adoption technology is low. Meanwhile, Kebede et al. (1990) show that land size has a positive effect on adoption of new technology. This variable has the most significant effect on adoption of production technologies. Adebayo and Oladele (2013) showed that farmers with a large land size are more likely to use organic farming practices than farmers with a small land size. The first statement of Proposition 3.2.2 makes precise these results. It shows that these empirical results hold if A is large enough.

The role of the land supply constraint is examined in Proposition 3.2.1. We will now, in Proposition 3.2.3, focus on the role of productivity A on the farmer's decision of technology adoption. We require Lemma 3.2.2 which helps us capturing some conditions on productivity A when the farmer wants to shift to organic product (new technology).

Lemma 3.2.2. *Assume* $\Phi'(0) = +\infty$, $\Phi'(+\infty) = 0$. *Let*

$$R = (P_2A)^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} - P_1^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}.$$

Let V_1, A_0, A_1, A_2, A_3 *be defined by* $V_1 = \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}$,

$$\begin{aligned}
&A_1 = \frac{P_1}{P_2},\\
&\text{when } V \leqslant V_1, \text{ then } A_0 = A_1 \times \left[1 - \frac{V}{V_1}\right]^{\alpha},\\
&\text{when } V > V_1, \text{ then } A_0 < 0,\\
&\text{when } V \geqslant V_1, \text{ then } \frac{A_2^{\frac{1}{\alpha}}}{\Phi(A_2)} = A_1^{\frac{1}{\alpha}} \times \left[\frac{V}{V_1} - 1\right],\\
&\text{when } V < V_1, \text{ then } A_2 < 0,\\
&\text{and } A_3 \text{ be defined by } \frac{A_3^{\frac{1}{\alpha}} - A_1^{\frac{1}{\alpha}}}{\Phi(A_3)} \times \frac{1}{A_1^{\frac{1}{\alpha}}} = \frac{V}{V_1}.
\end{aligned}$$

We have

(i) $R \geqslant 0 \Leftrightarrow A \geqslant A_1 = \frac{P_1}{P_2}$.

(ii) Assume $V > V_1$.

(ii.1) Then $V \leqslant Q(P_1, P_2, \alpha, w, \Phi, \gamma, A) \Leftrightarrow A \geqslant A_2$.
We have

$$A_2 \geqslant A_1 \quad \Leftrightarrow \quad \frac{1}{\Phi(A_1)} \leqslant \left[\frac{V}{V_1} - 1\right].$$

(ii.2) We have $A_2 < A_3$, $A_1 < A_3$ *and*

$$\frac{R}{\gamma\Phi(A)} \quad \leqslant \quad V \Leftrightarrow A \leqslant A_3.$$

(ii.3) We have $V > -\frac{R}{\gamma}$.

(iii) Assume $V \leqslant V_1$,

(iii.1) We have $V \leqslant -\frac{R}{\gamma} \Leftrightarrow A \leqslant A_0$,

(iii.2) $A_1 < A_3$ *and* $\frac{R}{\gamma\Phi(A)} \leqslant V \Leftrightarrow A \leqslant A_3$.

The proof of this lemma is given in Appendix 3.5.3.

Proposition 3.2.3. *We use the definitions given in Lemma 3.2.2.*
Let $V_1 = \frac{\alpha}{\gamma} P_1^{\frac{1}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{1-\alpha}{\alpha}}$. *Assume* $\Phi'(0) = +\infty$, $\Phi'(+\infty) = 0$.

(i) Assume $V \leqslant V_1$,

(i.1) If $A \leqslant A_0$, *then* $S_{2a}^{**} = 0$, $S_{1a}^{**} = V$, $L_{2a}^{**} = 0$, $L_{1a}^{**} = V \left\{ \frac{P_1(1-\alpha)}{w} \right\}^{\frac{1}{\alpha}}$.

(i.2) If $A_0 < A < A_3$, *then*

$$\begin{aligned}
S_{1a}^{**} &= \frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))} > 0, \\
L_{1a}^{**} &= \left[\frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))} \right] \left\{ \frac{P_1(1-\alpha)}{w} \right\}^{\frac{1}{\alpha}} > 0, \\
S_{2a}^{**} &= \frac{\gamma V + R}{\gamma(1+\Phi(A))} > 0, \\
L_{2a}^{**} &= \left[\frac{\gamma V + R}{\gamma(1+\Phi(A))} \right] \left\{ \frac{P_2 A(1-\alpha)}{w} \right\}^{\frac{1}{\alpha}} > 0.
\end{aligned}$$

(i.3) If $A \geqslant A_3$, *then* $S_{1a}^{**} = 0$, $S_{2a}^{**} = V$, $L_{1a}^{**} = 0$, $L_{2a}^{**} = V \left\{ \frac{P_2 A(1-\alpha)}{w} \right\}^{\frac{1}{\alpha}}$.

(ii) Assume $V > V_1$,

(ii.1) If $A \leqslant A_2$, then

$$\begin{aligned} S_{1a}^{*} &= \frac{\alpha}{\gamma} P_1^{\frac{1}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}}, \\ L_{1a}^{*} &= \frac{\alpha}{\gamma} P_1^{\frac{2}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(2-\alpha)}{\alpha}}, \\ S_{2a}^{*} &= \frac{\alpha}{\gamma \Phi(A)} (P_2 A)^{\frac{1}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}}, \\ L_{2a}^{*} &= \frac{\alpha}{\gamma \Phi(A)} (P_2 A)^{\frac{2}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(2-\alpha)}{\alpha}}, \\ V &> S_{1a}^{*} + S_{2a}^{*}. \end{aligned}$$

(ii.2) If $A_2 < A < A_3$, then

$$\begin{aligned} S_{1a}^{**} &= \frac{\gamma \Phi(A) V - R}{\gamma(1+\Phi(A))} > 0, \\ L_{1a}^{**} &= \left[\frac{\gamma \Phi(A) V - R}{\gamma(1+\Phi(A))} \right] \left\{ \frac{P_1(1-\alpha)}{w} \right\}^{\frac{1}{\alpha}} > 0, \\ S_{2a}^{**} &= \frac{\gamma V + R}{\gamma(1+\Phi(A))} > 0, \\ L_{2a}^{**} &= \left[\frac{\gamma V + R}{\gamma(1+\Phi(A))} \right] \left\{ \frac{P_2 A(1-\alpha)}{w} \right\}^{\frac{1}{\alpha}} > 0. \end{aligned}$$

(ii.3) If $A \geqslant A_3$, then $S_{1a}^{**} = 0,\ S_{2a}^{**} = V,\ L_{1a}^{**} = 0,\ L_{2a}^{**} = V \left\{ \frac{P_2 A(1-\alpha)}{w} \right\}^{\frac{1}{\alpha}}.$

The proof of Proposition 3.2.3 is given in Appendix 3.5.4.

Proposition 3.2.3 clarifies the role of productivity A. First, notice that V_1 is the required quantity of land when the producer has no constraint on land supply. We observe two cases. In the first case, land supply V is less than V_1 (Case (i)). Statement ($i.1$) says that, if the productivity of organic product (new technology) A is less than a productivity A_0, then it is not worthwhile to adopt organic product (new technology). The producers will only plant conventional product (old technology) S_{1a}^{**}, with their labor being L_{1a}^{**}. However, statement ($i.2$) indicates that if the productivity of organic product A is between a productivity A_0 and A_3, then the farmers will cultivate both types of product, conventional product land being S_{1a}^{**} with labor following L_{1a}^{**}

and organic product land S_{2a}^{**} with labor following L_{2a}^{**}. Also, in statement (i.3), we can see that if the productivity of organic product A is higher than productivity A_3, it becomes worthwhile for farmers to only cultivate organic product on the surface S_{2a}^{**} with labor L_{2a}^{**}.

In the second case, land supply becomes large enough, i.e. V is higher than V_1 (Case (ii)). Statement (ii.1) indicates that if the productivity of organic product A is less than some productivity A_2, then farmers will cultivate both types of product, conventional product land being S_{1a}^{*} with labor following L_{1a}^{*} and organic product land S_{2a}^{*} and labor L_{2a}^{*}. But they will not use all the available land V. Statement (ii.2) shows that if the productivity of organic product A is between productivity A_2 and productivity A_3 then the farmer will plant both types of product, conventional product land being S_{1a}^{**} with labor L_{1a}^{**} and organic product land being S_{2a}^{**} with labor L_{2a}^{**}. The difference with Case (ii.1) is that farmers will use all the available land.

In addition, if the productivity of organic product A is more than some productivity A_3, farmers will only product organic product using all the available land V and labor L_{2a}^{**} (Statement (ii.3)).

Our results show that the role of productivity are very important in the adoption of new technology. These results are consistent with the results of Zepeda (1994) and Ojiako et al. (2007). The results are very important for policy makers because basing on each different productivity the farmer has a different choice. Thus, this result may help policy markers in giving a reasonable policy to encourage farmers to produce organic product (new technology).

Scenario 3.2.2. ***Consider the situation when the government encourages the farmers to produce organic product by giving a subsidy*** $m(S_2,L_2)S_2$***. The subsidy per unit of land devoted to organic product depends on*** (S_2,L_2)***. However, the government is rational and hence also maximizes its gain. Let*** $\sigma > 0$ ***denotes the mark-up rate of the government. It pays the farmer with the price*** P_2 ***but resells on the market with the price*** $P_2(1+\sigma)$***.***

In this case, it solves the problem, $\max_{S_2 \geqslant 0}\left\{(1+\sigma)P_2 A S_2^{\alpha} L_2^{1-\alpha} - mS_2\right\}$. We get the solution $m(S_2,L_2) = \alpha(1+\sigma)P_2 A S_2^{\alpha-1} L_2^{1-\alpha}$. The producer maximizes the following problem $(\mathbb{P}_2)$

$$\left.\begin{array}{l} \max\left\{P_1 S_1^{\alpha} L_1^{1-\alpha} - wL_1 - C(S_1) + P_2 A S_2^{\alpha} L_2^{1-\alpha} - wL_2 - \Phi(A)C(S_2) + m(S_2,L_2)S_2\right\} \\ \text{subject to} \begin{cases} S_1 + S_2 \leqslant V, \\ S_1 \geqslant 0,\ S_2 \geqslant 0,\ L_1 \geqslant 0,\ L_2 \geqslant 0. \end{cases} \end{array}\right\} (\mathbb{P}_2)$$

This problem turns out to be

$$\max\left\{P_1 S_1^{\alpha} L_1^{1-\alpha} - wL_1 - C(S_1) + P_2 A' S_2^{\alpha} L_2^{1-\alpha} - wL_2 - \Phi(A)C(S_2)\right\},$$

with $A' = A\big[1+\alpha(1+\sigma)\big]$, A' define as productivity of this Scenario. We obtain the following propositions, the proofs of which can be easily adapted from the ones of Propositions 3.2.1 and 3.2.3.

Proposition 3.2.4. *Under Scenario 3.2.2, consider the problem* $(\mathbb{P}_2)$. *Let* $A_1 = \frac{P_1}{P_2}$ *and*

$$\begin{aligned} Q_1(P_1,P_2,\alpha,w,\Phi,\gamma,A') &= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} + \frac{\alpha}{\gamma\Phi(A)}(P_2A')^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} \\ &= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{1-\alpha}{\alpha}}\left[1+\frac{1}{\Phi(A)}\left(\frac{A'}{A_1}\right)^{\frac{1}{\alpha}}\right]. \end{aligned}$$

(i) If $V \geqslant Q_1(P_1,P_2,\alpha,w,\Phi,\gamma,A')$, *then the optimal lands and labors are the following*

$$\begin{aligned} \textit{land of conventional product,}\quad S_{1b}^{*} &= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}, \\ \textit{labor of conventional product,}\quad L_{1b}^{*} &= \frac{\alpha}{\gamma}P_1^{\frac{2}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}}, \\ \textit{land of organic product,}\quad S_{2b}^{*} &= \frac{\alpha}{\gamma\Phi(A)}\big(P_2A\big[1+\alpha(1+\sigma)\big]\big)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}, \\ \textit{labor of organic product,}\quad L_{2b}^{*} &= \frac{\alpha}{\gamma\Phi(A)}\big(P_2A\big[1+\alpha(1+\sigma)\big]\big)^{\frac{2}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}}, \\ \textit{and total land}\quad V &> S_{1b}^{*}+S_{2b}^{*}. \end{aligned}$$

(ii) If $V < Q_1(P_1,P_2,\alpha,w,\Phi,\gamma,A')$, *let* $A' = A\big[1+\alpha(1+\sigma)\big]$,

$$R = \big(P_2A\big[1+\alpha(1+\sigma)\big]\big)^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} - P_1^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}},$$

then the optimal lands and labors will be given in the following sequel.

(ii.a) $R \geqslant 0$ *is equivalent to* $A' \geqslant \frac{P_1}{P_2}$

(ii.a1) If $\frac{R}{\gamma\Phi(A)} < V < Q_1(P_1, P_2, \alpha, w, \Phi, \gamma, A')$*, then*

$$\begin{aligned}
\textit{land of conventional product,} \quad S_{1b}^{**} &= \frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))} > 0, \\
\textit{labor of conventional product} \quad L_{1b}^{**} &= \left[\frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0, \\
\textit{land of organic product,} \quad S_{2b}^{**} &= \frac{\gamma V + R}{\gamma(1+\Phi(A))}, \\
\textit{labor of organic product} \quad L_{2b}^{**} &= \left[\frac{\gamma V + R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_2A\big[1+\alpha(1+\sigma)\big](1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.
\end{aligned}$$

(ii.a2) If $V \leqslant \frac{R}{\gamma\Phi(A)}$*, then the optimal lands and labors are the following*

$$S_{1b}^{**} = 0,\ S_{2b}^{**} = V,\ L_{1b}^{**} = 0,\ L_{2b}^{**} = V\left\{\frac{P_2A\big[1+\alpha(1+\sigma)\big](1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

(ii.b) $R < 0$ *is equivalent to* $A' < \frac{P_1}{P_2}$.

(ii.b1) If $-\frac{R}{\gamma} < V < Q_1(P_1, P_2, \alpha, w, \Phi, \gamma, A')$*, then*

$$\begin{aligned}
S_{1b}^{**} &= \frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))} > 0, \\
L_{1b}^{**} &= \left[\frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0, \\
S_{2b}^{**} &= \frac{\gamma V + R}{\gamma(1+\Phi(A))}, \\
L_{2b}^{**} &= \left[\frac{\gamma V + R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_2A\big[1+\alpha(1+\sigma)\big](1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.
\end{aligned}$$

(ii.b2) If $V \leqslant -\frac{R}{\gamma}$*, then the optimal lands and labors are the following*

$$S_{2b}^{**} = 0,\ S_{1b}^{**} = V,\ L_{2b}^{**} = 0,\ L_{1b}^{**} = V\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

The comments of the results are similar to the ones for Proposition 3.2.1. The main difference is that, in Scenario 3.2.2, the land supply V must be larger than the one in Scenario 3.2.1.

Statement (*i*) show that under condition V must be larger than $Q_1(P_1, P_2, \alpha, w, \Phi, \gamma, A')$, when farmers are given subsidies they tend to invest on farm practices.

However, the subsidies in Statement (*ii*) are not significant. Statement (*ii*) are in line with the results of Lohr and Salomonsson (2000) in Sweden. They indicate that the subsidy helped offset transition costs to organic production for the farmers was not the effect. In addition, the result of Adebayo and Oladele (2013) also showed that subsidy received shows a significantly negative relationship with farmer' attitude to organic techniques. This implies that those that did not receive subsidy are more likely to practice organic farming. They argue that their result is not true because subsidy will encourage the farmers to adopt organic farming techniques. However, this argument is not sufficiently objective and unfounded.

We will now characterize the role of productivity $A' = A\big[1+\alpha(1+\sigma)\big]$ on farmer's behavior. The role of technology A' is given in Proposition 3.2.5.

Proposition 3.2.5. *The quantities defined in Lemma 3.2.2 are unchanged. We use Proposition 3.2.3. Let* $V_1 = \frac{\alpha}{\gamma} P_1^{\frac{1}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{1-\alpha}{\alpha}}$ *and assume* $\Phi'(0) = +\infty$, $\Phi'(+\infty) = 0$.

(i) Assume $V \leqslant V_1$,

(i.1) If $A' \leqslant A_0$, *then* $S_{2b}^{**} = 0,\ S_{1b}^{**} = V,\ L_{2b}^{**} = 0,\ L_{1b}^{**} = V\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}$.

(i.2) If $A_0 < A' < A_3$, *then*

$$
\begin{aligned}
S_{1b}^{**} &= \frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))} > 0,\\
L_{1b}^{**} &= \left[\frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0,\\
S_{2b}^{**} &= \frac{\gamma V + R}{\gamma(1+\Phi(A))} > 0,\\
L_{2b}^{**} &= \left[\frac{\gamma V + R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_2 A\big[1+\alpha(1+\sigma)\big](1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0.
\end{aligned}
$$

(i.3) If $A' \geqslant A_3$, *then* $S_{1b}^{**} = 0,\ S_{2b}^{**} = V,\ L_{1b}^{**} = 0,\ L_{2b}^{**} = V\left\{\frac{P_2 A\big[1+\alpha(1+\sigma)\big](1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}$.

(ii) Assume $V > V_1$.

(ii.1) If $A' \leqslant A_2$, then

$$\begin{aligned}
S_{1b}^{*} &= \frac{\alpha}{\gamma} P_1^{\frac{1}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}}, \\
L_{1b}^{*} &= \frac{\alpha}{\gamma} P_1^{\frac{2}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(2-\alpha)}{\alpha}}, \\
S_{2b}^{*} &= \frac{\alpha}{\gamma \Phi(A)} (P_2 A \left[1+\alpha(1+\sigma)\right])^{\frac{1}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}}, \\
L_{2b}^{*} &= \frac{\alpha}{\gamma \Phi(A)} (P_2 A \left[1+\alpha(1+\sigma)\right])^{\frac{2}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(2-\alpha)}{\alpha}}, \\
V &> S_{1b}^{*} + S_{2b}^{*}.
\end{aligned}$$

(ii.2) If $A_2 < A' < A_3$, then

$$\begin{aligned}
S_{1b}^{**} &= \frac{\gamma \Phi(A) V - R}{\gamma(1+\Phi(A))} > 0, \\
L_{1b}^{**} &= \left[\frac{\gamma \Phi(A) V - R}{\gamma(1+\Phi(A))} \right] \left\{ \frac{P_1(1-\alpha)}{w} \right\}^{\frac{1}{\alpha}} > 0, \\
S_{2b}^{**} &= \frac{\gamma V + R}{\gamma(1+\Phi(A))} > 0, \\
L_{2b}^{**} &= \left[\frac{\gamma V + R}{\gamma(1+\Phi(A))} \right] \left\{ \frac{P_2 A \left[1+\alpha(1+\sigma)\right](1-\alpha)}{w} \right\}^{\frac{1}{\alpha}} > 0.
\end{aligned}$$

(ii.3) If $A' \geqslant A_3$, then $S_{1b}^{**} = 0,\ S_{2b}^{**} = V,\ L_{1b}^{**} = 0,\ L_{2b}^{**} = V \left\{ \frac{P_2 A \left[1+\alpha(1+\sigma)\right](1-\alpha)}{w} \right\}^{\frac{1}{\alpha}}.$

The comments are similar to the ones for Proposition 3.2.3. However, we can observe that, since $A' = A\left[1+\alpha(1+\sigma)\right] > A$, compared to Scenario 3.2.1, the probability to produce only conventional product ($i.1$) becomes lower and the probability to produce only organic product ($i.3, ii.3$) becomes higher.

Scenario 3.2.3. ***When the government has a contract with the farmer. The farmer will have a bonus if the output of organic product is higher than some quantity $\widehat{Y}_2 > 0$, i.e. $AS_2^{\alpha} L_2^{1-\alpha} \geqslant \widehat{Y}_2$. Let $\widetilde{Y}_2$ denote the output of organic product without this additional constraint. The incentive constraint will be $\widehat{Y}_2 \geqslant \widetilde{Y}_2$. At the optimum we have $AS_2^{\alpha} L_2^{1-\alpha} = \widehat{Y}_2$. Indeed, suppose at the optimum, $AS_2^{\alpha} L_2^{1-\alpha} > \widehat{Y}_2$. In this case, this optimum corresponds to the problem without the constraint $AS_2^{\alpha} L_2^{1-\alpha} \geqslant \widehat{Y}_2$ and $AS_2^{\alpha} L_2^{1-\alpha} = \widetilde{Y}_2$. This is a contradiction.***

Consequently, the producer maximizes the problem $(\mathbb{P}_3)$, with m denoting the bonus:

$$\left.\begin{array}{l}\max\left\{P_1S_1^{\alpha}L_1^{1-\alpha}-wL_1-C(S_1)+P_2AS_2^{\alpha}L_2^{1-\alpha}-wL_2-\Phi(A)C(S_2)+m\right\}\\ \text{subject to}\begin{cases}S_1+S_2\leqslant V,\\ AS_2^{\alpha}L_2^{1-\alpha}\geqslant\widehat{Y}_2,\\ S_1\geqslant 0,\ S_2\geqslant 0,\ L_1\geqslant 0,\ L_2\geqslant 0.\end{cases}\end{array}\right\}(\mathbb{P}_3)$$

In the following proposition, for simplicity we assume that the land supply is larger than the required lands when there is no constraint on land supply. Its proof is given in Appendix 3.5.5.

Proposition 3.2.6. *Under Scenario 3.2.3, consider the problem* $(\mathbb{P}_3)$. *Assume that the total lands of farmer V is not limited,* $\frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}+\left\{\frac{w\alpha}{\gamma\Phi(A)}\right\}^{\frac{1-\alpha}{(2-\alpha)}}\left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{1}{(2-\alpha)}}\leqslant V$. *Then, the optimal solution is*

$$\begin{aligned}
\textit{land of conventional product } S_{1c}^{*} &= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}},\\
\textit{labor of conventional product } L_{1c}^{*} &= \frac{\alpha}{\gamma}P_1^{\frac{2}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}},\\
\textit{land of organic product } S_{2c}^{*} &= \left\{\frac{\alpha}{(1-\alpha)}\frac{w}{\gamma\Phi(A)}\right\}^{\frac{1-\alpha}{(2-\alpha)}}\left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{1}{(2-\alpha)}},\\
\textit{labor of organic product } L_{2c}^{*} &= \left\{\frac{\alpha}{(1-\alpha)}\frac{w}{\gamma\Phi(A)}\right\}^{-\frac{\alpha}{(2-\alpha)}}\left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{2}{(2-\alpha)}}.
\end{aligned}$$

In Proposition 3.2.6, when the land supply V is not limited, the production of organic products corresponds to demand from the government $\widehat{Y}_2$. Land and labor used for conventional products are independent from the target of products producers $\widehat{Y}_2$. At the same time, land and labor used for the organic products production in case with the target. In this case, productivity is not significant for the farmer decision.

Our result is interesting and surprising because when the farmers apply a new technology, they would be usually concerned about the productivity of the new technology. However, our result implies that farmers will not be concerned with productivity of organic products. This allows us to explain that, if productivity of organic products (new technology) is lower than the one of conventional products (old technology), it does not affect the transition to producing organic products (new technology). This finding is interesting and may help the policy makers to bring out good policy for a development strategy of organic products in the future.

3.3 Main results

In the first Scenario, the condition of adoption is derived under the assumptions including no constraint on the labor and limitation of the total quantity of land, V. If the farmer's lands are large enough and if we have a productivity A being low, e.g. $A \leqslant A_0$, then the farmers would use all their lands for the conventional product S_{1a}^{**}. If productivity A is between A_0 and A_3 ($A_0 < A < A_3$), then the farmer will produce both products. In the case of productivity A being relatively high, e.g. superior to A_3 ($A \geqslant A_3$), then the farmers will use all their lands for the organic products. In the other cases, the farmers would share out their lands to produce both products. However, in the case of a very large A, e.g. A_3 ($A \geqslant A_3$), lands would be used for planting only organic products.

In the second Scenario, a government could encourage the farmers to produce organic products by giving a subsidy $m(S_2, L_2)S_2$. The subsidy per unit of land devoted to new product depends on (S_2, L_2). To determine this subsidy, a government maximizes its benefits. Let $\sigma > 0$ denotes the mark-up rate of the government. It pays the farmers with the price P_2 but resells on the market with the price $P_2(1+\sigma)$. We obtain the following results. If lands are large enough, and if productivity is low, e.g. $A' = A\big[1+\alpha(1+\sigma)\big] \leqslant A_0$, then the farmers will use all their lands for the conventional products. In the case of productivity $A' = A\big[1+\alpha(1+\sigma)\big]$ being between A_0 and A_3 ($A_0 < A' < A_3$), the farmers would use their lands to produce both products. However, if productivity $A' = A\big[1+\alpha(1+\sigma)\big]$ is high, say more than A_3 ($A' \geqslant A_3$), then all lands would be used for planting only the organic product, S_{2b}^{**}. In the case lands are not large enough, the farmers would share lands for producing both products: conventional product being S_{1b}^{*} and organic product being S_{2b}^{*}. Besides this, as before, if productivity $A' = A\big[1+\alpha(1+\sigma)\big]$ is large, say higher than A_3 ($A' \geqslant A_3$), then all lands would be used for the organic products.

Existing studies did not consider elements of productivity of new technology that can affect its adoption (e.g., Kebede et al., 1990; Strauss et al., 1991; Rauniyar and Goode, 1992; Huang and Rozelle, 1996; Ayuk, 1997; Adesina et al., 2000; Läpple and Van Rensburg, 2011; Abebe et al., 2013; Adebayo and Oladele, 2013; Läpple and Kelley, 2015, etc.). To address these limitations, we mentioned some elements including land, labor and productivity in our model. Then, we investigate how these factors impact adoption of organic production. Our work highlights the role of productivity on farmer's behavior. We often think of the role of prices and other factors affecting the acceptance of technological change by farmers. However, in our results, price does not affect the acceptance of technological change, but the productivity is an important element affecting technology adoption. The results of Scenario 3.2.1 and 3.2.2 will bring a new point of view about the role of these factors on technological change, which most of empirical studies did not mention.

In the last Scenario, in order to give incentives for adoption of new technologies, a government could stimulate farmers to produce organic product by giving a bonus. But in exchange they impose a minimum of output of organic product. The result is as follows. If the lands are large enough, then the farmers produce both products. However, lands and labor used for conventional product are independent from the target of the government while lands and labor used for organic product are positively related to the target. Notably, the result of Scenario 3.2.3 indicates that the productivity is not significant for the farmer's decision.

3.4 Conclusion

In this chapter, the theoretical model is formulated to describe the farmers' decisions regarding adoption of organic production, given the constraints they face. The results imply significant policy implications. This should alert all policy makers to understand the impact of regulations concerning agricultural production process.

We consider three scenarios with three different assumptions: i) in the first scenario, we impose no constraint on the labor and the total quantity of land. ii) in the second, a government could encourage the farmers to produce organic products by giving a subsidy. iii) in the last scenario, a government could stimulate farmers to produce organic product by giving a bonus in exchange of imposing a minimum of organic production.

In the first and second scenarios, farmer's productivity fully determines the choice of production. If productivity is low, farmers will choose conventional product only whereas if productivity is high they will choose organic product only. In between, farmers will produce both products. An exception occurs when the farmer's lands are not large enough. In this case, farmers will never choose to produce only conventional product. However, in the second scenario, the subsidy do not help augmenting the organic production.

In the last scenario, the result indicates that the productivity is not significant for the farmer's decision. They will always choose to produce both product independently of their productivity. Our result implies that farmers will not be concerned about the productivity and productivity will not make the farmer to shift towards the new technology. In the long run, we may even have an adverse effect, because the farmers will reliance the role of government and they will refuse the creativity to increase productivity.

It is important to note that the results of this chapter are not completely confined in the agricultural literature. It is possible to open up applications in other fields related to technology transfer.

3.5 Appendix

3.5.1 Appendix 1: Proof of Lemma 3.2.1

Proof. Denote

$$M = \max\left\{P_1 S_1^{\alpha} L_1^{1-\alpha} - wL_1 - C(S_1) + P_2 A S_2^{\alpha} L_2^{1-\alpha} - wL_2 - \Phi(A)C(S_2)\right\}$$

$$\text{subject to} \begin{cases} S_1 + S_2 \leqslant V, \\ S_1 \geqslant 0,\ S_2 \geqslant 0,\ L_1 \geqslant 0,\ L_2 \geqslant 0. \end{cases}$$

Observe $M \geqslant 0$ (take $S_1 = S_2 = L_1 = L_2 = 0$).

(a) Suppose $S_1^* > 0$ and $L_1^* = 0$. Then,

$$P_1 {S_1^*}^{\alpha} {L_1^*}^{1-\alpha} - wL_1^* - C(S_1^*) = -C(S_1^*).$$

For $\varepsilon > 0$, define $\eta(\varepsilon) = P_1 {S_1^*}^{\alpha} \varepsilon^{1-\alpha} - w\varepsilon$. We have

$$\frac{\eta(\varepsilon)}{\varepsilon} = P_1 {S_1^*}^{\alpha} \varepsilon^{-\alpha} - w \to +\infty \text{ as } \varepsilon \to 0.$$

Hence, $\eta(\varepsilon) > 0$ for $\varepsilon > 0$, small enough. Take $L_1 = \varepsilon$. We get, for $\varepsilon > 0$, small enough

$$P_1 {S_1^*}^{\alpha} L_1^{1-\alpha} - wL_1^* - C(S_1^*) = \eta(\varepsilon) - C(S_1^*) > -C(S_1^*)$$

which is a contradiction since L_1^* is the optimal value. Thus $S_1^* > 0 \Rightarrow L_1^* > 0$.

(b) Let us prove the converse. Assume $L_1^* > 0$ and $S_1^* = 0$. Then,

$$P_1 {S_1^*}^{\alpha} L_1^{1-\alpha} - C(S_1^*) - wL_1^* = -wL_1^*.$$

For $\varepsilon > 0$, define $\eta(\varepsilon) = P_1 \varepsilon^{\alpha} {L_1^*}^{1-\alpha} - \frac{\gamma\varepsilon^2}{2}$. We have

$$\frac{\eta(\varepsilon)}{\varepsilon} = P_1 \varepsilon^{\alpha-1} {L_1^*}^{1-\alpha} - \frac{\gamma\varepsilon}{2} \to +\infty \text{ as } \varepsilon \to 0.$$

Hence, $\eta(\varepsilon) > 0$ for $\varepsilon > 0$, small enough. Take $S_1 = \varepsilon$. We get, for $\varepsilon > 0$, small enough

$$P_1 {S_1^*}^{\alpha} L_1^{1-\alpha} - C(S_1^*) - wL_1^* = \eta(\varepsilon) - wL_1^* > -wL_1^*$$

which is a contradiction since S_1^* is the optimal value. Thus $L_1^* > 0 \Rightarrow S_1^* > 0$. The proof is similar for $S_2^* > 0 \Leftrightarrow L_2^* > 0$. □

3.5.2 Appendix 2: Proof of Proposition 3.2.1

Proof. Let $\mathfrak{L}$ denote the Lagrangian. Assume first the optimal values of land and labor are strictly positive. We have

$$\begin{aligned} \mathfrak{L} \quad = \quad & \Big\{ P_1 S_1^{\alpha} L_1^{1-\alpha} - wL_1 - C(S_1) + P_2 A S_2^{\alpha} L_2^{1-\alpha} - wL_2 - \Phi(A) C(S_2) \\ & - \lambda(S_1 + S_2 - V) + \mu_1 S_1 + \mu_2 S_2 + \beta_1 L_1 + \beta_2 L_2 \Big\}, \end{aligned}$$

with some conditions as $\lambda \geqslant 0,\ \mu_1 \geqslant 0,\ \mu_2 \geqslant 0,\ \beta_1 \geqslant 0,\ \beta_2 \geqslant 0$. Assume first the optimal values $S_1^*,\ L_1^*,\ S_2^*,\ L_2^*$ are strictly positive. We obtain the following First Order Conditions (FOC)

$$\frac{\partial \mathfrak{L}}{\partial S_1} = 0 \Leftrightarrow P_1 \alpha \left(\frac{L_1^*}{S_1^*}\right)^{1-\alpha} - C'(S_1^*) - \lambda + \mu_1 = 0 \tag{3.1}$$

$$\text{or } P_1 \alpha \,(L_1^*)^{1-\alpha} - C'(S_1^*)\,(S_1^*)^{1-\alpha} - (\lambda - \mu_1)\,(S_1^*)^{1-\alpha} = 0$$

$$\frac{\partial \mathfrak{L}}{\partial L_1} = 0 \Leftrightarrow P_1(1-\alpha)\left(\frac{S_1^*}{L_1^*}\right)^{\alpha} - w + \beta_1 = 0 \tag{3.2}$$

$$\text{or } P_1\,(1-\alpha)\,(S_1^*)^{\alpha} - (w - \beta_1)\,(L_1^*)^{\alpha} = 0$$

$$\frac{\partial \mathfrak{L}}{\partial S_2} = 0 \Leftrightarrow P_2 A \alpha \left(\frac{L_2^*}{S_2^*}\right)^{1-\alpha} - \Phi(A) C'(S_2^*) - \lambda + \mu_2 = 0 \tag{3.3}$$

$$\frac{\partial \mathfrak{L}}{\partial L_2} = 0 \Leftrightarrow P_2 A(1-\alpha)\left(\frac{S_2^*}{L_2^*}\right)^{\alpha} - w + \beta_2 = 0 \tag{3.4}$$

$$\lambda\,(S_1^* + S_2^* - V) = 0 \tag{3.5}$$

$$\mu_1 S_1 = 0,\ \beta_1 L_1 = 0,\ \mu_2 S_2 = 0,\ \beta_2 L_2 = 0. \tag{3.6}$$

Since we assume the optimal values $S_1^*,\ L_1^*,\ S_2^*,\ L_2^*$ are strictly positive, from (3.6) we have $\mu_1 = \mu_2 = \beta_1 = \beta_2 = 0$. From equation (3.2), we have

$$\left(\frac{S_1^*}{L_1^*}\right)^{\alpha} = \frac{w}{P_1(1-\alpha)} \Leftrightarrow \left(\frac{L_1^*}{S_1^*}\right)^{(1-\alpha)} = \left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}. \tag{3.7}$$

From equations (3.1) and (3.7), we obtain

$$P_1^{\frac{1}{\alpha}} \alpha \left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} = \lambda + C'(S_1^*) = \lambda + \gamma S_1^*. \tag{3.8}$$

From equation (3.4), we get

$$\left(\frac{S_2^*}{L_2^*}\right)^{\alpha} = \frac{w}{P_2 A(1-\alpha)} \Leftrightarrow \left(\frac{L_2^*}{S_2^*}\right)^{(1-\alpha)} = \left\{\frac{P_2 A(1-\alpha)}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}. \tag{3.9}$$

From equations (3.3) and (3.9), we have the following result

$$(P_2 A)^{\frac{1}{\alpha}} \alpha \left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} = \lambda + \Phi(A) C'(S_2^*) = \lambda + \gamma \Phi(A) S_2^*. \tag{3.10}$$

From equations (3.8) and (3.10) lead to

$$(P_2A)^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} - P_1^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} = \gamma[\Phi(A)S_2^* - S_1^*]. \tag{3.11}$$

Assume λ strictly positive, in this case $S_1^* + S_2^* = V$ and collaborate with equations (3.8) and (3.10), we obtain

$$P_1^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} > \gamma S_1^* \tag{3.12}$$

$$(P_2A)^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} > \gamma\Phi(A)S_2^*. \tag{3.13}$$

Basing on equations (3.12) and (3.13), it can be seen that $Q(P_1,P_2,\alpha,w,\Phi,\gamma,A) > S_1^* + S_2^*$.

(i) If $V \geqslant Q(P_1,P_2,\alpha,w,\Phi,\gamma,A)$. In addition, from equation (3.8) lead to

$$\frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} = \frac{\lambda}{\gamma} + S_1^*. \tag{3.14}$$

It comes from equation (3.10) that

$$\frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} = \frac{\lambda}{\gamma\Phi(A)} + S_2^*. \tag{3.15}$$

From equations (3.14) and (3.15), we have

$$\frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} + \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} = \frac{\lambda}{\gamma}\left\{1+\frac{1}{\Phi(A)}\right\} + S_2^* + S_1^*. \tag{3.16}$$

Recall that

$$Q(P_1,P_2,\alpha,w,\Phi,\gamma,A) = \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} + \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}.$$

If $\lambda > 0$ then $V = S_1^* + S_2^*$ that is a contradiction. Indeed, calculation from equation (3.16) shows that

$$V = Q(P_1,P_2,\alpha,w,\Phi,\gamma,A) = \frac{\lambda}{\gamma}\left\{1+\frac{1}{\Phi(A)}\right\} + V > V.$$

Therefore, $\lambda = 0$, then we have

$$\begin{aligned}
\text{land of conventional product} \quad S_{1a}^* &= \frac{\alpha}{\gamma} P_1^{\frac{1}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}}, \\
\text{labor of conventional product} \quad L_{1a}^* &= \frac{\alpha}{\gamma} P_1^{\frac{2}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(2-\alpha)}{\alpha}}, \\
\text{land of organic product} \quad S_{2a}^* &= \frac{\alpha}{\gamma \Phi(A)} (P_2 A)^{\frac{1}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}}, \\
\text{labor of organic product} \quad L_{2a}^* &= \frac{\alpha}{\gamma \Phi(A)} (P_2 A)^{\frac{2}{\alpha}} \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(2-\alpha)}{\alpha}}.
\end{aligned}$$

Since $S_{1a}^* + S_{2a}^* = Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$, we have $S_{1a}^* + S_{2a}^* < V$ if $V > Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$ and $S_{1a}^* + S_{2a}^* = V$ if $V = Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$.

(ii) Consider $V < Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$, if $\lambda = 0$ then $S_1^* + S_2^* = Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$, and $\lambda = 0$ is absurd. Thus, we have $\lambda > 0$. This implies $S_1^* + S_2^* = V$. Recall that

$$\begin{aligned}
R &= (P_2 A)^{\frac{1}{\alpha}} \alpha \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}} - P_1^{\frac{1}{\alpha}} \alpha \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}} \\
&= \left[(P_2 A)^{\frac{1}{\alpha}} - P_1^{\frac{1}{\alpha}} \right] \alpha \left\{ \frac{1-\alpha}{w} \right\}^{\frac{(1-\alpha)}{\alpha}}.
\end{aligned}$$

From equation (3.11), we have

$$R = \gamma[\Phi(A) S_2^* - S_1^*] = \gamma \Big[\Phi(A) V - S_1^* (1 + \Phi(A)) \Big]. \tag{3.17}$$

From equation (3.17), we get

$$\gamma S_1^* (1 + \Phi(A)) = \gamma \Phi(A) V - R. \tag{3.18}$$

From equation (3.18), we obtain

$$\begin{aligned} S_1^* &= \frac{\gamma\Phi(A)V-R}{\gamma(1+\Phi(A))} \text{ if } \gamma\Phi(A)V-R \geqslant 0 \\ S_1^* &= 0 \text{ if } \gamma\Phi(A)V-R \leqslant 0 \\ S_2^* &= \frac{\gamma V+R}{\gamma(1+\Phi(A))} \text{ if } \gamma V+R \geqslant 0 \\ S_2^* &= 0 \text{ otherwise.} \end{aligned}$$

(ii.a1) If $\frac{R}{\gamma\Phi(A)} < V < Q(P_1,P_2,\alpha,w,\Phi,\gamma,A)$. $S_1^* \geqslant 0$ if and only if $\gamma\Phi(A)V-R \geqslant 0$ or $\gamma\Phi(A)V \geqslant R$. We have

$$\begin{aligned} \gamma\Phi(A)V &> (P_2A)^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} - P_1^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} \\ \Leftrightarrow V &> \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} - \frac{\alpha}{\gamma\Phi(A)}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} \\ \Leftrightarrow V &> \frac{R}{\gamma\Phi(A)}, \end{aligned}$$

with the condition $V < Q(P_1,P_2,\alpha,w,\Phi,\gamma,A)$ or equivalently

$$V < \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} + \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}.$$

We find the land of conventional product $S_{1a}^{**} = \frac{\gamma\Phi(A)V-R}{\gamma(1+\Phi(A))} > 0$.

From equation (3.7), we obtain $L_{1a}^{**} = \left[\frac{\gamma\Phi(A)V-R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0$.

When $S_2^*+S_1^* = V$, we obtain $S_{2a}^{**} = \frac{\gamma V+R}{\gamma(1+\Phi(A))}$.

From equation (3.9), we obtain $L_{2a}^{**} = \left[\frac{\gamma V+R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_2A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}$.

(ii.a2) If $V \leqslant \frac{R}{\gamma\Phi(A)}$. We have $\gamma\Phi(A)V-R \leqslant 0$ or $\gamma\Phi(A)V \leqslant R$. The optimal solution for S_{1a}^{**} cannot be anymore strictly positive. Hence, $S_{1a}^{**} = 0$. We easily obtain

$$S_{1a}^{**} = 0,\ S_{2a}^{**} = V,\ L_{1a}^{**} = 0,\ L_{2a}^{**} = V\left\{\frac{P_2A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

(ii.b1) If $R < 0$ and $-\frac{R}{\gamma} < V < Q(P_1,P_2,\alpha,w,\Phi,\gamma,A)$ then by the same computations as in (ii.a1), we obtain

$$\begin{aligned}
S_{1a}^{**} &= \frac{\gamma\Phi(A)V-R}{\gamma(1+\Phi(A))} > 0,\\
L_{1a}^{**} &= \left[\frac{\gamma\Phi(A)V-R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0,\\
S_{2a}^{**} &= \frac{\gamma V+R}{\gamma(1+\Phi(A))} > 0,\\
L_{2a}^{**} &= \left[\frac{\gamma V+R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_2A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0.
\end{aligned}$$

(ii.b2) If $V \leqslant -\frac{R}{\gamma}$ (observe that $Q(P_1,P_2,\alpha,w,\Phi,\gamma,A)+\frac{R}{\gamma} > 0$) then S_{2a}^{**} cannot be anymore non-negative. We have

$$S_{2a}^{**}=0,\ S_{1a}^{**}=V,\ L_{2a}^{**}=0,\ L_{1a}^{**}=V\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

□

3.5.3 Appendix 3: Proof of Lemma 3.2.2

Proof.

(i) The proof is obvious.

(ii.1) We have

$$\begin{aligned}
Q(P_1,P_2,\alpha,w,\Phi,\gamma,A) &= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} + \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}\\
&= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}\left[1+\frac{1}{\Phi(A)}\left(\frac{A}{A_1}\right)^{\frac{1}{\alpha}}\right]\\
&= V_1\times\left[1+\frac{1}{\Phi(A)}\left(\frac{A}{A_1}\right)^{\frac{1}{\alpha}}\right].
\end{aligned}$$

Hence

$$\begin{aligned}
V < Q(P_1,P_2,\alpha,w,\Phi,\gamma,A) &\Leftrightarrow \left[\frac{V}{V_1}-1\right] < \frac{1}{A_1{}^{\frac{1}{\alpha}}}\times\frac{A^{\frac{1}{\alpha}}}{\Phi(A)}\\
&\Leftrightarrow \frac{A^{\frac{1}{\alpha}}}{\Phi(A)} > A_1{}^{\frac{1}{\alpha}}\times\left[\frac{V}{V_1}-1\right].
\end{aligned}$$

Let

$$\phi(A) = \frac{A^{\frac{1}{\alpha}}}{\Phi(A)}$$

Since Φ is concave, the function ϕ is increasing. Let A_2 be defined by

$$\frac{A_2{}^{\frac{1}{\alpha}}}{\Phi(A_2)} = A_1^{\frac{1}{\alpha}} \times \left[\frac{V}{V_1} - 1\right].$$

Then obviously,

$$V \leqslant Q(P_1, P_2, \alpha, w, \Phi, \gamma, A) \Leftrightarrow A \geqslant A_2.$$

If $\frac{A_1^{\frac{1}{\alpha}}}{\Phi(A_1)} < A_1^{\frac{1}{\alpha}} \times \left[\frac{V}{V_1} - 1\right]$ or equivalently $\frac{1}{\Phi(A_1)} < \left[\frac{V}{V_1} - 1\right]$ then $A_2 > A_1$ since function ϕ is increasing. If $\frac{1}{\Phi(A_1)} = \left[\frac{V}{V_1} - 1\right]$ then $A_2 = A_1$ and obviously $\frac{1}{\Phi(A_1)} > \left[\frac{V}{V_1} - 1\right]$ then $A_2 < A_1$.

(ii.2) Let

$$\psi(A) = \frac{A^{\frac{1}{\alpha}} - A_1^{\frac{1}{\alpha}}}{\Phi(A)} \times \frac{1}{A_1^{\frac{1}{\alpha}}}.$$

Function ψ is increasing since ϕ is increasing. It satisfies $\psi(0) = -\infty$, $\psi(A_1) = 0$. Therefore $A_3 > A_1$ since $\psi(A_3) = \frac{V}{V_1}$. Now, observe that

$$\frac{A_3^{\frac{1}{\alpha}}}{\Phi(A_3)} = A_1^{\frac{1}{\alpha}} \times \frac{V}{V_1} + \frac{A_1^{\frac{1}{\alpha}}}{\Phi(A_3)}$$

while A_2 verifies

$$\frac{A_2^{\frac{1}{\alpha}}}{\Phi(A_2)} = A_1^{\frac{1}{\alpha}} \times \left[\frac{V}{V_1} - 1\right],$$

hence $A_3 > A_2$.

Since

$$R = (P_2 A)^{\frac{1}{\alpha}} \alpha \left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} - P_1^{\frac{1}{\alpha}} \alpha \left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}},$$

we get,

$$\frac{R}{\gamma \Phi(A)} = \frac{1}{A_1^{\frac{1}{\alpha}}} \times \left[\frac{A^{\frac{1}{\alpha}} - A_1^{\frac{1}{\alpha}}}{\Phi(A)}\right] V_1.$$

We have

$$\begin{aligned}\frac{R}{\gamma\Phi(A)} < V &\Leftrightarrow \psi(A) < \tfrac{V}{V_1} = \psi(A_3) \Leftrightarrow A < A_3,\\ \frac{R}{\gamma\Phi(A)} = V &\Leftrightarrow \psi(A) = \tfrac{V}{V_1} = \psi(A_3) \Leftrightarrow A = A_3.\end{aligned}$$

(ii.3) Since

$$R = (P_2A)^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} - P_1^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}},$$

we have

$$-\frac{R}{\gamma} = V_1 \times \left[1 - \left(\frac{A}{A_1}\right)^{\frac{1}{\alpha}}\right].$$

Hence,

$$\begin{aligned}V + \frac{R}{\gamma} &= V - V_1 \times \left[1 - \left(\frac{A}{A_1}\right)^{\frac{1}{\alpha}}\right] = V - V_1 + V_1\left(\frac{A}{A_1}\right)^{\frac{1}{\alpha}}\\ &> V - V_1 > 0.\end{aligned}$$

Thus, $V + \frac{R}{\gamma} > 0$, and we find $V > -\frac{R}{\gamma}$.

(iii.1) Since (ii.3), we have

$$-\frac{R}{\gamma} = V_1 \times \left[1 - \left(\frac{A}{A_1}\right)^{\frac{1}{\alpha}}\right].$$

Hence

$$\begin{aligned}V \leqslant -\frac{R}{\gamma} &\Leftrightarrow V \leqslant V_1 \times \left[1 - \left(\frac{A}{A_1}\right)^{\frac{1}{\alpha}}\right]\\ &\Leftrightarrow \left(\frac{A}{A_1}\right)^{\frac{1}{\alpha}} \leqslant \left[1 - \frac{V}{V_1}\right]\\ &\Leftrightarrow A \leqslant A_1 \times \left[1 - \frac{V}{V_1}\right]^{\alpha} = A_0 \Leftrightarrow A \leqslant A_0.\end{aligned}$$

(iii.2) Let

$$\psi(A) = \frac{A^{\frac{1}{\alpha}} - A_1^{\frac{1}{\alpha}}}{\Phi(A)} \times \frac{1}{A_1^{\frac{1}{\alpha}}}.$$

Function ψ is increasing since ϕ is increasing. It satisfies $\psi(0) = -\infty$, $\psi(A_1) = 0$. Therefore

$A_3 > A_1$ since $\psi(A_3) = \frac{V}{V_1}$. Since

$$\frac{R}{\gamma\Phi(A)} = \frac{1}{A_1^{\frac{1}{\alpha}}} \times \left[\frac{A^{\frac{1}{\alpha}} - A_1^{\frac{1}{\alpha}}}{\Phi(A)}\right] V_1,$$

we have

$$\frac{R}{\gamma\Phi(A)} \leqslant V \quad \Leftrightarrow \psi(A) \leqslant \tfrac{V}{V_1} = \psi(A_3) \Leftrightarrow A \leqslant A_3.$$

□

3.5.4 Appendix 4: Proof of Proposition 3.2.3

Proof. (i.1) We have $A_0 < A_1$, hence $A \leqslant A_0 \Rightarrow A < A_1 \Leftrightarrow R < 0$ (see (i) of Lemma 3.2.2). From (iii.1) of Lemma 3.2.2 we have $A \leqslant A_0 \Leftrightarrow V \leqslant -\frac{R}{\gamma}$. From (ii.b2) of Proposition 3.2.1, we get

$$S_{2a}^{**} = 0,\ S_{1a}^{**} = V,\ L_{2a}^{**} = 0,\ L_{1a}^{**} = V\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

(i.2) We have $A_1 < A_3$ (see (iii.2) of Lemma 3.2.2). First suppose $A_0 < A < A_1$. We know that $A < A_1 \Leftrightarrow R < 0$ from (i) of Lemma 3.2.2, and $A_0 < A \Leftrightarrow V > -\frac{R}{\gamma}$ from (iii.1) of the same lemma. We have

$$-\frac{R}{\gamma} < V \leqslant V_1 < Q(P_1, P_2, \alpha, w, \Phi, \gamma, A).$$

Use (ii.b1) of Proposition 3.2.1. Now suppose $A_1 \leqslant A < A_3$. If $A_1 \leqslant A \Leftrightarrow R \geqslant 0$ from (i) of Lemma 3.2.2 and $A < A_3 \Leftrightarrow \frac{R}{\gamma\Phi(A)} < V$. We have

$$R \geqslant 0,\ \frac{R}{\gamma\Phi(A)} < V \leqslant V_1 < Q(P_1, P_2, \alpha, w, \Phi, \gamma, A).$$

Use (ii.a1) of Proposition 3.2.1. Both cases imply

$$\begin{aligned}
S_{1a}^{**} &= \frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))} > 0,\\
L_{1a}^{**} &= \left[\frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0,\\
S_{2a}^{**} &= \frac{\gamma V + R}{\gamma(1+\Phi(A))} > 0,\\
L_{2a}^{**} &= \left[\frac{\gamma V + R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_2A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0.
\end{aligned}$$

(i.3) We know that $A_3 > A_1$ (see (iii.2) of Lemma 3.2.2). Hence $A \geqslant A_3 \Rightarrow A > A_1 \Leftrightarrow R > 0$. But $A \geqslant A_3 \Leftrightarrow V \leqslant \frac{R}{\gamma\Phi(A)}$ (see (ii.2) of Lemma 3.2.2). Use (ii.a2) of Proposition 3.2.1 to get the results

$$S_{1a}^{**} = 0,\ S_{2a}^{**} = V,\ L_{1a}^{**} = 0,\ L_{2a}^{**} = V\left\{\frac{P_2A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

(ii) We distinguish two cases:

(ii.a) $V \geqslant V_1\left\{1 + \frac{1}{\Phi(A_1)}\right\} \Leftrightarrow A_2 \geqslant A_1$,

(ii.b) $V_1 < V < V_1\left\{1 + \frac{1}{\Phi(A_1)}\right\} \Leftrightarrow A_1 > A_2$.

(ii.a1) We have $A \leqslant A_2 \Leftrightarrow V \geqslant Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$. From (i) of Proposition 3.2.1, we get

$$\begin{aligned}
S_{1a}^{*} &= \frac{\alpha}{\gamma}P_1^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}},\\
L_{1a}^{*} &= \frac{\alpha}{\gamma}P_1^{\frac{2}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}},\\
S_{2a}^{*} &= \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{1}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}},\\
L_{2a}^{*} &= \frac{\alpha}{\gamma\Phi(A)}(P_2A)^{\frac{2}{\alpha}}\left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}},\\
V &> S_{1a}^{*} + S_{2a}^{*}.
\end{aligned}$$

(ii.a2) If $A > A_2$ then $A > A_1 \Rightarrow R > 0$. Also

$$\begin{aligned} A > A_2 &\Leftrightarrow V < Q(P_1, P_2, \alpha, w, \Phi, \gamma, A) \\ A < A_3 &\Leftrightarrow \frac{R}{\gamma\Phi(A)} < V. \end{aligned}$$

Use (ii.a1) of Proposition 3.2.1 to get

$$\begin{aligned} S_{1a}^{**} &= \frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))} > 0, \\ L_{1a}^{**} &= \left[\frac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0, \\ S_{2a}^{**} &= \frac{\gamma V + R}{\gamma(1+\Phi(A))} > 0, \\ L_{2a}^{**} &= \left[\frac{\gamma V + R}{\gamma(1+\Phi(A))}\right]\left\{\frac{P_2 A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0. \end{aligned}$$

(ii.a3) If $A \geqslant A_3$ then $A > A_1 \Rightarrow R > 0$ and $V \leqslant \frac{R}{\gamma\Phi(A)}$ (see (ii.1) of Lemma 3.2.2). Use (ii.a2) of Proposition 3.2.1 to obtain

$$S_{1a}^{**} = 0,\ S_{2a}^{**} = V,\ L_{1a}^{**} = 0,\ L_{2a}^{**} = V\left\{\frac{P_2 A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

(ii.b1) We have $A \leqslant A_2 \Leftrightarrow V \geqslant Q(P_1, P_2, \alpha, w, \Phi, \gamma, A)$. From (i) of Proposition 3.2.1, we get

$$\begin{aligned} S_{1a}^{*} &= \frac{\alpha}{\gamma} P_1^{\frac{1}{\alpha}} \left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}, \\ L_{1a}^{*} &= \frac{\alpha}{\gamma} P_1^{\frac{2}{\alpha}} \left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}}, \\ S_{2a}^{*} &= \frac{\alpha}{\gamma\Phi(A)} (P_2 A)^{\frac{1}{\alpha}} \left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}, \\ L_{2a}^{*} &= \frac{\alpha}{\gamma\Phi(A)} (P_2 A)^{\frac{2}{\alpha}} \left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}}, \\ V &> S_{1a}^{*} + S_{2a}^{*}. \end{aligned}$$

(ii.b2) We first consider the case $A_2 < A \leqslant A_1$. We have successively

$$\begin{array}{lll} A \leqslant A_1 & \Leftrightarrow & R \leqslant 0 \text{ (see (i) of Lemma 3.2.2)} \\ A > A_2 & \Leftrightarrow & V < Q(P_1, P_2, \alpha, w, \Phi, \gamma, A) \text{ (see (ii.1) of Lemma 3.2.2)} \\ V > V_1 & \Rightarrow & V > -\dfrac{R}{\gamma} \text{ (see (ii.3) of Lemma 3.2.2).} \end{array}$$

Hence

$$-\frac{R}{\gamma} < V < Q(P_1, P_2, \alpha, w, \Phi, \gamma, A).$$

Use (ii.b1) of Proposition 3.2.1. Now, consider the case $A_1 < A < A_3$. We have successively

$$\begin{array}{lll} A > A_1 & \Leftrightarrow & R > 0 \text{ (see (i) of Lemma 3.2.2)} \\ A > A_1 & \Rightarrow & A > A_2 \Leftrightarrow V < Q(P_1, P_2, \alpha, w, \Phi, \gamma, A) \text{ (see (ii.1) of Lemma 3.2.2)} \\ A < A3 & \Leftrightarrow & V > \dfrac{R}{\gamma\Phi(A)} \text{ (see (ii.2) of Lemma 3.2.2).} \end{array}$$

To sum up

$$R > 0, \ \frac{R}{\gamma\Phi(A)} < V < Q(P_1, P_2, \alpha, w, \Phi, \gamma, A).$$

Use (ii.a1) of Proposition 3.2.1. Both cases give

$$\begin{array}{rcl} S_{1a}^{**} & = & \dfrac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))} > 0, \\ L_{1a}^{**} & = & \left[\dfrac{\gamma\Phi(A)V - R}{\gamma(1+\Phi(A))}\right]\left\{\dfrac{P_1(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0, \\ S_{2a}^{**} & = & \dfrac{\gamma V + R}{\gamma(1+\Phi(A))} > 0, \\ L_{2a}^{**} & = & \left[\dfrac{\gamma V + R}{\gamma(1+\Phi(A))}\right]\left\{\dfrac{P_2 A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}} > 0. \end{array}$$

(ii.b3) Now assume $A \geqslant A_3$. If $A \geqslant A_3$ then $A > A_1 \Rightarrow R > 0$ and $V \leqslant \frac{R}{\gamma\Phi(A)}$ (see (ii.2) of Lemma 3.2.2). Use (ii.a2) of Proposition 3.2.1 to obtain

$$S_{1a}^{**} = 0, \ S_{2a}^{**} = V, \ L_{1a}^{**} = 0, \ L_{2a}^{**} = V\left\{\frac{P_2 A(1-\alpha)}{w}\right\}^{\frac{1}{\alpha}}.$$

□

3.5.5 Appendix 5: Proof of Proposition 3.2.6

Proof. We have:

$$Y_2^* = \widehat{Y}_2 \Leftrightarrow AS_2^{*\alpha} L_2^{*1-\alpha} = \widehat{Y}_2 \Leftrightarrow AL_2^{*1-\alpha} = \widehat{Y}_2 S_2^{*-\alpha}.$$

The problem of the producer is

$$\max\{P_1 S_1^{\alpha} L_1^{1-\alpha} - wL_1 - C(S_1) + P_2\widehat{Y}_2 - w\left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{1}{(1-\alpha)}} S_2^{-\frac{\alpha}{(1-\alpha)}} - \Phi(A)C(S_2)$$

using the constraints

$$S_1 \geqslant 0,\ S_2 \geqslant 0,\ L_1 \geqslant 0,\ S_1 + S_2 \leqslant V.$$

Assume the optimal values of land and labor are strictly positive. Let $\mathfrak{L}$ denote the Lagrangian. We have

$$\begin{aligned} \mathfrak{L} &= \Big\{P_1 S_1^{\alpha} L_1^{1-\alpha} - wL_1 - C(S_1) + P_2\widehat{Y}_2 \\ &\quad - w\left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{1}{(1-\alpha)}} S_2^{-\frac{\alpha}{(1-\alpha)}} - \Phi(A)C(S_2) - \lambda(S_1 + S_2 - V)\Big\} \\ &\quad \text{with } \lambda \geqslant 0,\ \lambda(S_1 + S_2 - V) = 0. \end{aligned}$$

We obtain the following First Order Conditions (FOC)

$$\frac{\partial \mathfrak{L}}{\partial S_1} = 0 \Leftrightarrow P_1\alpha\left(\frac{L_1^*}{S_1^*}\right)^{1-\alpha} - C'(S_1^*) - \lambda = 0 \tag{3.19}$$

$$\frac{\partial \mathfrak{L}}{\partial L_1} = 0 \Leftrightarrow P_1(1-\alpha)\left(\frac{S_1^*}{L_1^*}\right)^{\alpha} - w = 0 \tag{3.20}$$

$$\frac{\partial \mathfrak{L}}{\partial S_2} = 0 \Leftrightarrow w\left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{1}{(1-\alpha)}} \frac{\alpha}{(1-\alpha)} S_2^{-\frac{1}{(1-\alpha)}} - \Phi(A)C'(S_2^*) - \lambda = 0 \tag{3.21}$$

$$\lambda(S_1^* + S_2^* - V) = 0. \tag{3.22}$$

From equation (3.20), we have

$$\left(\frac{S_1^*}{L_1^*}\right)^{\alpha} = \frac{w}{P_1(1-\alpha)} \Leftrightarrow \left(\frac{L_1^*}{S_1^*}\right)^{(1-\alpha)} = \left\{\frac{P_1(1-\alpha)}{w}\right\}^{\frac{(1-\alpha)}{\alpha}}. \tag{3.23}$$

From equations (3.19) and (3.23), we get

$$P_1^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} = \lambda + \gamma S_1^*. \tag{3.24}$$

From equation (3.21), we obtain

$$\frac{\alpha}{(1-\alpha)} w \left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{1}{(1-\alpha)}} S_2^{-\frac{1}{(1-\alpha)}} = \lambda + \gamma\Phi(A) S_2^*. \tag{3.25}$$

Assume λ equal to zero. From equation (3.24) and equation (3.25), we obtain

$$P_1^{\frac{1}{\alpha}}\alpha\left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} = \gamma S_1^* \tag{3.26}$$

$$\frac{\alpha}{(1-\alpha)} w \left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{1}{(1-\alpha)}} S_2^{-\frac{1}{(1-\alpha)}} = \gamma\Phi(A) S_2^*. \tag{3.27}$$

From equations (3.26) and (3.27), we get

$$\frac{\alpha}{\gamma} P_1^{\frac{1}{\alpha}} \left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}} = S_1^* \tag{3.28}$$

$$\frac{\alpha}{(1-\alpha)} \frac{w}{\gamma\Phi(A)} \left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{1}{(1-\alpha)}} = S_2^{*\frac{(2-\alpha)}{(1-\alpha)}}. \tag{3.29}$$

Summing up:

$$\text{land of conventional product } S_{1c}^* = \frac{\alpha}{\gamma} P_1^{\frac{1}{\alpha}} \left\{\frac{1-\alpha}{w}\right\}^{\frac{(1-\alpha)}{\alpha}},$$

$$\text{labor of conventional product } L_{1c}^* = \frac{\alpha}{\gamma} P_1^{\frac{2}{\alpha}} \left\{\frac{1-\alpha}{w}\right\}^{\frac{(2-\alpha)}{\alpha}},$$

$$\text{land of organic product } S_{2c}^* = \left\{\frac{\alpha}{(1-\alpha)} \frac{w}{\gamma\Phi(A)}\right\}^{\frac{1-\alpha}{(2-\alpha)}} \left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{1}{(2-\alpha)}},$$

$$\text{labor of organic product } L_{2c}^* = \left\{\frac{\alpha}{(1-\alpha)} \frac{w}{\gamma\Phi(A)}\right\}^{-\frac{\alpha}{(2-\alpha)}} \left\{\frac{\widehat{Y}_2}{A}\right\}^{\frac{2}{(2-\alpha)}}.$$

We have $S_{1c}^* + S_{2c}^* \leqslant V$ from the assumption stated in the proposition. Hence, the values S_{1c}^*, L_{1c}^*, S_{2c}^*, L_{2c}^* are optimal. □

Chapter 4

Farmers' decisions on tea varieties

4.1 Introduction

Recently, studies concerning behavior and perception have been emphasized, especially in the agricultural sector. Despite all the development regarding decision theories by economists or sociologists, farmers today still largely rely on perception and intuition for decision-making. Variables that affect farmers' access to information, and hence their perception (e.g., experience, education, individual characteristics, etc.) are typically used in economic models of the determinants of adoption (Kebede et al., 1990; Polson and Spencer, 1991; Adesina and Baidu-Forson, 1995; Jayasuriya, 2003; Mafuru et al., 2007; Mpogole and Kadigi, 2012; Kaguongo et al., 2012). Besides, some studies find that farmers' characteristics influence their reactions to technological changes and innovations. Such factors include risk-aversion (Ghadim et al., 2005; Feder et al., 1985; Feder and Umali, 1993; Just and Zilberman, 1983) and wealth or household income (Sall et al., 2000). However, exciting studies often implicitly assume that the technology to be adopted is suitable (Adesina and Baidu-Forson, 1995), but it is often difficult to evaluate the advantages or disadvantages of a new technology, such as a new crop variety or a new choice of variety. For example, the choice of a type of new tea variety can be seen as a new technology that delivers utility in terms of both production (e.g., land, labor and yield) and consumption (e.g., quality, prices or market). The decision to adopt one type of tea variety is not only determined by the farmer's risk attitude but also by their preference regarding different product attributes. Even when one type of tea variety has better production-related attributes, farmers may continue growing types of tea variety that possess the preferred consumption or market related attributes.

Developing these arguments, this chapter seeks to make several contributions to the literature on the adoption of improved crop varieties. Some existing studies focused on ware potato farmers producing for the market (e.g., Abebe et al., 2013; Gildemacher et al., 2011), while others focused on soybean, corn and chickpea (Ojiako et al., 2007; Ouma and De Groote, 2011; Shiyani et al., 2002). While tea represents an important part of the crop in developing countries, it has received little attention in the adoption literature, compared to other staple crops such as potato, rice, corn and sorghum. Hence, the findings from the existing adoption literature may not be sufficient to understand farmers' decisions about whether or not to choose the type of tea varieties.

In most cases, Probit, Logit, Tobit or Bivariate Probit models were applied (see Ayuk, 1997; Adesina et al., 2000; Nkamleu and Adesina, 2000; Adesina and Chianu, 2002; Shiyani et al., 2002;Ojiako et al., 2007; Akinola et al., 2010; Dey et al., 2010). Similarly, some studies suggested the use of panel data such as Cameron (1999), Conley and Udry (2010) but argued that a lack of panel data has often been a problem in adoption behavior applications. However, to overcome this limit, few studies proposed the solution which consisted of using data on each farmer's adoption history (Besley and Case, 1993; Moser and Barrett, 2006). In these studies, adoption decisions can be analyzed using probit or logit models. The farmers' decision is assumed to be of a dichotomous nature.

In addition, some researches proposed the multinomial logit model (MNL) (see McFadden, 1973; So and Kuhfeld, 1995) and applied it to their research (Bhat and Guo, 2004; Nguyen Van et al., 2004; Dow and Endersby, 2004; Nkamleu and Kielland, 2006; Hassan and Nhemachena, 2008). The advantage of the MNL is that it permits the analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories. Moreover, some studies have shown that cross-sectional data can be safely used to analyze adoption decisions when the adoption process moves toward its completion; i.e., when the new technology has already been used for some time (Besley and Case, 1993; Cameron, 1999). Our study applies the MNL and examines the determinants of the farmers' choice regarding different tea varieties.

The aim of this chapter is to provide insights into the determinants of adoption of choice tea varieties by analyzing tea producers' assessment in Vietnam. The remaining of the study is organized as follows. Section 4.2 discusses the determinants of choice variables, including factors which are related to tea variety choice by farmers. Section 4.3 describes the data we collected in Vietnam. Section 4.4 presents the probability model which can be applied to our data. Section 4.5 reports the estimation results and provides interpretation for them. Finally, Section 4.6 concludes the study.

4.2 Literature review

The literature on the choice model is large enough. Furthermore, reviews about adoption of improved varieties in agriculture using choice model can be found in many studies (Adesina et al., 2000; Adesina and Chianu, 2002; Ojiako et al., 2007; Akinola et al., 2010; Dey et al., 2010). For example, Adesina et al. (2000) used the logit model in their study. Variables such as gender, farmers' membership in association, contact with extension agencies have a positive significance. The result implies that male farmers are more likely to adopt new technologies than women, etc. In addition, the negatively significant age variable suggested that younger farmers are more likely to adopt improved technologies. The positively significant variable on possession of full rights over trees suggested that it has a positive influence on the likelihood to adopt improved technologies. Finally, the education variable has a positive effect on the farmers' adoption decisions.

Shiyani et al. (2002) examined the adoption decision of improved chickpea varieties in farms in Gujarat, India and applied a Tobit model. In their study, several variables were significantly influencing the farmers' adoption decision, such as duration of crop maturity, size of land holding, yield risk, etc. The coefficient of land size holding was found to be negatively correlated with the adoption of new chickpea varieties, which means that adoption of new variety is growing faster for small farmers than for large ones. Experience of growing chickpea was significantly positive, which implies that farmers with higher experience are more likely to adopt new varieties. The coefficient of yield risk was positive and significant at 10% level, suggesting that the non-adopters were more risk averse. They also mentioned distance to output market and education as variables but these were not significant. Ojiako et al. (2007) investigated the adoption of the improved soybean variety in northern Nigeria, trying to identify the factors influencing the farmers' adoption decisions by applying both Logit and Tobit models. The results showed that over 60% of the farmers adopted the improved variety. Factors such as superior yield, grain size, color, resistance to pests and diseases were the farmers' reasons for adopting the improved varieties. The adoption of improved soybean technology by farmers is significantly and positively influenced by productivity, hired labor, membership of associations and exposure to extension services.

Another interesting study by Asfaw et al. (2011) analyzed the adoption determinants and estimated the effect of adopting improved chickpea technologies on small farms holders in Ethiopia and applied a Tobit model. Variables included active family labor force, non-oxen tropical livestock unit per capita, walking distance to the main market, contact with government extension agents, number of improved varieties known in previous years and farmers' perception of improved varieties. Their effects were significant and positive. There results showed that the level of adoption of improved varieties was strongly related to household wealth indicator variables. The households with more family labor force, livestock and land were considerably more likely to allocate extra land for the improved chickpea varieties. However, this shows the importance of wealth/poverty level in production and technology choice decision behavior of small farms holders. In addition, they put on other variables such as gender, age, education, etc. But in fact the latter are not significant. Ouma and De Groote (2011) computed the factors affecting adoption of improved corn varieties and fertilizer by farmers in Kenya by applying a Heckman model. Variables considered are education, access to credit, hired labor, extension contacts, distance to market, fertilizer. The result concerning the education variable is significantly positive, revealing its association with adoption of improved maize varieties. However, it had no significant impact on adoption of fertilizer. Access to credit and hired labor were positive and significant in explaining the adoption decision of improved maize varieties and fertilizer. The number of extension contacts was important in determining the adoption of improved maize varieties but not for the use of fertilizer. Distance to market was negatively associated with adoption of fertilizer, although it was positively associated with the intensity of fertilizer's use. Use of fertilizer and improved maize seed were significantly positive at 1% level, respectively. It means that it is strongly associated with adoption of improved maize seed and fertilizer. Abebe et al. (2013) determined the adoption of improved potato varieties in Ethiopia. The result indicated that higher education of the household head, gender, access to credit, family size, stew quality of local variety and the presence of a radio and/or television also have a significant positive effect on adoption. As to the scale of adoption, other variables are also included (the percentage of owned land, age, tuber size (of ware potatoes), stew quality, yield of local variety, disease resistance of local variety, maturity period of local variety and presence of a mobile phone) but their effects were not significant.

4.3 Data and variables

The summary statistics of the variables is reported in Table 4.1. Tea incomes are measured in million VND. We observe that the average tea income is about 65.6 million VND per farmer, with a standard deviation of 66.67, and the rank of tea income is found between around 2.4 and 403 million VND which indicates the large variability in tea income among the farmers.

The average of households size (number of members) is 4.3 people, with a standard deviation of 1.2, and the rank of people between around 1 and 10 persons which indicates the large variability in members among the tea producers. The average experience of farmers is 29.89 with a standard deviation of 13.85 which indicates the large variability in experience among households. However, we would like to test which household member influences the tea varieties choice, and in this case, we examine the presence of children and the elderly in the household.

Table 4.1: Summary statistics of the tea producer's characteristics

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Tea income	65.67	66.70	2.4	403	244
Household size	4.30	1.20	1	10	244
Experience	29.89	13.85	2	64	244
Children	0.217	0.413	0	1	244
Elderly	0.159	0.367	0	1	244
Minority	0.107	0.309	0	1	244
High education	0.328	0.470	0	1	244
Chemical fertilizer	0.732	0.443	0	1	243
Organic fertilizer	0.488	0.501	0	1	242
Contract	0.553	0.498	0	1	244
Youth Union	0.504	0.501	0	1	244
Farmer's Union	0.578	0.499	0	1	244
Communist Party	0.204	0.404	0	1	244
Tea Association	0.367	0.483	0	1	218

A summary of the variables definitions is available in Appendix A6. Our analysis includes dummies corresponding to household characteristics like high education and minority. The data contain 80 households with high education, and 26 households belonging to a minority ethnic group. The purpose of considering these factors is to check whether they can impact the household's varieties choice. Indeed, a high level of education might favor the access to new production technology and to any information that can improve the production. On the contrary, being part of a minority ethnic group can involve a lack of advantage comparing to the majority groups.

We define dummies corresponding to household's characteristics such as the use of chemical fertilizer, organic fertilizer, and contract. The data contain 118 households with chemical fertilizer, 178 households with organic fertilizer and 135 household with a contract. Our analysis also includes dummies corresponding to household's characteristics such as membership of Communist Party, Youth Union, Farmer's Union, Tea Association. The data contain 50 households with a member belonging to the Communist Party, 123 households with a member belonging to the Youth Union, 141 households with a member belongs to the Farmer's Union and 80 households with a member belonging to the Tea Association. The purpose of considering these factors is to check whether they can impact the choice of tea varieties.

Furthermore, we mention in our data, that tea varieties are classified following 5 categories: 'Trung-Du' (the oldest variety), 'PH1', 'LDP1', 'Bat-Tien', and the remaining types (category 'Other'). We note that farmers can cultivate several tea varieties at the same time. Table 4.2 gives the distribution of the data following tea varieties. The oldest variety 'Trung-Du' is cultivated by 47 households, about 19.3 percent of the data sample. The 'PH1' is cultivated by 32 households, about 13.1 percent of the data sample. The 'LDP1' is cultivated by 37 households, about 15.2 percent of the data sample. The 'Bat-Tien' is cultivated by 58 households, about 23.8 percent of the data sample and the Other variety is cultivated by 69 households, about 28.4 percent of the data sample.

Table 4.2: Distribution tea varieties

Tea varieties	Freq.	Percent	Cum.
'Trung-Du'	47	19.34	19.34
'PH1'	32	13.17	32.51
'LDP1'	37	15.23	47.74
'Bat-Tien'	58	23.87	71.60
'Other'	69	28.40	100.00

So, we create the new variables from 5 varieties in below, including green tea, black tea, new tea and old tea. Green tea and black tea may be made from ‘Trung-Du’, ‘PH1’, ‘LDP1’, ‘Bat-Tien’ and Other varieties. A dummy variable for black tea is then defined to check whether there exists a difference between black tea production and green tea production. The collected data include 138 green tea producers, about 56.7 percent of the data sample and 105 black tea producers, about 43.2 percent of the data sample (Table 4.3).

Table 4.3: Distribution tea varieties

Tea varieties	Freq.	Percent	Cum.
Black	105	43.21	43.21
Green	138	56.79	100.00

Table 4.4 gives the distribution of the data following multiple choice tea varieties. The old tea correspond to ‘Trung-Du’ variety. The new tea includes ‘PH1’, ‘LDP1’, ‘Bat-Tien’ and Other varieties. The collected data include 18 new/black (N/B), about 7.4 percent of the data sample, 67 new/green (N/G), about 27.5 percent of the data sample, 59 old/black (O/B), about 24.2 percent of the data sample, 20 old/green (O/G), about 8.2 percent of the data sample, 28 new/old/black (N/O/B), about 11.5 percent of the data sample and 51 new/old/green (N/O/G) tea producers, about 20.9 percent of the data sample.

Table 4.4: Distribution following multiple choice for tea varieties

Choice	Freq.	Percent	Cum.
Old-Black (OB)	59	24.28	24.28
New-Black (NB)	18	7.41	31.69
New/Old-Black (NOB)	28	11.52	43.21
Old-Green (OG)	20	8.23	51.44
New-Green (NG)	67	27.57	79.01
New/Old-Green (NOG)	51	20.99	100.00

4.4 A discrete choice model for tea varieties

We propose here an econometric model to characterize farmer’s choice about tea varieties among six categories as presented in Table 4.4.

4.4.1 Model without farmer's heterogeneity

The general model presented here is based on works of Nerlove and Press (1973), Greene (2012) and Hausman and McFadden (1984). We mention that farmer i faces J alternatives and his utility derived from choice alternatives j, $j = 1,...,J$ are

$$V_{ij} = \beta_j X_i' + \varepsilon_{ij}, \tag{4.1}$$

where the random errors, ε_{ij}, in equation (4.1) that are independent and identically distributed across the J alternatives. Let y_{ij} be the dependent variable with J outcomes numbered from 1 to J.

In this analysis, the six categories considered are given as follows: (1) old/black (O/B), (2) new/black (N/B), (3) new/old/black (N/O/B), (4) old/green (O/G), (5) new/green (N/G) and (6) new/old/green (N/O/G). If there is a random sample of farmers, $i = 1,...,n$ given six choices of tea variety categories, $j = 1,...,6$ the MNL model assigns probabilities $Pr(y_i = j \mid X_i)$ to events characterized as "i_{th} choice in j_{th} category".

We assume that the vector of characteristics X_i' influences the probability of category j. After imposing the usual identifying restriction $\beta_1 = 0$, our MNL model for choice across J alternatives ($j = 1,...,6$) can then be specified as

$$Pr(y_i = 1) = \frac{1}{1 + \sum_{k=2}^{J} \exp(\beta_k X_i')} \tag{4.2}$$

and

$$Pr(y_i = j) = \frac{\exp(\beta_j X_i')}{1 + \sum_{k=2}^{J} \exp(\beta_k X_i')}, \tag{4.3}$$

where $j = 1,...,J$ and $k = 2,...,K$.

The likelihood function takes the form

$$L = \prod_{i}^{n} \prod_{j}^{J} Pr(y_i = j \mid X_i)^{n_{ij}}, \tag{4.4}$$

where n_{ij} is the household-choice indicator of category j; $n_{ij} = 1$ if $y_i = j$; and $= 0$ otherwise.

Then the log-likelihood is

$$\mathrm{Log}L = \sum_{i=1}^{N}\sum_{j=1}^{J} n_{ij}\,\mathrm{Log}Pr(y_i = j \mid X_i). \tag{4.5}$$

Maximization of 4.5 yields the maximum likelihood (ML) estimation for $\widehat{\beta}_j$.

4.4.2 Model with farmer's heterogeneity

To obtain more general specifications, we now allow for the possibility of presence of individual heterogeneity or individual random effects. We mention that a farmer i faces J alternatives and the utility derived from choice alternatives j, $j = 1,...,J$ is

$$V_{ij} = \beta_j X_i' + u_i + \varepsilon_{ij}, \tag{4.6}$$

where u_i is the random effects (or individual heterogeneity).

The heterogeneity terms u_i are assumed to be mutually independent and independent of X', with a standard normal distribution. A similar approach was adopted by Allenby and Lenk (1995), for instance. The probabilities of different choices become:

$$Pr(y_i = 1) = \frac{1}{1+\sum_{k=2}^{J}\exp(\beta_k X_i' + \sigma_k u_i)} \tag{4.7}$$

and

$$Pr(y_i = j) = \frac{\exp(\beta_j X_i' + \sigma_j u_i)}{1+\sum_{k=2}^{J}\exp(\beta_k X_i' + \sigma_k u_i)}. \tag{4.8}$$

We have to integrate (4.4) with respect to the heterogeneity distribution, so that we get

$$L = \prod_{i}^{n}\int_{-\infty}^{+\infty}\left\{\prod_{j}^{J} Pr(y_i = j \mid X_i, u_i)\right\}\mathrm{d}\varphi(u_i).$$

Therefore, the ML estimator is obtained by maximizing the quantity

$$\ln L_j = \sum_{i}^{n}\ln\int_{-\infty}^{+\infty}\left\{\prod_{j}^{J} Pr(y_i = j \mid X_i, u_i)\right\}\mathrm{d}\varphi(u_i).$$

Basing on a presentation of the method of simulated ML (see Stern, 1997), the integral can be replaced by a simulator,

$$\ln L_j = \sum_i^n \ln \frac{1}{H} \sum_{h=1}^{H} \prod_j^J Pr(y_i = j \mid X_i, u_i^h),$$

where

$$Pr(y_i = 1 \mid X_i, u_i^h) = \frac{1}{1 + \sum_{k=2}^{J} \exp(\beta_k X_i' + \sigma_k u_i^h)} \tag{4.9}$$

and

$$Pr(y_i = j \mid X_i, u_i^h) = \frac{\exp(\beta_j X_i' + \sigma_j u_i^h)}{1 + \sum_{k=2}^{J} \exp(\beta_k X_i' + \sigma_k u_i^h)}, \tag{4.10}$$

and for each u_i, a number H of pseudo random draws u_i^h are generated. Basing on discussion of McFadden and Train (2000), we chose $H = 50$ for our simulations.

4.5 Estimation results

We estimate two different versions of the MNL model in order to analyze the probabilities of the households' choice of tea varieties: a model without unobservable heterogeneity and a model with unobservable heterogeneity.

We first compare the models with and without unobservable heterogeneity. We also produce a LR test of the model with heterogeneity against model without heterogeneity. The LR test statistic is 2(-241.8723+242.2572)=0.769. The computed value of the LR test statistic is smaller than $\chi^2_{.95}(5) = 11.07$. Hence the model without heterogeneity is not rejected at the 5% level against the model with heterogeneity. Consequently, we report solely the estimation results for the model without unobserved heterogeneity of type u_i. Table 4.5 presents the estimation results of the model without unobserved heterogeneity. We use Wald test to check whether the model is significant. The computed value of Wald test statistic is $\chi^2_{.95}(70) = 114.24$, strongly higher than the 1% level. This implies that the variables included in the model are jointly significant. In other words, the factors used can provide a good explanation for the effect on households' tea varieties choices.

Moreover, the MNL model is the most commonly used regression model for nominal outcomes in economics and social sciences. However, the assumption of the independence of irrelevant alternatives (IIA) is implicit in the model, hence many researchers have expressed concern about this. Basing on approach of Hausman and McFadden (1984) and Cheng and Long (2007), we test for the validity of the households' choice of tea varieties. All test statistics are $\chi^2(56)$ distributed (critical value, 31.02). Our results cannot reject the IIA hypothesis.

Our results from Table 4.5 can be interpreted as follows. Tea income has a significantly negative influence on new/black choice ($j = 2$). This result is consistent with other studies (Afxentiou and Hawley, 1997). Moreover, tea income has a significantly positive effect on both new/green choice ($j = 5$) and new/old/green choice ($j = 6$) at the 5% level, respectively. This result is also in line with study of Udensi et al. (2011).

Our estimation results also suggest that elderly members in the household have a significantly positive effect on the probability of adopting new/black ($j = 2$) and ($j = 6$) new/old/green. This could be explained by the fact that older people are more receptive to new technologies for black tea ($j = 2$), but they are not willing to take risks for green tea ($j = 6$). Our result is consistent with study of Timu et al. (2014). In addition, we also examine the effect of children on the households' choices. Nkamleu and Kielland (2006) noticed how children are kept out of both farming cocoa and schooling in wealthier communities. In our study the children variable is not significant.

Households size has a significantly negative impact on old/green ($j = 4$) and ($j = 6$) new/old/green. The households size effect for choosing the old/green ($j = 4$) and new/old/ green ($j = 6$) are -0.818 and -0.663, respectively. The significant negative effect also shows how family labor is unimportant for old/green ($j = 4$) and new/old/green ($j = 6$). It is also possible that these new varieties may require less labor. They may require improved agronomic practices (e.g., weeding, harvesting, etc.). The negative effect of this variable also seems to contradict others studies (Gebremedhin et al., 2009; Asfaw et al., 2011 and Abebe et al., 2013). However, our result is consistent with the result of Timu et al. (2014).

Moreover, in our estimation, three variables directly characterize the household as experience, minority and high education relationship to the head of household. The only significant impact of minority is related to choose new/black ($j = 2$). This suggests that ethnic minorities have a preference for new/black ($j = 2$).

At the same time, farmer education has negative effect on old/green choice ($j = 4$) at 10%

level. This suggests that the farmers will not choose old/green tea. This result does not seem to contradict existing results. Clay et al. (1998) found that education was an insignificant determinant of adoption decisions, while other studies found that education was negatively correlated with such decisions (Gould et al., 1989; Okoye, 1998; Adesina et al., 2000; Hassan and Nhemachena, 2008; Gebremedhin et al., 2009; Ouma and De Groote, 2011; Abebe et al., 2013; Adisa et al., 2013). Shiyani et al. (2002) who also used the level of education found that it was not significant.

Our result shows that the experience of household is not significant in our estimation. While, Shiyani et al. (2002) also show that experience of growing chickpea was significant with positive sign. This indicates that farmers more experienced in growing chickpea are more likely to adopt new varieties. Such a pattern is expected because more experienced farmers may have better skills and access to new information about improved technologies through extension services.

Now considering membership of political groups, we find that the tea association variable has a significantly positive impact on old/green choice ($j = 4$). Similarly, this variable has a significantly positive affect on new/old/green choice ($j = 6$). Our result is consistent with the result of Adesina et al. (2000) and Ojiako et al. (2007).

Our estimation results also indicate that the Farmer's Union variable has a significantly positive effect on adopting new/old/green ($j = 6$). Youth Union variable has a significantly positive impact on both new/green ($j = 5$) and new/old/green ($j = 6$). The Youth Union variable effect for choosing the new/green ($j = 5$) and new/old/green ($j = 6$) are 1.097 and 1.090, respectively. This means that farmers who belong to social organizations, cooperatives, meeting groups and other associations of farmers are more likely to adopt a new innovation. This result is consistent with the result of Atta-Krah and Francis (1987) and Versteeg and Koudokpon (1993).

Contract variable has a significantly positive impact on new/black ($j = 2$) and ($j = 5$) new/green. This variable effect for choosing the new/black ($j = 2$) and new/green ($j = 5$) are 1.704 and 2.097, respectively. This could be explained by the fact that farmers having a contract with buyers are more receptive to new varieties.

We also examine the fertilizer variable in this estimation. Fertilizer in this case includes organic and chemical use. The organic fertilizer variable is positively and significantly related to the choice of new/black ($j = 2$), new/green ($j = 5$) and new/old/green ($j = 6$). The positive effect of the organic fertilizer variable is also consistent with other studies (Ouma and

Table 4.5: Estimation results for the model without heterogeneity

Variable	N/B ($j=2$)	N/O/B ($j=3$)	O/G ($j=4$)	N/G ($j=5$)	N/O/G ($j=6$)
Tea income	-1.360**	-0.071	-0.480	0.810**	1.409**
	(-2.83)	(-0.23)	(-1.16)	(2.66)	(4.20)
Children	-0.762	-0.307	0.280	0.936	0.640
	(-0.77)	(-0.48)	(0.33)	(1.63)	(1.07)
Elderly	1.937*	0.561	1.820	1.169	1.651*
	(2.06)	(0.73)	(1.76)	(1.57)	(2.07)
Household size	-0.311	-0.099	-0.818*	-0.001	-0.663**
	(-1.06)	(-0.46)	(-2.35)	(-0.00)	(-2.61)
Experience	-0.002	0.041	-0.043	0.005	-0.004
	(-0.05)	(1.76)	(-1.72)	(0.24)	(-0.17)
Minority	1.981*	-0.095	-1.822	-0.453	-0.152
	(2.01)	(-0.09)	(-0.98)	(-0.41)	(-0.14)
High education	1.205	-0.254	-2.587*	0.134	-0.979
	(1.48)	(-0.42)	(-2.09)	(0.25)	(-1.65)
Tea Association	-0.009	0.929	2.597**	0.819	1.640**
	(-0.01)	(1.49)	(2.92)	(1.46)	(2.67)
Farmer's Union	1.053	-0.397	0.924	0.689	1.218*
	(1.22)	(-0.72)	(1.21)	(1.32)	(2.13)
Communist Party	0.090	-0.439	-0.499	-0.712	-1.199
	(0.12)	(-0.74)	(-0.55)	(-1.22)	(-1.71)
Youth Union	0.318	-0.320	0.200	1.097*	1.090*
	(0.45)	(-0.59)	(0.28)	(2.20)	(2.08)
Contract	1.704*	0.203	0.661	2.097**	1.092
	(2.06)	(0.35)	(0.83)	(3.77)	(1.87)
Organic fertilizer	2.138*	-0.294	-1.063	2.457**	1.239*
	(2.23)	(-0.48)	(-1.25)	(4.03)	(2.03)
Chemical fertilizer	-0.146	14.16	-2.948**	-1.105	-0.979
	(-0.15)	(0.03)	(-3.59)	(-1.89)	(-1.60)
Intercept	0.602	-14.97	5.355*	-6.377**	-4.933**
	(0.29)	(-0.04)	(2.55)	(-3.78)	(-2.82)

t statistics in parentheses, n = 216

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

Likelihood-ratio test of $\chi^2(70) = 114.24$; $Prob > \chi^2 = 0.0016$

De Groote, 2011; Owusu et al., 2013) but it is inconsistent with the result of De Groote et al. (2013). Besides, our estimation shows that the chemical fertilizer has a significantly negative effect on old/green choice ($j = 4$) at 5% level. This could be explained that the farmers will not choose old/green tea.

Table 4.6 also presents the results that ideally should be compared with MNL results for the tea variety choice. In most cases the results also coincide qualitatively for coefficients that were significant for choice of new/black ($j = 2$). This table shows that the result of MNL model without unobservable heterogeneity is robust. This robustness of the results is very encouraging. Considering the difference in the proportions of choice of tea "$j = 1$", "$j = 2$", "$j = 3$", "$j = 4$", "$j = 5$" and "$j = 6$"; these are 12.9, 26.9, 24.9, 8.3, 8.4 and 18.6 percent, respectively.

Table 4.6: Percentages of prediction for each choice use categories

	O/B ($j = 1$)	N/B ($j = 2$)	N/O/B ($j = 3$)	O/G ($j = 4$)	N/G ($j = 5$)	N/O/G ($j = 6$)
Observed	58	18	28	18	54	40
Predicted	72	18	19	11	60	36
Percentages of prediction (%)	12.9	26.9	24.9	8.3	8.4	18.6

Moreover, in a study of Nkamleu and Kielland (2006) indicated that the MNL does not share the monotonic behavior of the binomial logit probability. Hence, the usual focus in the literature is on coefficient estimations rather than on marginal effects. Because the marginal effects depend on the point of evaluation and due to the non monotonic nature, the marginal effect can vary in sign according to the value of the dependent variable. Thus, there is some potential for confusion, as marginal effects coefficients do not need to have the same sign as model coefficients.

Our estimations from Table 4.7 can be interpreted as follows. Tea income variable in the first, third and final column has a statistically significant. The negative coefficient of tea income implies that the probability of adopting new/black ($j = 2$) and old/green ($j = 4$) decreases by 8.3 and 4.2 percent, respectively. The results of the marginal effects in the final column implies that a 1 percent increase in tea income will lead to a 13.2 percent increase in the probability of adopting new/old/green ($j = 6$).

Household size in the fourth and final column has statistically significant coefficients. The results of the marginal effects in this variable implies that a 1 percent increase in household size will lead to a 5.2 percent increase in the probability of adopting new/green ($j = 5$). As expected, a larger household size allows one to experiment new tea varieties because the new varieties may imply the need for a lot of workers. On the contrary, the results of the marginal effects in this variable implies that a 1 percent increase in household size will lead to a 6.6 percent decrease in the probability of adopting new/old/green ($j = 6$).

Table 4.7: Estimation results marginal effects without heterogeneity

Variable	N/B ($j=2$)	N/O/B ($j=3$)	O/G ($j=4$)	N/G ($j=5$)	N/O/G ($j=6$)
Tea income	-0.083**	-0.025	-0.042*	0.053	0.132**
	(-4.14)	(-1.22)	(-2.43)	(1.91)	(4.80)
Children	-0.053	-0.047	0.003	0.103	0.025
	(-1.11)	(-0.90)	(0.07)	(1.70)	(0.46)
Elderly	0.059	-0.019	0.049	0.009	0.087
	(1.50)	(-0.33)	(1.13)	(0.13)	(1.32)
Household size	-0.008	0.008	-0.031	0.052*	-0.066**
	(-0.61)	(0.47)	(-1.98)	(2.27)	(-2.69)
Experience	-0.003	0.004*	-0.002*	0.001	-0.001
	(-0.23)	(2.06)	(-2.10)	(0.31)	(-0.42)
Minority	0.113**	-0.006	-0.091	-0.063	0.022
	(2.72)	(-0.07)	(-1.02)	(-0.55)	(0.22)
High education	0.075*	-0.006	-0.121*	0.086	-0.095
	(2.09)	(-0.13)	(-2.07)	(1.56)	(-1.71)
Tea Association	-0.038	0.032	0.096*	-0.023	0.101
	(-1.11)	(0.68)	(2.45)	(-0.43)	(1.93)
Farmer's Union	0.036	-0.080	0.023	0.005	0.093
	(0.91)	(-1.76)	(0.67)	(0.09)	(1.74)
Communist Party	0.026	-0.009	-0.002	-0.016	-0.087
	(0.77)	(-0.18)	(-0.04)	(-0.25)	(-1.27)
Youth Union	-0.003	-0.067	-0.012	0.084	0.065
	(-0.09)	(-1.48)	(-0.38)	(1.61)	(1.35)
Contract	0.045	-0.050	-0.007	0.188**	-0.013
	(1.26)	(-1.09)	(-0.21)	(3.44)	(-0.25)
Organic fertilizer	0.071	-0.097*	-0.096*	0.246**	0.008
	(1.70)	(-2.06)	(-2.68)	(4.01)	(0.16)
Chemical fertilizer	-0.116	1.492	-0.216	-0.317	-0.247
	(-0.01)	(0.02)	(-0.04)	(-0.02)	(-0.02)

t statistics in parentheses, n = 216

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

The negative coefficient of experience in the third column implies that the probability of adopting old/green ($j = 4$) decreases by 0.2 percent. This could be explained by the fact that more experience farmers are less likely to adopt old/green ($j = 4$). On the contrary, the more experienced farmers tend to choose diversification in order to avoid risks. The choice of new/old/black tea ($j = 3$) could be explain by the positive coefficient of experience in the second column which implies that the probability of adopting new/old/black ($j = 3$) increases by 0.4 percent.

The results also suggest that the likelihood of adoption increases with the minority variable. The positive coefficient of this variable implies that the probability of adopting new/black ($j = 2$) increases by 11.3 percent.

The positive coefficient of high education implies that the probability of adopting new/ black ($j = 2$) increases by 7.5 percent. This result is compatible with the studies of Mishra and El-Osta (2002) and Timu et al. (2014). The coefficient for education in the third column is negative and statistically significant at 5% level. The negative coefficient of high education implies that the probability of adopting old/green ($j = 4$) decreases by 12.1 percent.

Besides, tea association was also found to affect the adoption of old/green choice ($j = 4$). This variable was positive and statistically significant at 5% level. The results of the marginal effects show that a 1 percent increase in the number of farmers belonging to an association increases the likelihood of adoption by 9.6 percent. This finding implies that tea association intensify the likelihood of adopting of old/green ($j = 4$). The results is inconsistent with the findings of Timu et al. (2014).

Contract variable has a significantly positive impact on new/green ($j = 5$). The results implies that a 1 percent increase in contract will lead to a 18.8 percent increase in the probability of adopting new/green ($j = 5$).

Furthermore, organic fertilizer was also found to impact negatively on new/old/black ($j = 3$) and old/green ($j = 4$). The negative coefficient of this variable in the second and third column implies that the probability of adopting new/old/black ($j = 3$) and old/green ($j = 4$) decreases by 9.7 and 9.6 percent, respectively. Meanwhile, the positive coefficient of this variable in the fourth column implies that the probability of adopting new/green ($j = 5$) increases by 24.6 percent.

4.6 Conclusions

The main aim of our study is to provide insights about the determinants of choosing tea varieties in Vietnam, focusing on the role of farmer characteristics and the role of external factors. Our measure of the farmers' choice is the extent of adoption of tea varieties, when they are provided with a menu of six choices (old/black ($j = 1$), new/black ($j = 2$), new/old/black ($j = 3$), old/green ($j = 4$), new/green ($j = 5$) and new/old/green ($j = 6$)).

We compared two versions of the econometric model: a model without unobserved heterogeneity, and a model with unobserved heterogeneity. We found that the former model is preferred.

The results reveal that important factors which influenced the adoption of tea varieties include tea income, presence of elderly, household size and organic fertilizer. Moreover, some important factors that influence adoption of type of tea varieties included membership of Tea Association, Farmer's Union, Youth Union and having a Contract with buyers. These variables correspond to the factors to which one should pay attention in order to favor the adoption of a certain type of tea varieties.

Chapter 5

Impact of political connection on farming households' income[1]

5.1 Introduction

Research on the political connection is really abundant in economic literature. Some authors emphasized the relationship between political connection and economic growth (e.g., Bardhan and Mookherjee, 2000; Ferraz and Finan, 2008). In addition, connections between firms and politicians have been extensively widespread in recent years. Several recent studies indicate that a significant part of a firm's value comes from political links that could increase the firm value (Fisman, 2001; Faccio et al., 2006; Claessens et al., 2008). Politically connected firms may also receive advantages from governments' decisions such as the awarding of licenses, government contracts, bailouts for distressed firms (Fisman, 2001; Khwaja and Mian, 2005; Faccio et al., 2006; Charumilind and Wiwattanakantang, 2006; Leuz and Oberholzer-Gee, 2006; Firth et al., 2011).

Furthermore, the literature has also identified the value of political connections in corruptive countries (e.g., Fisman, 2001; Li et al., 2008; Bunkanwanicha and Wiwattanakantang, 2009; Cingano and Pinotti, 2013; Goldman et al., 2009). Certain studies estimated the market value of political connections (e.g., Fisman, 2001; Faccio et al., 2006). However, examining the relationship between political connection and household income, especially in agriculture, is still scarce. Our research aims at filling this gap by investigating the role of political connection on farmers' income in Vietnam.

[1] This chapter is drawn from To-The N., Tran-Nam Q. (2015) "Impact of political connection on farming households' income of tea production in Vietnam", *Journal of Agricultural Science,* Vol. 7, No. 12.

Before proceeding, we first discuss the concept of “political connection". Generally, political connection has always been defined in a inconsistent and non-obvious way. In fact, Faccio (2006) suggested the definition that a firm considered having a political connection if one of its large shareholders or top officers is: (i) a member of parliament, (ii) a minister or the head of state, or (iii) closely related to top officials. Similarly, Faccio et al. (2006) also defined that a firm could be politically connected if at least one type leaders (chief executive officer, chairman of the board, president, vice-president, or secretary of the board or a large shareholder) becomes a head of state (i.e., president, king, prime minister, a government minister or a member of the national parliament). However, on another aspect, Firth et al. (2011) supposed that a political connection would be formed when at least one of the board members, top managers, or major stockholders has a relationship with someone in the government. The important role of informal connections between government officials and private agents were also mentioned. In addition, Dalton et al. (2002) also examined the patterns of social relations and social capital. They used variables such as family, friend, work, religious, education, age, gender and income, but they only compared the interaction between these variables by a simple method.

Theoretically, formulating a consistent definition of political connection seems to be impossible because it depends on several social and cultural backgrounds in a specific country or even in a region. For instance, in Vietnam, there are some organizations such as the Farmers' Union, the Youth Union, the Communist Party, the Women' Union and the Veteran's Union which are considered as the group components forming up the Communist Party, the unique political party in Vietnam. As a result, they have strong links with the state and their membership could help getting advantages in business, job search, education, promotion, etc. Therefore, in this research, we define that a household will be considered as having a political connection if one or more members of the household is involved into these organizations. However, a member of an organization does not necessary always join the Communist Party at the same time. Our data set contains information about these households that will be used to investigate the effects of these variables on household income in Vietnam.

To estimate this relationship, we use primary data surveying tea farming households in three provinces in Vietnam and apply a Box-Cox regression. We find that households without political ties could not obtain as much information as the well connected households. This is likely to imply a certain significant impact of political link on economic income.

The chapter is organized as follows. Section 5.2 discusses the role of political connection on firms and households following on previous research. Section 5.3 presents the estimation method and describes the data we collected in Vietnam. Empirical findings is analyzed in Section 5.4. Finally, Section 5.5 gives some conclusion and suggests some policy implications.

5.2 Literature review on the role of political connection on firms and household income

Studies on political connection are numerous. Studying firms in Malaysia, Adhikari et al. (2006) examined the relation between political link and effective tax rates. They found that political connection can cause a negative effect on tax rate. Independent variables include proxies for political connections, firm size, capital structure, asset mix, firm income, growth prospects. Charumilind and Wiwattanakantang (2006) investigated the influence of political ties on firm's loans in Thailand and pointed out that firms having a political connection could have more long-term loans although less collateral. Faccio et al. (2006) analyzed the government bailouts of 450 politically connected firms from 35 countries over the period 1997-2002. The results illustrated that politically connected firms have much more opportunities to be bailed out when facing complications than unconnected firms. They also found that political ties in countries with high levels of corruption generated a statistically significant cumulative abnormal return (CAR) of 4.32%, versus an insignificant CAR of 0.02% in countries with low levels of corruption. Besides, Leuz and Oberholzer-Gee (2006) used a data set of 130 Indonesian firms to explore the role of political relationships in firm's financing. The paper applied a probit model to estimate effects of independent variables including Closeness to Suharto (President Suharto), Suharto family owned, state-owned enterprise, firm size, ratio of operating income to total assets, capital intensity, financial leverage and industry including agriculture, manufacturing, transports, trade and finance. They indicated the interesting evidence that strongly politically connected firms are less likely to have publicly traded foreign securities.

In a more recent work, Li et al. (2008) examined, for private firms in China, the role of association with Communist Party for business activities, by estimating the profitability and using return on assets and on equity as the dependent variables. The research pointed out that party membership and education variables have a significantly positive effect on dependent variables. However, management experience, former public firm manager, former cadre, PC (People's Congress) membership, CPPCC (Chinese People's Political Consultative Conference) membership are not significant statistically. Niessen and Ruenzi (2010) investigated politically connected firms in Germany. The result showed that firms with political ties are less risky, however, the market value is lower than firms without political connection. They also specified that politically connected firms provide better stock market income. Furthermore, politically connected firms have significantly higher returns on equity and returns on investments. Boubakri et al. (2012) found that firms with political link have a lower cost of equity and are generally considered as less risky than non-connected firms.

Analyzing Chinese firms during 1999-2006, Wu et al. (2012) found that private politically connected firms have a higher value and obtain more government subsidies than others. Meanwhile, local state-owned firms have a lower value. Similarly, Amore and Bennedsen (2013) gave evidence of Danish firms being able to increase significantly their income when they have a connection with local politicians. Contrarily, concerning Italian firms over the period 1985-1997, Cingano and Pinotti (2013) found that political connection may entail significant economic losses.

Some authors focus on the impact of political connection on stock market. Faccio (2006) examined the relationship between publicly traded firms and politically linked in 47 countries and showed the existence of this relationship in 35 countries. This study also showed that national political ties are valuable, especially in countries having weak political institutions. Fan et al. (2007) released empirical evidence of the negative relationship between politically connected of chief executive officer and the first day stock return. That could be interpreted as a signal of government intervention. In addition, Goldman et al. (2009) explored the effects of political connection on stock market in the United States. They used a data set of board members of 500 companies connected to the Republican Party and the Democratic Party for the 2000 presidential election. As a result, the stock value of companies connected to the Republican Party increased and, on the contrary, the stock value of companies connected to the Democratic Party decreased.

Moreover, Caeyers and Dercon (2012) examined the role of political connections in the allocation of food aid in rural Ethiopia, applying a probit model. They used variables including the number of persons in the household, per capita real consumption, average work ability score of the household head, land area owned per capita, household size. They found that household size have a significantly negative effects to allocation of food. The research also found strong evidence of politically connected and favoritism; for instance, it indicated that a well-connected household had a 10% higher probability to obtain free food than the unwell-connected households. In addition, few studies mentioned the relation between political link and household income. Recently, Markussen and Tarp (2014) explored the effects of political power on farmers' agricultural investment decisions and a significant increase in land-investment of household when their relatives are working into public sector. The authors also mentioned the relation between political connections and property rights, using of credit, worker wage.

5.3 Econometric modeling and data

5.3.1 Econometric modeling

In this research, to deal with the dropping issue, the Box-Cox model will be applied to estimate the role of political connection factors on tea producers' income in Vietnam.[2] We reply to the works of Wooldridge (1992), Sakia (1992) and Abrevaya (2002).[3] We assume that household income is a function of political connection and other explanatory variables.

We use maximum likelihood to obtain estimates of the parameters for the Box-Cox model. The most general Box-Cox model is

$$y_i^{(\theta)} = \beta_0 + \beta_1 x_{1i}^{(\lambda)} + \beta_2 x_{2i}^{(\lambda)} + ... + \beta_K x_{Ki}^{(\lambda)} + \alpha_1 z_{1i} + \alpha_2 z_{2i} + ... + \alpha_h z_{hi} + \varepsilon_i \qquad (5.1)$$

where $\varepsilon \sim N(0;\sigma^2)$. Each of the independent variable, $x_1, x_2, ..., x_K$, has a Box-Cox transform with the parameter λ. The $z_1, z_2, ..., z_h$ are explanatory variables that are not transformed. In this model, the Box-Cox transform of the dependent variable y with the parameter θ. Hence,

[2]Box and Cox (1964) developed the transformation and argued that the transformation could make the residuals more closely normal and less heteroscedastic.

[3]Some studies applied a double-log function to model the relation between household earnings and land (see Ravallion and Van de Walle, 2008). It is also used in other researches such as Jayne et al. (2003) and Finan et al. (2005); in which they dropped the variable of landless. In order to avoid dropping observed independent variables, some authors (e.g., González and Lopez, 2007; Deininger and Jin, 2008; Onumah et al., 2010; Rao et al., 2012; Larochelle and Alwang, 2013; Nguyen and Tran, 2014, etc.) applied the method of Battese (1997).

the Box-Cox transform for all variables in the model is

$$\omega^{(\gamma)} = \begin{cases} \omega - 1 & \text{if} \quad \gamma = 1 \\ \ln(\omega) & \text{if} \quad \gamma = 0 \\ \frac{\omega - 1}{\omega} & \text{if} \quad \gamma = -1 \end{cases}$$

where $\omega = y,\ x_i$ and $\gamma = \theta,\ \lambda$. The log-linear model is supported if $\widehat{\theta}$ is close to 0, the linear model is supported if $\widehat{\theta} = 1$ and the multiplicative model is supported if $\widehat{\theta} = -1$.

Basing on the works of Poirier (1978), Amemiya and Powell (1981), Spitzer (1982), Seaks and Layson (1983) and Davidson and MacKinnon (1985), the log-likelihood of this model is

$$\ln L = \left\{ \frac{-n}{2} \right\} \left\{ \ln(2\pi) + \ln(\sigma^2) \right\} + (\theta - 1) \sum_{i=1}^{n} \ln(y_i) - \left\{ \frac{1}{2\sigma^2} \right\} \varepsilon_i^2, \qquad (5.2)$$

where ε_i is implicitly defined as a function of y_i by (5.1), and n is the number of observations.

5.3.2 Data description

The summary statistics of the variables are reported in Table 5.1. A definition of variables is given in the Appendix A6. We observe that the average total income of household is about 128.9 million VND per year, with a standard deviation of 112.9, and the rank of total income between about 8.67 and 1287.1 million VND which indicates a large variability in total income among the tea producers. Meanwhile, average tea income is approximately 65.6 million VND per farming household, with a standard deviation of 66.7, and the rank of tea income between about 2.4 and 403 million VND, which also shows a large variability. Average land surface for tea is about 5866 m^2 per farming household. The mean quantity of labor participating in tea production (planting, harvesting, cultivating, etc.) is about 225 person-days.

The average household size is 4.299, with a standard deviation of 1.188, and the rank of people between about 1 and 10 which indicates a large variability in the number of household members among the tea producers. Children is the number of household's members less than 18 year old. This variable is 1.119 on average, with a standard deviation of 0.988. The average of elderly, who are more than 60 year old, is just 0.299 per household. Meanwhile, there is a large variability in experience between households. The research also includes dummies corresponding to household characteristics like gender (= 1 if household head is male, and = 0

Table 5.1: Summary statistics of the characteristic for the tea producers

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Total income	128.94	112.96	8.76	1287.1	244
Tea income	65.67	66.70	2.4	403	244
Land (m^2)	5866.47	5997.24	130	45000	241
Labor (person-days)	224.63	542.59	5	7863	244
Household size	4.299	1.188	1	10	244
Children	1.119	0.988	0	4	244
Elderly	0.299	0.592	0	2	244
Experience	29.893	13.855	2	64	244
Education	3.266	0.702	1	6	244
Gender	1.430	0.496	1	2	244

if household head is female).

The data set contains information about whether household's members are public officials (or members in associations such as Communist Party, Youth Union Veteran's Union and Farmer's Union). These mass organizations are under strict control of Communist Party; their members, however, are not always involved in the Communist Party.

Table 5.2: Data distribution following political connections

Organizations	Freq.		Percent	
	No: 0	Yes: 1	No: 0	Yes: 1
Member of Communist Party	194	50	79.51	20.49
Member of Youth Union	121	123	49.59	50.41
Member of Farmer's Union	103	141	42.21	57.79
Member of Veteran's Union	79	164	32.51	67.49

Table 5.2 gives the distribution of the data following different types of political connection which is a dummy variable, coded one if the farmer is politically connected. We define dummies corresponding to household characteristics like membership of Communist Party, Youth Union, Farmer's Union and Veteran's Union. The number of households having at least a member participating into the Communist party, Youth Union, Farmer's Union and Veteran's Union are 50, 123, 141, and 164, respectively. These dummy variables help to investigate impact of political connection on farming household income specifically. In addition, we also test how age, education level and experience of the household-heads affect the household total and tea income.

5.4 Estimation results

In this section, we use tea income and total income as the dependent variables and explanatory variables include agricultural land, labor, household size, elderly, children, experience, household head's education and gender.

Applying the Box-Cox model, we test the null hypothesis $H_0 : \theta = \gamma = 0$, $H_0 : \theta = \gamma = 1$ and $H_0 : \theta = \gamma = -1$. The null hypothesis of $\theta = \gamma = -1$ and $\theta = \gamma = 0$ are then strongly rejected leading to rejections of the multiplicative inverse and log-linear models (Table 5.3). As discussed above, Box and Cox (1964) also argued that the transformation could make the residuals more closely normal and less heteroscedastic. Furthermore, this method may help to avoid the dropping of observable independent variables. Therefore, Box Cox model is applied to farmer households' income, in which land is interacted with different political connections. Similarly, we also test the null hypothesis $H_0 : \theta = \gamma = 0$, $H_0 : \theta = \gamma = 1$ and $H_0 : \theta = \gamma = -1$. The result of computed value of the statistic show that the null hypothesis of $\theta = \gamma = -1$ and $\theta = \gamma = 0$ are then strongly rejected leading to rejections of the multiplicative inverse and log-linear model in two tables 5.4 and 5.5.

Our estimation shows that land, labor, member of household, household head's education, household head's experience and gender variables are statistically significant. The results indicate the significant impacts of these variables on household's income. This finding suggests a relation between total income and these factors. The significantly positive sign of the coefficient of land shows a positive effect of this variable on total income of household. The finding is in contradiction to Nguyen et al. (2011). Meanwhile, other variables such as labor, household size, household head's education give positively effects to total household's income, except gender. It implies that income could be improved by increasing labor, expanding land farming, and extending education. Household size also has a positive effect on total income of household. This results is consistent with those of Leuz and Oberholzer-Gee (2006), Chen et al. (2009) and Wu et al. (2012). However, it is inconsistent with Nguyen et al. (2011). In addition, a significantly negative effect of gender on total income implies an important role of gender of household's head on total income of household. Intuitively, as producing tea is a physically demanding activity, a male household's head is more likely to endure it better than a female household's head.

Table 5.3: Determinants of variables of income of tea producer

Variable	Total income (Model-A)		Tea income (Model-B)	
	Coef.	Chi2(df)	Coef.	Chi2(df)
Intercept	0.754	0.000	-3.131	0.000
Land	0.236**	19.211	0.686**	50.852
Labor	0.133**	6.612	0.543**	42.942
Household size	0.105*	3.673	-0.010	0.029
Children	-0.013	0.044	0.033	0.234
Elderly	0.105	1.029	-0.154	1.886
Experience	0.008	2.713	0.012*	5.718
Education	0.270**	11.010	0.170*	3.788
Gender	-0.270*	5.128	-0.265*	4.200
H0: θ=λ=-1	-261.03**	91.21	-403.78**	256.63
H0: θ=λ=0	-228.12**	25.39	-306.01**	61.09
H0: θ=λ=1	-215.80	0.75	-275.90	0.88

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

Similarly, the results in Table 5.3 show the important role of households' head; in fact, they can make a significantly positive impact on income. In addition, land, labor, household head's education, household head's experience variables give statistically significant positive effects on tea income. The coefficients of education are significantly positive in both models showing increasingly effect of extending education on income. This result is also consistent with the findings of Li et al. (2008). Furthermore, experience of households' head also give a positive influence on income, that is statistically significant. This is consistent with Cingano and Pinotti (2013). However, interestingly, households' female-head might have lower income contribution in terms of income compared to male ones.

Now we turn to estimate the effect of having relative's political connection on total household income. Table 5.4 shows that the interaction effects between land, labor and household income become consistent. Moreover, the role of land and labor become more important when they are interacted with other political connection variables. The other factors associated with political connection also give stronger effects on household income.

Almost all coefficients of these factors are statistically significant and positive. Furthermore, heterogeneity could be appeared between political connection variables. The empirical results indicate that the relationship between political connection and household income is significantly positive. However, only two proxies of political connection, member of the Farmer's Union and Youth Union, are statistically significant.

Table 5.4: Relationship between political ties and total income of household

Variable	Model A1	Model A2	Model A3	Model A4
Intercept	0.436	-0.547	0.832	0.507
	(0.000)	(0.000)	(0.000)	(0.000)
Land	0.231**	0.525**	0.246**	0.238**
	(13.977)	(22.322)	(17.594)	(21.851)
Labor	0.099**	0.184*	0.134*	0.093*
	(6.639)	(6.822)	(6.272)	(5.225)
Household size	0.105*	0.099*	0.108*	0.080
	(3.141)	(3.524)	(3.854)	(2.480)
Children	-0.024	-0.020	-0.018	0.008
	(0.118)	(0.115)	(0.080)	(0.022)
Elderly	0.142	0.086	0.107	0.108
	(1.597)	(0.735)	(1.808)	(1.274)
Experience	0.009*	0.008*	0.007	0.007*
	(2.975)	(2.971)	(2.620)	(2.888)
Education	0.281**	0.266**	0.273**	0.236**
	(10.054)	(11.388)	(11.224)	(9.916)
Gender	-0.227*	-0.265*	-0.270*	-0.237*
	(2.747)	(5.341)	(5.129)	(4.660)
Veteran's Union	1.297			
	(1.464)			
Veteran's Union × Land	-0.180			
	(2.004)			
Farmer's Union		1.969*		
		(4.989)		
Farmer's Union × Land		-0.231*		
		(4.803)		
Communist Party			0.002	
			(0.000)	
Communist Party × Land			-0.008	
			(0.003)	
Youth Union				1.522*
				(3.560)
Youth Union × Land				-0.162*
				(2.801)
H0: $\theta=\lambda=-1$	-259.09**	-257.98**	-260.74**	-256.32**
	(92.74)	(90.13)	(90.87)	(87.74)
H0: $\theta=\lambda=0$	-226.21**	-225.13**	-227.92**	-224.15**
	(26.98)	(24.43)	(25.23)	(23.42)
H0: $\theta=\lambda=1$	-213.29	-213.25	-215.68	-212.68
	(1.14)	(0.66)	(0.73)	(0.46)

Notes: * and ** mean for significance at the 10% and at the 5% level, respectively.
chi2(df) statistics in parentheses, n = 240

As shown in Model A2 of Table 5.4 points out that an increase of 1% in land and labor leads to an increase at 0.525% and 0.184% in farming household total income, respectively. Moreover, the results show that the relation between membership of Farmer's Union and total income of household is positive (1.969); this implies membership of Farmer's Union may help to increase households' income. This finding is consistent with the results of other studies (Markussen and Tarp, 2014) but seems to contradict with Cingano and Pinotti (2013), who confirmed that access to political connections increases firm revenues by almost 6%, yielding an equivalent change in profits. Meanwhile, the coefficient of the interaction between land and Farmer's Union has a significantly negative effect (-0.231), representing a substitution between these two factors, which means being in Farmer's Union decreases the positive effect of land or alternatively having more land reduces the positive impact of being in Farmer's Union.

Model A4 in Table 5.4 points out that an increase of 1% in land and labor could lead to an increase at 0.238% and 0.093% in farming household total income, respectively. Simultaneously, the relation between membership Youth Union and total income is positive (1.522) implying that households' income could be improved by participating to Youth Union. Moreover, the correlation between land and Youth Union has a significantly negative effect (-0.162), representing a substitution between two factors.

Besides, we also examine the impact of political connection on tea income. The results in Table 5.5 illustrate the positive impact of political connection on household income tea. The coefficient effects are positive and significant at the 5% and 10% level. Meanwhile, only two political connection variables, Veteran's Union and Communist Party, are significant statistically.

More specifically, as shown in Model B1, an increase of 1% in land and labor could lead to an increase around 0.819% and 0.502% in farming household tea income, respectively. Surprisingly, the interaction between land and Veteran's Union has a significantly negative effect (-0.243), representing a substitution between these two factors. The negative coefficients on these interaction terms mean that Veteran's Union membership becomes less valuable the volume of land increases.

In addition, the results in Model B3 of Table 5.5 show that an increase of 1% in land and labor may lead to an increase 0.848% and 0.601% in tea income, respectively. The interaction between land and Communist Party also has a significantly negative effect (-0.278), implying a substitution effect between land and membership of the Communist Party. This finding is consistent with the results of Li et al. (2008), which showed that the negative coefficients of these interaction terms implies a power impact of becoming a Party's member in the context of

Table 5.5: Relationship between political ties and tea income of household

Variable	Model B1	Model B2	Model B3	Model B4
Intercept	-4.229	-3.779	-3.827	-2.707
	(0.000)	(0.000)	(0.000)	(0.000)
Land	0.819**	0.843**	0.848**	0.592**
	(32.494)	(31.687)	(53.836)	(27.833)
Labor	0.502**	0.610**	0.601**	0.513**
	(43.246)	(44.301)	(41.764)	(41.636)
Household size	-0.016	-0.007	0.003	-0.018
	(0.074)	(0.017)	(0.003)	(0.097)
Children	0.027	0.028	0.018	0.037
	(0.143)	(0.167)	(0.066)	(0.286)
Elderly	-0.129	-0.149	-0.147	-0.134
	(1.233)	(1.684)	(1.579)	(1.403)
Experience	0.013*	0.014**	0.130*	0.012*
	(5.678)	(7.148)	(5.838)	(5.669)
Education	0.168**	0.190*	0.196*	0.169*
	(3.426)	(4.533)	(4.617)	(3.743)
Gender	-0.231	-0.282*	-0.303*	-0.253*
	(2.655)	(4.612)	(5.055)	(3.837)
Veteran's Union	1.798			
	(2.711)			
Veteran's Union × Land	-0.234*			
	(3.243)			
Farmer's Union		0.843		
		(0.686)		
Farmer's Union × Land		-0.123		
		(1.031)		
Communist Party			2.024	
			(2.276)	
Communist Party × Land			-0.278*	
			(2.940)	
Youth Union				-0.732
				(0.601)
Youth Union × Land				0.098
				(0.752)
H0: $\theta=\lambda=-1$	-401.82**	-402.95**	-403.56**	-402.66**
	(258.70)	(258.02)	(262.02)	(255.59)
H0: $\theta=\lambda=0$	-303.85**	-305.08**	-304.83**	-305.24**
	(62.74)	(62.27)	(64.56)	(60.76)
H0: $\theta=\lambda=1$	-273.01	-274.53	-273.29	-275.26
	(1.07)	(1.19)	(1.49)	(0.80)

Notes: * and ** mean for significance at the 10% and at the 5% level, respectively.
chi2(df) statistics in parentheses, n = 240

the stronger legal framework. The result is also consistent with the results of Boubakri et al. (2012) who found the negative effect of political ties on cost of firms' equity capital.

5.5 Conclusions

The relation between households' income, land and labor has raised many puzzling issues that are interesting for a policy makers as well as for researchers. In this study, we also focus on whether there is an impact of political connections on farming households' income, especially in tea production in Vietnam.

We compare three different model specifications following the Box-Cox method. The result shows that the multiplicative inverse and log-linear models are strongly rejected in favor the linear model. Therefore we run a linear regression model on two different dependent variables, namely the total income and the tea income.

First, both estimations show that land, labor, household's size, household head's education, household head's experience and gender variables are statistically significant. As expected, the coefficient of land is significantly positive. This suggest that an increase in the production surface rises both farmer's total income and tea income.

Second, for the total income estimation, our findings indicate that being a members of Farmer's Union or Youth Union has a positive effect on total income of household. This positive effect can be due to the fact that being part of a Union helps farmers to get better and privileged information. This information would contribute to improve their income (better job, higher access to tea market, etc.). They can also learn from each other and increase their productivity. However, the interaction effects of Farmer's/Youth Unions and land on total income are negative. This means that if a farmer has a political connection, the positive effect of augmenting the surface of land on total income is reduced. Alternatively, having more land reduces the positive impact of being in Farmer's Union.

Third, for tea income estimation, we find that being part of a Union has no significant impact on household's revenue. Nevertheless, we find that the interaction coefficient are still significantly negative for Veteran/Communist Party.

As the direct impact of land and political connection are positive and the interaction coefficients are negative, we will further calculate the marginal effects to improve our analysis.

General Conclusion

Main results and suggestions for policy makers

The aim of this thesis is to identify and investigate some limits regarding recent empirical and theoretical contributions in the field of farmers' behavior as related to tea production in Vietnam. Chapter 1 provides the reader a quick overview about tea production in the world and Vietnam in recent years, presenting brief analysis of the situation of the world's tea production and the characteristics of the tea industry in Vietnam. In fact, tea production shows modest growth before the 1990s and a more rapid thereafter. The world tea area accounts for 3.5 million hectares in 2012 while this number in Vietnam only accounts for 130 thousand hectares. The world's tea production has reached about 5 millions of tons, compared to 230 thousands of tons for Vietnam. The average exporting prices of Vietnamese tea were lower than the average world's prices. This is probably due to the use of inconsistent fertilizers and pesticides, low processing technologies, old varieties, which normally causes a decrease in quality for tea.

This research also contributes to the agricultural economic literature, by employing research methods such as stochastic frontier analyses of production efficiency in Chapter 2, using a survey database collected in Vietnam. The result in this chapter shows that the average technical efficiency of the tea production is very low, only 41% of the maximum reachable output. This result shows that there exists a huge potential for improving technical efficiency. Hence, the main concern remains to identify the factors which could help reducing production inefficiency. Moreover, we observe that among different factors included in our model, agricultural policy and tea varieties can influence technical efficiency. Concerning agricultural policy, we focus on training, as related to the way of using pesticides and fertilizers. Training on these inputs can be provided in its existing form to tea producers as it can help reducing technical inefficiency. Other kinds of training and information under their current state have no significant role. Hence, they should be modified in order to get expected effects on production efficiency. Regarding tea varieties, our findings about the heterogeneity of their effects on technical efficiency suggests that tea producers should be careful in adopting new varieties. In particular, the oldest variety, 'Trung-Du', still remains efficient. Among new tea varieties, farmers should not choose 'PH1' and 'LDP1', but they can adopt 'Bat-Tien' or other new types because of their higher efficiency.

This research is also expected to provide useful information concerning the conditions under which a farmer change from a conventional to an organic production. Chapter 3 presents a theoretical model in order to understand the farmers' decisions regarding the adoption of organic production in agriculture. The results suggest significant policy implications, which should give insight to policy makers and encourage them to regulate the agricultural production processes efficiently. In this chapter, we consider three scenarios with three different assumptions: i) in the first scenario, we impose no constraint on the labor and the total quantity of land. ii) in the second, a government could encourage the farmers to produce organic products by giving a subsidy. iii) in the last scenario, a government could stimulate farmers to produce organic product by giving a bonus in exchange of imposing a minimum of organic production. Our results in the first and second scenario shows that farmer's productivity fully determines the choice of tea production. If productivity is low, farmers will choose conventional tea only whereas if productivity is high they will choose organic tea only. In between, farmers will produce both products. Our results in second scenario suggest that it may not be efficient for a government to give subsidies to farmers as they will not concentrate it for shifting to organic production. Moreover, if a government gives a bonus to farmers, our results in this scenario indicate that the productivity is not significant for the farmer's decision. This result implies that farmers will not be concerned about the productivity and productivity will not make the farmer to shift towards the new technology. They will only choose to produce the minimum organic product in order to receive the bonus. In the long run, we may even have an adverse effect, because the farmers will be dependent on the government bonus. As our results indicate that it may not be efficient to either give subsidies nor bonuses, we suggest that a good policy would be to improve farmer's productivity so that they would shift to organic production themselves. It is important to note that the results of this chapter are not completely confined in the agricultural literature. It is possible to open up applications in other fields related to technology transfer.

This research provides baseline information for the Vietnamese government to help formulating policies for achieving agricultural production targets involving high quality standards, and competitive agricultural products for the global market. In addition, our study provides insights about the determinants of tea varieties decisions in Vietnam, focusing on the role of farmers characteristics and other external factors. Farmers' choice is measured as the extent of adoption of type of tea varieties, which provides a six-point ordinal change (old/black ($j = 1$), new/black ($j = 2$), new/old/black ($j = 3$), old/green ($j = 4$), new/green ($j = 5$) and new/old/green ($j = 6$)). Our result shows that the important factors that influence the adoption decision include income, elderly, household size and organic fertilizer, as well as being involved in associations, such as Tea Association, Farmer's Union, Youth Union or being in a contractual relation (see Chapter 4).

Finally, in Chapter 5, the result shows that the multiplicative inverse and log-linear models are then strongly rejected so that we must prefer the linear model. Therefore we run a linear regression model on two different dependent variables, namely the total income and the tea income. For the total income estimation, our findings indicate that being a members of Farmer's Union or Youth Union has a positive effect on total income of household. This positive effect can be due to the fact that being part of a Union helps farmers to get better and privileged information. These information would contribute to improve their income (better job, higher access to tea market, etc.). They can also learn from each other and increase their productivity. However, the interaction effects of Farmer's/Youth Unions and land on total income are negative. This means that if a farmer has a political connection the positive effect of augmenting the surface of land on total income is reduced. Alternatively, having more land reduces the positive impact of being in Farmer's Union. For tea income estimation, we find that being part of a Union has no significant impact on household's revenue. Nevertheless, we find that the interaction coefficient are still significantly negative for Veteran/Communist Party. Overall, we show that being part of some Unions can affect positively farmers' income but we might compute the marginal effects to quantity the benefits.

Limitations and extensions

This work contributes to the literature in several aspects as discussed in the previous chapters. However, it also encountered a number of limitations, which need to be considered as below:

First, our analysis in Chapter 1 is concise. In fact, we expected to use a VAR model in order to highlight some macroeconomic factors affecting the tea sector in Vietnam. Second, the number of observations in the data is small, due to time and manpower limitations. Hence, in Chapter 2, we only analyze and measure the technical efficiency under cross section data. We will update to build up the panel data to have a more adequate analysis. In addition, we also expected to use a semi-parameter for estimating the technical efficiency. Third, in Chapter 3, we found some interesting theoretical results however we lacked sufficient data for testing those results. We expect that it would make in the result more persuadable. Next, for in Chapter 4, we will also extend the analysis by applying the semi parameter method and panel data to have a more general view. Finally, concerning Chapter 5, we will also update and extend our data in order to build a more objective conclusion. As the direct impact of land and political connection are positive and the interaction coefficient is negative, we will further calculate the marginal effects.

Table A6: Definition of variables

Variable name	Definition	Nature
Land	land surface used in tea production (in m^2)	continuous
Labor	total labor employed (person-days)	continuous
Production	total tea production (tons)	continuous
Total income	total income of household (millions VND)	continuous
Tea income	income of tea of household (millions VND)	continuous
Experience	the number year of the heads of household	continuous
Household size	number of member of household	continuous
Education	educational level of the heads of household	continuous
Tea varieties		
‘Trung-Du’	the name of tea variety, $\geqslant$ 5 year old	dummy
‘PH1’	the name of tea variety, $\geqslant$ 5 year old	dummy
‘LDP1’	the name of tea variety, $\geqslant$ 5 year old	dummy
‘Bat-Tien’	the name of tea variety, $\geqslant$ 5 year old	dummy
‘Other’	the name of other tea varieties, $\geqslant$ 5 year old	dummy
Agricultural policy		
Cultivation	training on cultivation techniques	dummy
Inputs	training on fertilizers & pesticides	dummy
Harvest. & conserv.	training on harvesting & conservation	dummy
Information	information on tea market	dummy
Sale	training on sale skills	dummy
Organic fertilizers	use of organic fertilizers	dummy
Chemical fertilizers	use of chemical fertilizers	dummy
Contract	household has a contract with company	dummy
Black tea	black tea production	dummy
High income	subjective perception of high income	dummy
High education	high educ. level of the hh’s head (high school or above)	dummy
Gender	gender of the heads of household (male = 1, female = 0)	dummy
Minority	being part of a minority ethnic group	dummy
Children	members of household less than 18 years old	dummy
Elderly	members of household more than 60 years old	dummy
Tea Association	one of the household members belongs to this association	dummy
Farmer’s Union	one of the household members belongs to this association	dummy
Youth Union	one of the household members belongs to this association	dummy
Communist Party	one of the household members belongs to this association	dummy
Veteran’s Union	one of the household members belongs to this association	dummy

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ANALYSE ÉCONOMIQUE DES DÉCISIONS DES AGRICULTEURS: APPLICATIONS À LA PRODUCTION DE THÉ AU VIETNAM

Résumé

Dans cette thèse, nous nous intéressons aux décisions de production des agriculteurs et plus particulièrement des producteurs de thé au Vietnam. Plus précisément, le Chapitre 1 donne un aperçu rapide de l'évolution observée dans le monde et au Vietnam. Le Chapitre 2 porte sur l'analyse de l'efficacité technique de la production de thé au Vietnam. Il permet de conclure que l'efficacité technique moyenne de la production de thé est très faible (seulement 41%). Le Chapitre 3 de cette thèse présente un modèle théorique analysant les décisions d'agriculteurs dans le cadre d'une conversion à la production biologique. Il s'agit de déterminer les conditions optimales pour la conversion compte tenu des contraintes concernant l'allocation des terres pour les produits conventionnels et biologiques. Il montre notamment l'importance de (i) la quantité disponible de terres consacrées aux produits biologiques, (ii) la productivité de la technologie de production de produits biologiques, (iii) les mécanismes d'incitation et enfin (iv) les contraintes inhérentes à la production de produits biologiques. Le Chapitre 4 compare deux modèles économétriques, l'un avec une hétérogénéité individuelle non observable et l'autre sans hétérogénéité. Les résultats obtenus révèlent certains facteurs importants qui influent sur l'adoption des différentes variétés de thé: le revenu, la présence de personnages âgées au sein du ménage, la taille du ménage et l'usage d'engrais biologique. Le Chapitre 5, enfin, s'intéresse aux impacts des relations politiques sur le revenu total et le revenu issu de la production de thé des ménages. Nos résultats soulignent le rôle important des relations politiques sur l'amélioration des revenus des agriculteurs.

ECONOMIC ANALYSIS OF FARMERS' DECISIONS: APPLICATIONS TO THE VIETNAM'S TEA PRODUCTION

Abstract

The aim of this thesis is to identify and investigate some limits regarding recent empirical and theoretical contributions in the field of farmers' behavior as related to tea production in Vietnam. Chapter 1 provides a quick overview about tea production in the world and in Vietnam. Chapter 2 in our thesis analyzes the technical efficiency of the tea production in Vietnam. This study finds that the average technical efficiency of tea production is very low (only about 41%). Chapter 3 presents a theoretical model in order to figure out the farmer's decision to adopt for organic production. The decision concerns the allocation of lands for conventional and organic products. It shows the importance of (i) the available quantity of land devoted to agricultural plants, (ii) the productivity of the organic products, (iii) the incentive mechanism, and finally (iv) the constraints on output of organic products. In Chapter 4, we compared two version of econometric model: a model with household's unobserved heterogeneity and a model without unobserved heterogeneity. We found that the former model is preferred. The results revealed that some important factors which influence the adoption of tea varieties included tea income, presence of elderly, household size and use of organic fertilizers. In Chapter 5, we focus on investigating the impacts of political connections both farmer's total income and tea income. The findings indicate the significant role of political connection on improving farming households' income.