5132

AN ANALYSIS OF ECONOMIC AND ENVIRONMENTAL IMPACTS FOR THE TRANSITION TO ORGANIC TEA PRODUCTION IN THE THAI NGUYEN PROVINCE OF VIETNAM

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DISSERTATION COMMITTEE

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TABLE OF CONTENTS

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ABSTRACT

The Thai Nguyen province is well-known for its high quality tea in Vietnam. In order to improve the quality of tea products that satisfy health requirement standards, a recent movement from conventional tea production to organic tea production has occurred. To analyze gains and losses from this conversion, impacts to the environment should be evaluated and analyzed to determine both short term and long term effects on tea growers in particular and on society as a whole.

Surveys are used to collect panel data from 4 representative tea producing villages involving 180 tea producing households in the Thai Nguyen province in 2007. Soil, water and tea samples were collected on a monthly basis during the research period in order to analyze pesticide residues and agro-chemicals in the soil, water and tea products. The Stochastic Production Frontier (SPF) model was used to analyze production and profit efficiency. A probit model was employed to determine factors affecting the adoption of organic tea and Monte Carlo simulation was used to analyze risk and uncertainty involved in the conversion to organic tea production in the Thai Nguyen province. A Cost Benefit Analysis (CBA) was carried out to determine and compare net present value (NPV) of both private and social benefits for different tea production methods. The results show that organic tea production has high production efficiency (0.998), profit efficiency (0.836), and NPV of social benefit. Organic tea production also contributes substantially to the reduction of chemical residues in the soil, water and tea products (residues of chemicals and pesticides were not found in water and tea samples taken at the end of the tea production season for the first year converted organic tea farm).

However, organic tea production has a lower NPV of private benefits during the transition period (five years). External support, such as government subsidies has a significant contribution to farmers' decision of whether or not to switch to organic tea production. The adoption rate for organic tea production would equal to zero if the premium price and outside support were removed.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CBA	Cost-Benefit Analysis
CIA	Central Intelligent Agency
DEA	Data Envelop Analysis
EEPSEA	Economic and Environmental Program for South East Asia
EPA	U.S. Environmental Protection Agency
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GSO	General Statistics Office
IFOAM	International Foundation of Organic Agriculture Movement
IGCI	International Global Changing Institute
MARD	Ministry of Agriculture and Rural Development
NPV	Net Present Value
OTP	Organic Tea Production
SFA	Stochastic Frontier Analysis
TUAF	Thai Nguyen University of Agriculture and Forestry
TUEBA	Thai Nguyen University of Economics and Business Administration
VIF	Variance Inflation Factor
VTA	Vietnam Tea Association
WTA	Willingness to Accept
WTO	World Trade Organization
WTP	Willingness to Pay

CHAPTER I

INTRODUCTION

1.1 Background information

Tea has been a popular beverage for a long period of time. Tea was first used in China as a medical drink and gained popularity worldwide.

Table 1. Tea Production and Consumption in the World over the Last 5 Years

Variable	2002	2003	2004	2005	2006
Area harvested (ha)	2,467,757	2,505,525	2,521,795	2,652,809	2,717,398
Yield (Mt/ha)*	12.66	12.67	13.07	13.35	13.43
Production (Mt)**	3,123,179	3,176,770	3,295,281	3,542,877	3,649,491
Export					
- Quantity (Mt)	1,446,657	1,375,260	1,383,544	1,487,530	-
- In value ($1000)	2,832,845	2,514,029	2,578,155	2,762,357	-
Import					
- Quantity (Mt)	1,385,246	1,444,102	1,319,574	1,391,190	-
- In value ($1000)	2,823,712	2,815,203	2,657,914	1,896,136	-
Average export price ($/kg)	1.96	1.83	1.86	1.95	-

Source: FAO database 2008.
* Yield is measured in tons of fresh tea per ha
** Production is measured in metric tons of dried tea (final product)

The global average annual per capita consumption of tea was about 0.75 kg; however, this varies widely from country to country. For example, in Britain the average annual per capita tea consumption was 4.4 kg while in India and in the U.S, per capita consumption was 0.3 kg and 2.7 kg respectively (Vietnam National Tea Corporation [Vinatea], 2005). As the demand for tea in the world market has increased significantly over the past decade, tea production has also expanded. The data in table 1 illustrate that tea farm sizes in the world continue to expand with tea yields growing slowly overtime. The tea market has also become more competitive with increasing international tea trade. In order to expand the export of tea and find product niches, it as important that tea product quality also improves, e.g. organic tea would be a possible solution (VTA, 2005).

Vietnam is an agrarian country where agricultural production still accounts for 20.1% of its GDP and 56.8% of the labor force (CIA, 2007). In Vietnam, tea has a long and glorious history, rich in traditional and cultural significance. Also, tea is one of the primary industrial export crops. According to Phuong & Trung (2004), Vietnam has more than 130,000 hectares of fertile plantation land favorable for tea production. The Vietnamese people living in both rural and urban areas have an established custom of drinking tea. Northern Vietnam is considered the origin of tea production. Many places still grow tea "wild" in forests where local people can harvest this tea as a non-timber product of the forests (e.g., Sham tea in the Ha Giang province). Currently, the principal tea production areas remain in the northern region.

After occupying Indochina in 1882, the French began growing teas. Although French companies tried to expand tea production throughout Vietnam, the northern part of the country remained the largest tea producing area. Currently, tea is grown in more than 39 provinces while being highly concentrated in 14 northern mountainous and midland provinces[1] which account for 61% of the total production areas of the country (see Figure 1). Tea production in Vietnam has been increasing in both acreage and yield. It is expected that by the year 2010 the total tea farm size will be 120,000 ha (Michael & Koen 2001). However, it already reached the target of 122,700 ha in 2006. Tea in Vietnam is already exported to more than 59 countries (Vinatea, 2005).

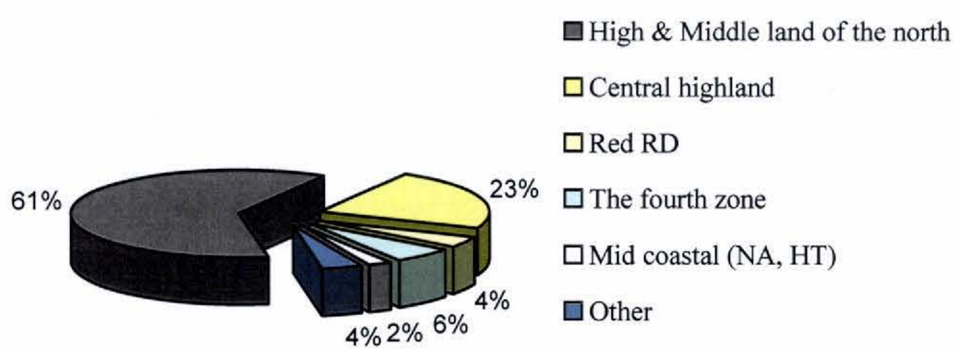


Figure 1 Tea Production in Vietnam

Source: Phuong and Trung, 2004.

In August 2005, the Vietnam Tea Association (VTA) proposed a new set of measures to improve the quality of exported tea. An important requirement is for tea producing businesses to apply for business licenses in tea production which certifies that their product meet required standards set by the Ministry of Agriculture and Rural Development (MARD). As Mr. Tao, the chief of VTA stated "facing problems of high production cost and low productivity, Vietnam's tea production should shift to organic production by creating organic substance, irrigation, intensive cultivation, ecology and

[1] The mountainous, midland and lowland provinces are classified administratively based on its elevation.

sustainable development for tea" (VN Economy, 2003). Presently, Vietnam is ranked as one of the top 10 countries in tea production and exports (the 9th in production, and the 7th in exports). "Experts warn the most difficulty Vietnamese tea faces is that it does not have a well-known trade mark, and its price and quality are not competitive" (Phuong & Trung, 2004). As stated in Vietnam's National Policy Framework and its 10-year Strategic Plan, organic farming especially organic tea production was encouraged by MARD. Becoming a member of the World Tea Association (WTA) in July 2004, Vietnam is committed to comply with a strict pesticide control standard (IS03720) that allows very limited use of pesticides in tea production.

1.2 Problem Statement

Like other agrarian countries, the organic market in Vietnam is very small and characterized by niche markets. According to the Codex Alimentarius Commission[2] (2004) "organic farming involves holistic production management systems (crops and livestock) emphasizing the use of management practices in preference to the use of off-farm inputs. This is accomplished by using, where possible, cultural, biological and mechanical methods in preference to synthetic materials". More specifically, organic tea production is a production system with only limited use of pesticides and other synthetic agricultural inputs.

For a poor country like Vietnam, one of the potential ways for tea farmers to increase earnings is to improve their marketing while keeping costs low. Although Vietnam is ranked as the 7th largest tea exporter in the world market, most of Vietnam's tea products are in traditional markets such as China, Taiwan, Russia, etc. The potential

[2] Codex Alimentarius Commission was created in 1963 by FAO and WHO to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Program.

of exporting tea from Vietnam is growing due to recent publicity about the usefulness of green tea in preventing ulcers and stomach cancer. Presently, Vietnamese tea accounts for only 3 - 4 % of international tea exports (Phuong & Trung, 2004). As Vietnam became the 150th member of the World Trade Organization (WTO), the WTO rules, notably the Technical Barriers to Trade Agreement (TBT) and the international standards for organic farming clearly defined a stringent path toward compliance (Lu, 2004). It is essential that the tea produced in Vietnam be competitive in the world market. This can be accomplished by satisfying required health quality standards. At the moment, there are no Vietnamese tea products certified as organic products. However, hundreds of hectares of tea are being converted to organic production as a way of satisfying tougher tea quality standards in the world market.

Table 2. Tea Production in Vietnam over the Last 5 Years

	2002	2003	2004	2005	2006 [c]
Area harvested (ha)	98,000	99,000	102,000	122,500	122,700
Yield (Mt/ha)[a]	9.61	10.08	10.63	10.84	11.59
Production (Mt)[b]	94,200	99,750	108,422	132,525	142,300
Export					
- Quantity (Mt)	67,900	77,000	59,800	51,000	80,000
- In value ($1000)	78,406	82,000	70,000	52,00	80,000
Export price ($/kg)	1.15	1.06	1.17	1.02	1.00

Source: Vietnam GSO Yearbook 2007.
[a] Yield is measured in tons of fresh tea per ha.
[b] Production is measured in Metric tons of dried tea (final product).
[c] Statistics for 2006 were reportedly estimated only.

The information shown in Tables 1 and 2 indicate that prices of Vietnam's tea products are approximately half the average price in the world market. Two important factors contributing to the low price for Vietnamese tea are low product quality and lack of its own brand name. "Vietnamese tea's export price is approximately U.S. $0.96 or about 50% less than the average export price of tea products of other nations" (Tea & Coffee Asia, 2005). Que and Que (2000) estimated that if per capita income increased by 1% then tea consumption would increase by 0.15 to 0.20%. With national income increasing over the past two decades, the domestic tea market has been expanding.

The growth in tea production and demand requires that industry adjust its production and marketing channels toward greater efficiency and higher product quality. Currently, Shan Tuyet tea in Ha Giang, Yen Bai, Son La and Lai Chau of Vietnam is well-known and registered for origin protection in the world. It is fragrant and has a delicious taste. Shan Tuyet tea also provides high yields without using any chemical fertilizers and insecticides (Kiet, 2002).

Table 3. Tea Production in the Thai Nguyen Province

Variable	2002	2003	2004	2005	2006
Planted Area (ha)	14,538	15,285	15,841	16,446	16,985
Harvested area (ha)	12,009	12,713	13,439	14,133	16,548
Yield (Mt/ha)	6.00	5.37	6.20	6.64	8.86
Production (Mt)	72,100	68,300	83,391	93,746	146,622

Source: Thai Nguyen Provincial Department of Agriculture and Rural Development (2007)

Among principal tea growing provinces in Northern Vietnam, the Thai Nguyen province is very well-known for its high quality tea although it is not the largest tea production area.

According to Que and Que (2000), Thai Nguyen is not the largest province in terms of tea-growing area and production volume but it is well known in terms of producing tea products of the highest quality. In the domestic market, Thai Nguyen tea products usually receive the highest prices. Table 3 shows significant increases in tea production, harvested area and yield for Thai Nguyen in 2006. This province is also one of the provinces which participate in the International Global Changing Institute (IGCI) project (funded by the New Zealand government) as a mean for moving toward organic tea production.

Although there are no Vietnamese tea products certified as organic by any internationally qualified institution, there has been a movement toward converting conventional tea production to organic tea production. In the transition period, the products are called "safe tea[3]". The rules for most certifying organizations require a conversion period of at least one year. According to the Vietnamese Tea Association (VTA) (2004), the conversion period for organic tea production in Vietnam is at least 2 years. During the conversion period, tea growers face some difficulties concerning: (i) not allowed to use pesticides or chemical inputs and (ii) not certified as organic. The latter difficulty is a major concern since their tea products can not command the higher premium prices. This transition period is especially difficult for small tea growers in Vietnam whose family income depends solely on tea production. In the conversion

[3] A tea product that is free of pesticide and chemical residues but this product is not certified as an organic product.

period, tea growers may also face the problem of higher production costs due to using labor intensive pest and weed control practices. After many years of using pesticides and chemical fertilizers, tea farms may be out of ecological balance which may also cause problems such as reductions in crop yields.

Another disadvantage is the market for organic tea is still relatively small and mainly concentrated outside of Vietnam. The domestic market for organic tea is undeveloped, most tea processors and tea trading companies producing "safe tea" on requests by foreign importers. However, there are also advantages for converting to organic production such as a rapidly growing market for organic tea fueled by recent publicity concerning health benefits from drinking green tea and premium prices.

The models for sustainable agriculture most preferred or practiced by local proponents of sustainable agriculture are "organic farming". According to Quah (1999), organic agriculture is a holistic production management system which promotes and enhances biodiversity, the biological cycle and soil biological activity. It is based on the low use of internal inputs and non-use of artificial fertilizers and pesticides. Therefore, organic tea in general and organic tea in Vietnam in particular will be very environmentally beneficial. According to Ngo et al. (2001) "the inadequate use of pesticides, particularly those of high toxicity has caused a great number of harmful impacts on human health and the environment".

Table 4. Actual Use of Pesticide in Tea Production in Vietnam

Items	Unit	Surveyed in tea production
Surveyed households	Count	540
Households using pesticides	% of total	100
Pesticide users		
Male	% of total	62.0
Female	% of total	38.0
Knowledge of using pesticides	% of total	49.7
Using special instrument to measure applied dozes	% of total	0.0
Protective means when applying pesticides for tea		
Sufficient	% of total	7.0
Partial	% of total	64.9
Absence	% of total	28.1
Place for cleaning spraying equipments		
Special area reserved	% of total	0.0
Lake, pond or rivers	% of total	51.4
Well or other water sources	% of total	49.6
Collecting wastes after spraying	% of total	48.0

Source: Ngo, et al. 2001.

The survey results in Table 4 show that pesticide use in tea production is very high and tea growers have little knowledge and understanding about safety and effective use of pesticides. The excessive use of pesticides and agro-chemicals in tea production does not only produce negative impacts to the environment and to human health (indirectly by retaining residues in tea products, in the water and in the soils), but also produces high risk to the environment and the health of the tea growers when poor protective equipment is used for pesticides applications, pesticide wastes are left on the field, and spraying equipment is cleaned in portable water sources. Complying with strict rules and requirements for qualified organic tea production, all artificial and synthetic agro-chemicals will not be allowed for use in tea production. Therefore, pesticide residues and wastes will no longer be a problem. However, these positive impacts to the environment should be evaluated and analyzed in terms of both short run and long run effects from converting to organic tea production. These impacts should be evaluated in terms of tea growers in particular and society in general.

Presently, there has been no research done which analyzes and provides information about economic and environmental impacts of this conversion in tea production for Vietnam. Several questions require answers including: i) what factors affect tea farmers' decision to convert their production from conventional to organic tea? ii) If a tea grower switches to organic farming, what challenges and risks would he/she face? iii) What are the costs and benefits of converting from conventional production to organic tea production for tea growers and for society as a whole in the Thai Nguyen province? and iv) What is the government's role in assisting farmer adoption of organic farming?

1.3 Research Objectives

In searching for answers to these questions, this research has the following objectives:

1. To examine the efficiency of organic/clean[4] tea production as compared to conventional tea farming practices in the Thai Nguyen province in Vietnam.
2. To determine effects of risks in the decision making process of switching to organic farming for the Thai Nguyen province of Vietnam.
3. To assess the environmental impacts of these two tea farming methods (organic and conventional).
4. To determine the government's role in assisting farmers switching to organic tea production.
5. To develop policy recommendations for ensuring food security and income stability for tea growers in the transition from conventional to organic farming.

1.4 Research contribution

Organic farming in general and organic tea production in particular is a sophisticated alternative agricultural system. Ample data exist to conclude that it can compete economically with conventional farming (Charles, 1998). Organic tea benefits society substantially by reducing pollution and improving tea quality to meet high quality standards required in the world markets. However, virtually no credible data are available to policy makers reflecting the magnitude of these benefits. They are unable to compare organic tea production with other policy alternatives. Although organic farming has a long history and is widely known, it is new to farmers in Vietnam. One of the difficulties

[4] Clean tea production is a tea farming practice that minimize uses of pesticides and other chemical inputs and adopts Integrated Pest Management (IPM) for pest and disease control in tea production. The products from clean tea production method may be free of pesticide and chemical residues but not classified as organic

in the conversion from conventional cultivation practices to organic farming is the required transition period of 1-3 years (e.g., at least 2 years for tea production in Vietnam [VTA, 2004]). This is a difficult time for farmers since their products are not certified as "organic" and crop yields and product quality are usually lower than before due to nutrition deficiencies, pests, and diseases. Although the literature on production efficiency is abundant, no studies have been completed on Vietnam or for organic tea production. This research will provide baseline information for the government of Vietnam to help formulate policies for achieving agricultural production target involving high quality standards, competitive agricultural products in the global market, and a cleaner and safer environment.

This research will also contribute to agricultural economics literature by employing research methods which combine stochastic and non stochastic frontier analyses of production efficiency and integrate frontier analysis with selection problem analyses in risk assessment models. The fourth component of the analytical framework, cost-benefit analysis, will determine the present values of net benefits (NPV) for different tea production methods as one of benchmarks for policy consideration. This research is also expected to provide useful and accurate information about how, where and under what conditions tea production conversion from conventional to organic production will be successful in the Thai Nguyen province. Policy makers also need information about the impact of organic tea production on tea marketing possibilities, the environment and on tea grower communities.

1.5 Organization

The second chapter of the dissertation provides a methodological overview of theoretical models to be developed within the analytical framework of the dissertation. The developed models include stochastic frontier analytical (SFA) models for production and profit efficiency, adoption models (e.g., probit model), the Monte Carlo model for risk analysis and the cost-benefit analytical model (CBA). Chapter 3 provides information about site selection, how the sample size was determined, and how interviewees were selected. Chapters 4 through 8 examine the analytical models developed for production and profit efficiency, adoption analysis, risk analysis and net present value analysis for different tea production methods. These chapters propose empirical models, provide estimated results, and analyze and discuss these results. The final chapter includes a summary of findings, an analysis of policy implications and recommendations for further research.

CHAPTER II

METHODOLOGY REVIEW

2.1 Analytical Framework

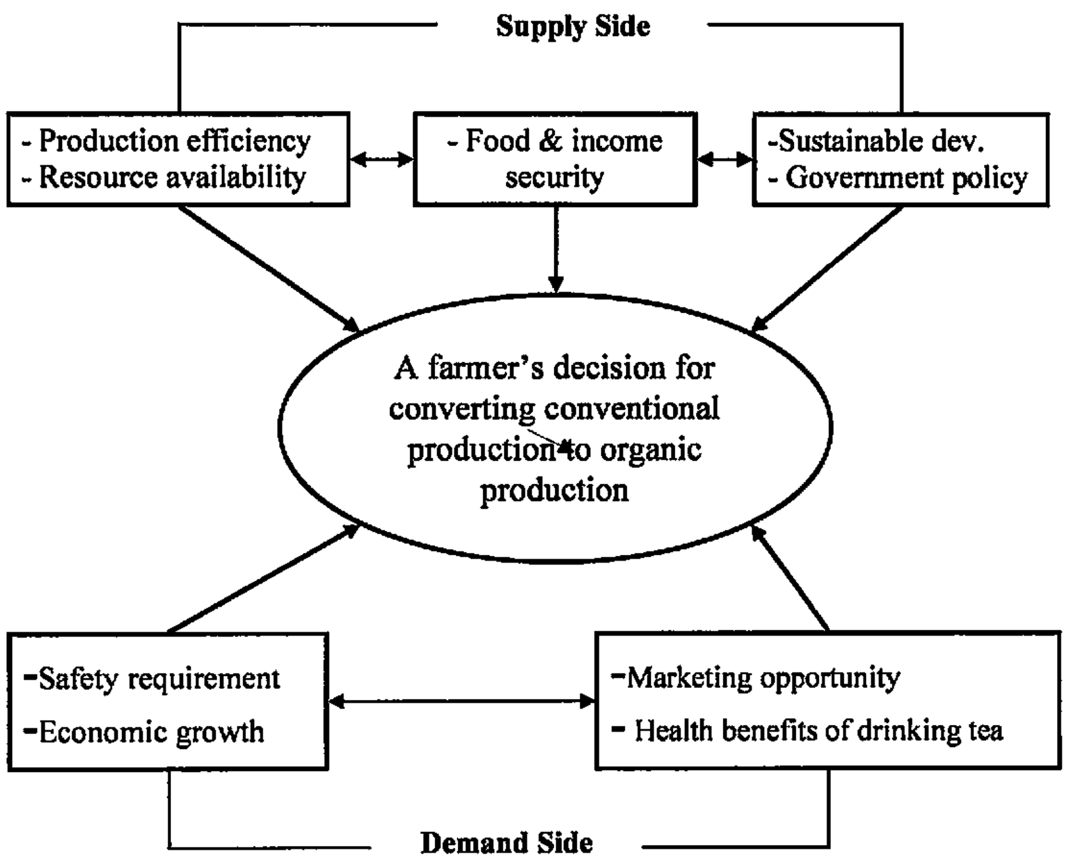


Figure 2. Analytical Framework

To carry out this analytical framework, the following assumptions are made

1- Tea is the primary income generating crop for a representative tea growing household and the leading crop to satisfy a family's food security.

2- Farmers consider food security in physical terms to be the most important goal they can achieve.

3- Farm households are assumed to be rational. They will sell labor if the selling price of labor is higher than the value of the marginal product of farm labor. They will purchase labor if the buying price is less than the opportunity cost of labor. Family labor will be employed up to the point where the opportunity cost of labor equals to the market buying price.

4- Cash income generation is an important goal of farming when household food security has already been ensured. When food has been secured, maximizing cash income, will involve expanding activities and products that earn more cash income.

5- The generation of cash income for a tea growing farm is the goal that conflicts with the excessive use of pesticides and chemical inputs leading to negative impacts on the environment, sustainability of production and human health.

6- Household endowments, tea growing technology, and market development strongly affect the tea growing practice, household food security status, and income generation of the farm.

7- Tea is assumed to have an economic life of 100 years with the first 3 years devoted to crop establishment and during this establishment period there is no harvesting, hence no income.

8- The discount rate used is the prevailing financial market rate at the time of the survey and obtained from the Vietnamese Bank for Agriculture.

9- The markets for tea products both domestic and international are assumed to operate competitively.

10- Pesticide residues are assumed to remain at average levels as found in laboratory studies for a typical type of pesticide used in the region.

The analytical process will be carried out as follows:

1. Efficiency analysis compares efficiencies of three different tea production methods, i.e., conventional production clean and organic production.
2. Adoption analysis using limited dependent variable methods (probit and tobit) determines factors which affect the farmer's choice of whether or not to convert their tea production from conventional to organic or clean tea production methods.
3. Assuming that a decision is made, the Monte Carlo risk analytical model will be used to analyze what risks and uncertainties are involved for the choice selected. The results of efficiency and selection analyses will be used as inputs for risk assessment models.
4. The CBA model will be used to compare NPV of the three different alternatives (e.g., conventional, clean and organic tea production) in a 5 year span.

2.2 Organic Production versus Conventional Production

Organic production refers to the production of a crop without using synthetic pesticides, chemical fertilizers or growth regulators. The organic food movement focuses on the method by which the food ends up free of contaminants, namely, by being farmed in a unique chemical-free way and linked to sustainable agricultural practices (Lu 2004). The farmer must be knowledgeable of alternative practices on how to manage pests and soil fertility organically while maintaining crop productivity and profitability.

According to the International Foundation of Organic Agriculture Movement (IFOAM, 2005), the 4 approved principles of organic agriculture are: i) organic agriculture should sustain and enhance the health of soil, plant, animal and human as one and indivisible, ii) organic agriculture should be based on living ecological systems and cycles, iii) organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities, and iv) organic agriculture should be managed in a precautionary and responsible manner to protect the health and well being of current and future generations and the environment (IFOAM, 2005).

The European Organic Agriculture standard specifies that an organic production

> system is designed "to enhance biological diversity within the whole system, to increase soil biological activity, to maintain long term soil fertility; to recycle wastes of plant and animal origin in order to return nutrients to the land; to rely on renewable resources in locally organized agricultural systems; to promote the healthy use of soil, water and air as well as minimize all forms of pollution thereto that may result from agricultural practices; to handle agricultural products with emphasis on careful processing integrity and vital qualities of the product at all stages; and to become established on any existing farm through a period of conversion, whose appropriate length is determined by site-specific factors such as the history of the land, and type of crop and livestock to produce" (EC Directorate-General for Agriculture, 2005).

In Vietnam, organic tea production must meet a long list[5] of requirements including the prohibition in using any type of synthetic pesticide, agricultural fertilizer or growth regulator and prohibited to use equipment and tools that were used to apply synthetic pesticides and chemical fertilizers for other crops on organic tea farms. Equipment and tools are required to be cleaned before using on organic farms. The organic tea grower is also not allowed to produce tea organically and inorganically at the same time.

[5] Details in appendix E

2.3 Household Income Security and Sustainable Development

Household Food Security and Environmental Sustainability

Environmental Sustainability: Sustainability is associated with the words maintain and prolong (Sajise, 2000). Environmental sustainability, therefore, refers to maintaining and prolonging the quantity and the quality of natural resources to ensure productive capacity from the natural resource base to satisfy social needs.

Household food security and environmental sustainability involve the basic relationships between population pressure, food security and environmental sustainability as shown in Figure3.

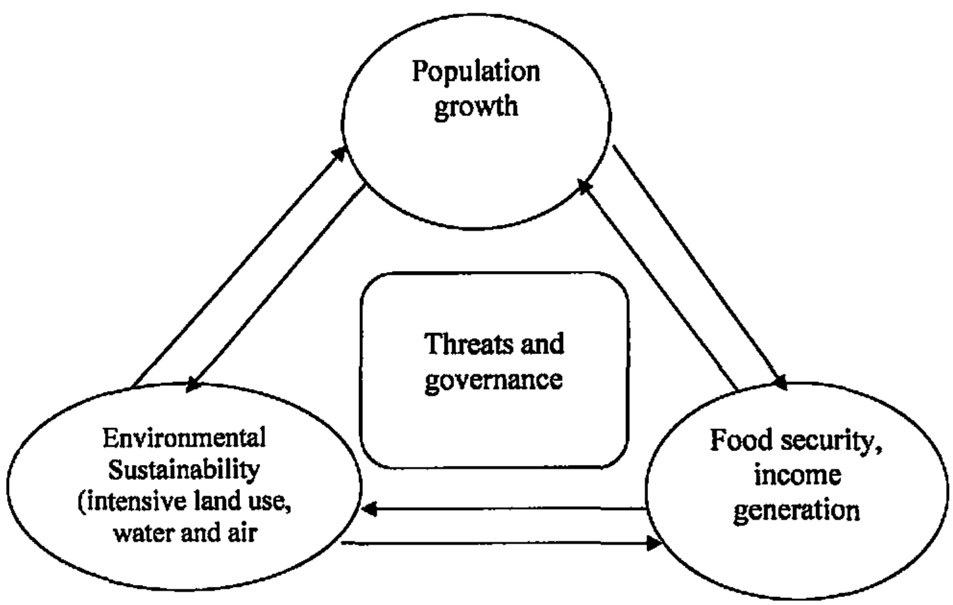


Figure 3. Population Pressure, Food Security and Environmental Sustainability (Modified from Malayang III, 1999)

Population growth places pressure on a country's natural resources in particular land, forest, and water resources. In Vietnam, especially in the Thai Nguyen province many tea growers depend solely on tea production as the primary source of income and therefore the principal source for family food security. The productivity of the crop depends on the health status of the crop and soil, and the application of proper management practices by farmers. Intensive use of different agricultural chemical inputs leaves residuals in soils and the surrounding environment. This is the primary source of environmental degradation and a threat to long-term food security and environmental sustainability. Therefore, the sustainable development of society is threatened. Organic tea production is a potential solution to the sustainable development problem.

2.3.2 Goals and Resources of Farming Households

Jayasuriya (1991) stated that farming is a goal-oriented system. Farmers are decision-makers with many different goals for utilizing, conserving, and sustaining resources. Usually, they want to increase income, avoid risk, provide enough food for subsistence, and other essential requirements, and reduce costs and losses.

Zandstra et al. (1981) classified farm resources into two categories, namely: on-farm and off-farm resources. On-farm resources include land, labor, crops, animals, farm tools, etc. Off-farm resources consist of credit, price support, road, irrigation system, extension services, and so on. Off-farm resources also include the carrying capacity of the environment in which the farm operates.

Resources on a tea farm are not very diverse. In a typical tea producing area, farmers don't have many choices in terms of combining different crop patterns and crop rotations. Intercropping with tea can only occur during the first few years of the tea growing cycle or with fruit or other shading trees (Do & Le, 2000). Therefore, a diversified production mix can be economical during the early stage of land use planning or with livestock production as part of farm operations.

FAO (2001) showed that farmers in mixed systems have to divide their attention and resources over several activities, thus leading to reduced economies of scale. Advantages of mixed systems include the possibility of reducing risk, spreading labor over several operations and re-utilizing resources. Those enterprises allow resource requirements, such as labor or draft power, to be spread evenly over the agricultural seasons. It also provides the possibility to protect the farm from natural and market risks. Moreover, it enables farmers to use their capital flexibly, improve their management skills, and adjust more quickly to cope with a market weakening or failure. On the contrary, diversity may be offset by a loss in average profit or income that the farm incurs due to not specializing in the most profitable enterprise.

Given limited flat and irrigated areas, the endowment of irrigated land is still a "critical determinant" of food security in the uplands or midlands where tea is primarily produced. Cash income generated from livestock and wages are also important and become more important when access to the market improves (Pandey and Minh, 1997). Livestock is also important during the period after trimming and during the winter when tea goes dormant.

Phu (1999) says that there are two approaches for northern upland households to maintain food security. For remote areas, food is secured by a subsistent, self-production approach. With better access to markets, farming orientation will shift to "food security by money", in which animal husbandry and cash crop production are dominant.

In the Northern uplands and middle lands, farming systems are primarily mixed or combinations of several crops, animals, and other economic activities. Tea usually plays an important role in generating household cash income. The importance of tea varies by farm households depending on the households' farm size.

2.3.3 Farm Households, Food Security and Environmental Sustainability

To be food self-reliant, the household has to fully utilize its resources in a sustainable manner, either directly to produce food or to generate income for purchasing food or combinations of these two approaches. This is a farm-planning problem in which many goals must be taken into account over a long time horizon. The problem must include many farming options (activity mixes) with the goal of choosing the "best" one.

Figure 4 presents the biophysical, socio-economic and policy conditions that influence the farmer's (with his/her knowledge and experiences) use of resources to conduct on-farm and off-farm activities satisfying his/her different objectives. However, his/her on-farm activities can have environmental impacts, which, in turn, affects farm production, farm resources, farm knowledge, bio-physical condition, socio-economic condition, and governmental policies. Therefore, Figure 4 is a good conceptual framework or qualitative model to illustrate the upland household farming system as an input-output process in which the farmer, as a manager, seeks sustainable household food security while maximizing household income.

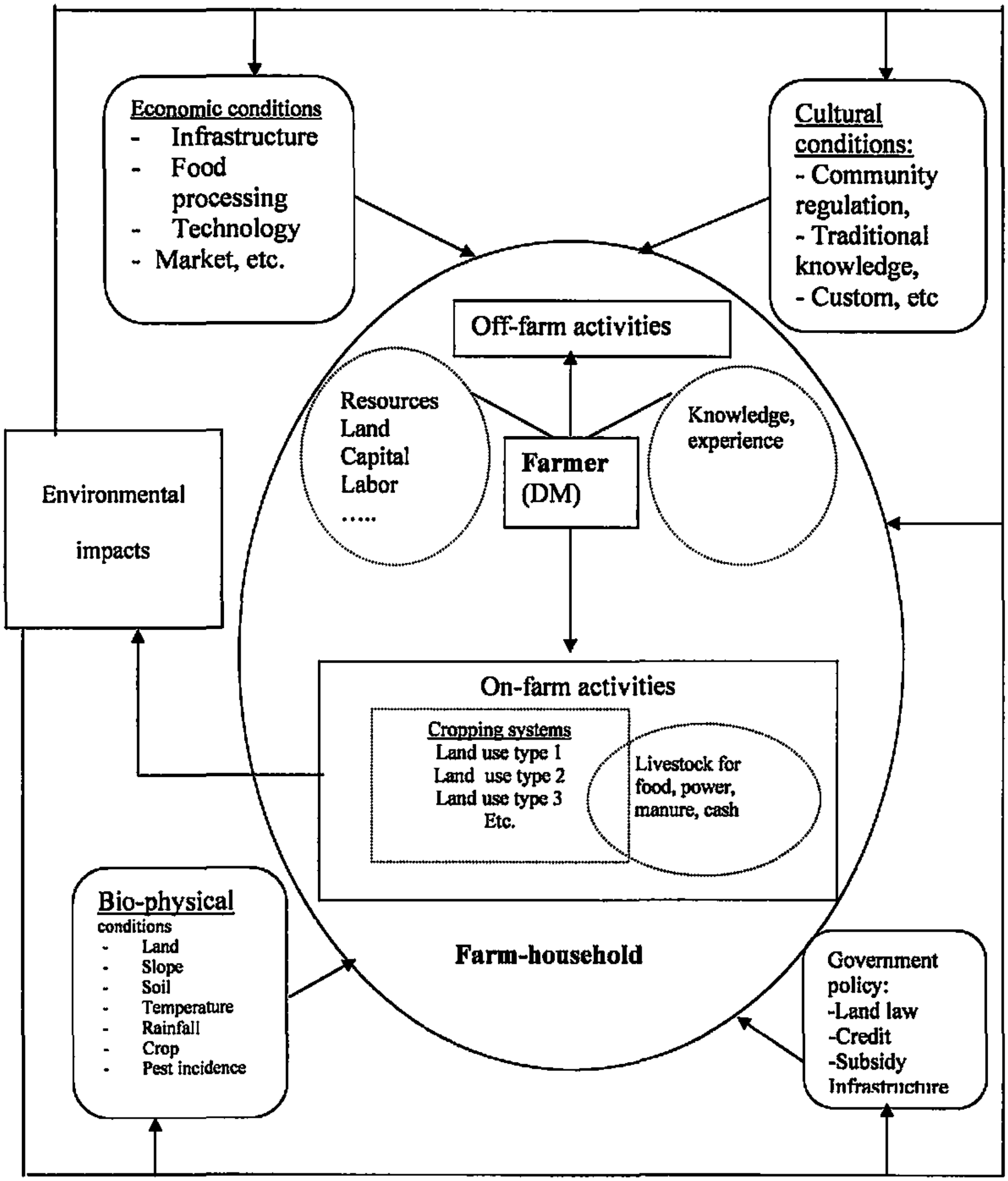


Figure 4. Farm Households, Food Security and Environmental Sustainability

(Developed from Richard, *et al.*, 1989)

2.4 Efficiency Analysis

2.4.1 Methods for Analyzing Production Efficiency

As described in the analytical framework of this research, production efficiency of the three different tea production methods is an important element in analyzing tea growers' decision making. "Efficiency is economic and is measured by comparing observed and optimum cost, revenue, profit or whatever the production unit is assumed to pursue, subject to the appropriate constraints on quantities and prices" (Fried, et al. 1993). Efficiency studies can be broadly classified into three categories. The first category uses the primal approach where parameters of the behavioral model are estimated using Ordinary Least Squares (OLS). These estimates are then used to see if the first order conditions of profit maximization are met. Examples of studies using this approach include Hopper (1965), Sahota (1968), and Saini (1971). The second category of efficiency studies examines profit maximizing behavior of the dual profit function. Examples of using this approach include Yotopoulos and Lau (1973), Junankar (1987) and Sidhu (1974). The third approach is known as the frontier analysis that is currently used in the production economics literature. This is a regression model in which disturbances may be normally distribution. A lengthy literature commencing with empirical work by Knight (1933), Debreu (1951) and Farrell (1977) and the pioneering empirical study by Aigner, Lovell and Schmidt (1977) have directed frontier production modeling. The production function is a theoretical ideal. Since the theoretical production function is an ideal, any nonzero disturbance must be the result of inefficiency.

Production efficiency has two components. The technical component reflects the ability to produce as much output as input usage allows or to use as little input as output production allows whereas the allocative component refers to the ability to combine inputs and outputs in optimal proportions with given prices. There are two main analytical frontier approaches used to analyze productive efficiency, the econometric approach and the programming approach (or mathematical approach). The econometric approach is stochastic, and it has a number of virtues including its internal consistency and its ease of implementation. Another advantage of this approach is its ability to shift the deleterious effect of measurement error away from estimates of efficiency. However the disadvantages of the econometric approach are that it is parametric and it compounds the effects of misspecification of functional form with inefficiency. The mathematical approach is nonstochastic, nonparametric and less prone to specification error. It can handle multiple input and multiple output models. Inputs and outputs used in the programming approach can have very different units. The disadvantages of the mathematical approach are that it is nonstochastic and it lumps disturbance and inefficiency together (Fried, et al. 1993). The programming approach is estimated by data envelop analysis (DEA) which is an extreme point technique therefore, noise such as measurement error can cause significant problems. DEA is good at estimating "relative" efficiency of a decision making unit but it converges very slowly for "absolute" efficiency (Fried, et al. 1993). Since DEA is a nonparametric technique, statistical hypothesis testing is difficult. The desirable model for analyzing productive efficiency would be to make the programming approach stochastic or to make the econometric approach more flexible in its parametric structure. By far the most widely used econometric model is the single equation cross-sectional model (Fried, Lovell & Schmidt 1993).

2.4.2. Stochastic Frontier Analysis (SFA)

Farrell (1957) proposed specific measures of technical and allocative efficiency. Technical efficiency reflects the ability of a firm to obtain optimal output from a given set of inputs. Allocative efficiency refers to the firm's ability to use inputs in optimal proportions, given their respective prices. In doing that, the assumption here is that the production function of the fully efficient firm is known. Fried, Lovell and Schmitz (1993) have shown the econometric approach like Stochastic Frontier Analysis (SFA) is stochastic and attempts to distinguish the effects of noise from the effects of inefficiency. The principal advantage of the parametric approach over the non-parametric approach is its ability to characterize frontier technology in a simple mathematical form and to accommodate non-constant returns to scale. As Subal and Subrata (2005) pointed out, SFA produces efficiency estimates or efficiency scores for individual producers. Since efficiency scores vary across producers, they can be related to producer characteristics such as size, ownership, location, etc. SFA provides a powerful tool for examining the effects of intervention. However, the parametric approach often imposes structure on the frontier and a limitation on the number of observations that can be technically efficient. One of the objectives of this research is to examine the production efficiency (score) of individual tea growers applying the organic production method as compared to those using conventional tea production. The SFA is selected as the method to measure technical and allocative efficiency.

The model equation for stochastic frontier analysis is:

$$y_i = f(x_i; \beta)\exp(-u_i) \qquad i = 1, 2, \ldots N \qquad (2.1)$$

where y_i represents output level for ith farm,

x_i is a vector of inputs for ith farm,

β is a vector of unknown variables,

u_i is the non-negative random variables associated with the firm specific factors contributing to the ith farm not attaining maximum efficiency, and

N is the number of farms.

Technical efficiency of a given farm is defined by the factor exp $(-u_i)$ which measures the level of the farm's production lying beneath the frontier output curve. If TE_i represents technical efficiency for the ith firm, then TE_i can be expressed as follows

$$TE_i = \frac{y_i}{y_i^*} = \frac{f(x_i;\beta)\exp(-u_i)}{f(x_i;\beta)} = \exp(-u_i) \qquad (2.2)$$

where $y^*_i = f(x_i; \beta)$ is the maximum feasible output, y_i is the observed output, and β is a vector of parameter estimated by the maximum likelihood (ML) procedure or by corrected ordinary least squares (COLS). Since there are no statistical assumptions for the earlier equation, inferential results can not be obtained.

Aigner, Lovell and Schmidt (1977) introduced the stochastic frontier model which incorporates an error term composed of two components: a symmetric component capturing random variations of the frontier across firms and the effects of measurement error and a one-sided component capturing the effects of inefficiency relatively to the stochastic frontier.

The stochastic frontier production function can be expressed as follows:

$$Y_i = x_i \beta + E_i \qquad (2.3)$$

$$\text{and } E_i = V_i - U_i \qquad (2.4)$$

where Y_i denotes output for the ith firm (i = 1, 2,… , N); x_i is a 1x k vector of inputs associated with the ith firm; β is a k x 1 vector of the coefficients for the associated independent variables in the production function.

V_i ~ i.i.d. $N(0, \sigma^2_v)$ and independent distributed of U_i

U_i are non-negative, technical inefficient effects that can follow a half normal, a truncated normal, an exponential or a gramma distribution (Aigner, Lovell and Schmitz, 1977; Greene, 1990; Meeusen and Van den Broeck, 1977).

The maximum likelihood estimation of equation (2.3) yields consistent estimators for β, λ and σ^2 where β is a vector of unknown parameters, $\lambda = \sigma_u / \sigma_v$ and $\sigma^2 = \sigma^2_u + \sigma^2_v$. Jondrow, *et al* (1982) have shown that inference about the technical inefficiency of individual farmers can be made by considering the conditional distribution of *u* given the fitted values of ε and the respective parameters. Based on assumptions: v ~ $N(0, \sigma^2_v)$, u~ | $N(0, \sigma^2_u$ | and $E_{(ev)}$ =0, they compute the conditional mean of u_i given $\varepsilon_i = v_i$ as a measure of technical efficiency as

$$E(u_i| v_i) = \sigma^* \frac{f^*(\varepsilon_j\lambda/\sigma)}{1-F^*(\varepsilon_j\lambda/\sigma)} - \frac{\varepsilon_j\lambda}{\sigma} \qquad (2.5)$$

where f* and F* are standard normal density and cumulative distributions respectively evaluated at $\varepsilon_i\lambda/\sigma$, $\sigma^2 = \sigma^2_u + \sigma^2_v$, $\lambda = \sigma_u/\sigma_v$, and σ $\sigma^2_u \sigma^2_v/\sigma^2$. The estimates of σ^2, λ and parameter vector β are obtained by maximum likelihood. Jondrow, *et al* (1982) also derived a similar formula for the exponential distribution while Green (1990) derived a formula using the gamma distribution.

Replacing ε, σ and λ by their estimates in equations (2.3) and (2.5), the estimates for *v* and *u* are derived. Subtracting v from both sides of equation (2.3), yields the stochastic production frontier:

$$Y^* = f(X_i; \beta) - u = Y - v \qquad (2.6)$$

where Y^* is defined as the farm's observed output adjusted for the statistical noise contained in v (Bravo-Ureta and Rieger, 1991 and Bravo-Ureta and Pinheiro, 1997). Equation (2.6) can be used to derive an indirect cost function frontier and from this cost frontier, the minimum cost factor demand equations can be obtained, which become the basis for calculating the economically efficient input levels.

Kumbhakar and Lovell (2000) present a profit frontier function:

$$\pi(p, w) = \max_{y,x}\{p^T y - w^T x) \qquad (2.7)$$

where p is output price, w is a vector of input prices,

y is a scalar of output (y >0), and x is a vector of inputs.

The term $\pi(p, w)$ is the maximum profit obtainable from given output and input prices.

A measure of profit efficiency is, therefore, a function $\pi E(y,x,p,w) = (p^T y - w^T x)/ \pi(p, w)$, provided $\pi(p, w) > 0$. This is the ratio of actual profit to maximum profit.

There are two different approaches for estimation of stochastic profit inefficiency, the primal production frontier approach and the dual variable profit frontier approach. The primal frontier approach begins with the production frontier used by Kumbhakar and Lovell (2000):

$$y = f(x, z; \beta)\exp\{-u\} \qquad (2.8)$$

where $y \geq 0$ is scalar output, $x = (x_1, x_2, \ldots\ldots. x_N) \geq 0$ is a vector of variable inputs, $z = (z_1, z_2, \ldots\ldots. z_Q) \geq 0$ is a vector of quasi-fixed inputs, and $u \geq 0$ represents output-oriented technical inefficiency. If producers attempt to maximize variable profit, the first order conditions can be written as

$$f_n(x, z; \beta)\exp\{-u\} = (w_n/p)\exp\{\xi_n\},\ n = 1\ldots\ldots.N \qquad (2.9)$$

where $f_n(x, z; \beta) = \partial f(x, z; \beta)/\partial x_n$ and

ξ_n is called allocative inefficiency representing non-fulfillment of the first order conditions for variable profit maximization.

If the production frontier takes the Cobb-Douglas form, the first –order conditions for variable profit maximization (2.9) can be written as:

$$\text{Ln } y = \beta_o + \sum_n \beta_n \ln x_n + \sum_q \gamma_q \ln z_q + v - u \qquad (2.10)$$

$$\text{Ln } x_n = \beta_o + \ln\beta_n + \sum_k \beta_k \ln x_k + \sum_q \gamma_q \ln z_q - \ln\frac{w_n}{p} - u + \xi_n \qquad (2.11)$$

$n = 1, \ldots\ldots N$

where v is the stochastic noise error component associated with the production frontier. In deriving the first-order conditions, we start with the deterministic production frontier evaluated at v = 0.

In the dual variable profit frontier approach, we also start from the production frontier (2.8). The dual variable profit frontier is

$$v\pi = v\pi(pe^{-u}, w, z; \beta) = v\pi(p, w, z;\beta).h(p, w, z;\beta) \qquad (2.12)$$

where $v\pi = py - w^T x = v\pi\{(pe^{-u})(ye^{u}) - w^{T}x\}$, $h(p, w, z;\beta) = v\pi(pe^{-u}, w, z;\beta)/ v\pi(p, w, z;\beta)$ is the ratio of maximum variable profit with technical inefficiency and maximum variable profit.

2.5 Adoption Analysis

Although organic tea is not an innovation, it requires the adoption of a different farming practice. As required by the organic certification organization mentioned in the first section of this research, a tea grower when deciding to convert his/her farm from conventional production to organic production has to select either keeping the tea farm as a conventional practice or converting it to organic tea. Technology adoption studies usually involve data where the dependent variable is a zero-one variable. The simplest model used to analyze technology adoption is the linear probability model (LPM). However, the application of ordinary least squares to data with a binary dependent variable has some drawbacks: (i) it contains a heteroskedastic error structure and inefficient parameter estimates (Goldberger, 1964; Pindyck and Rubinfeld, 1976; Wooldridge, 2003); (ii) it can produce predicted probabilities that are less than zero or greater than one and it implies a constant marginal effect of each explanatory variable (Wooldridge, 2003). Due to the presence of heteroskedasticity, classical tests, such as the t-test and F-test, are invalid (Wooldridge, 2003). Therefore, the alternative is to use probability models or binary response models which ensure the fitted values lie between zero and one. The behavioral model accounts for a dichotomous dependent variable such as adopting or not adopting organic tea. In general, this type of model is known as the "adoption model". According to Wooldridge, 2003 for a binary response model, interest lies primary in the response probability.

$$P(y = 1 | x) = P(y=1 | x_1, x_2, , \quad , x_k) \qquad (2.13)$$

where x denotes the full set of explanatory variables

To avoid the LPM limitations, consider a class of binary response models of the form

$$P(y = 1 | x) = G(\beta_0 + \beta_1 x_1 + \dots \quad + \beta_k x_k) = G(\beta_0 + x\beta) \qquad (2.14)$$

where G is a function taking on values strictly between zero and one: $0 < G(z) < 1$, for all real numbers z. This ensures that the estimated response probabilities are strictly between zero and one.

Various nonlinear functions have been suggested to estimate the function G in order to make sure that the probabilities are between zero and one. Logit and probit are used in the vast majority of applications (Wooldridge, 2003).

For the logit model, G is the logistic function:

$$G(z) = \exp(z) / [1+ \exp(z)] \qquad (2.15)$$

where G is between zero and one for all real numbers of z. This is a cumulative distribution function for a standard logistic random variable.

In the probit model, G is the standard normal cumulative distribution function (cdf) and can be written as follows:

$$G(z) = \Phi(z) = \int_{-\infty}^{z} \phi(v)dv \qquad (2.16)$$

where $\phi(z)$ is the standard normal density

$$\phi(z) = (2\pi)^{-1/2} \exp(-z^2/2) \qquad (2.17)$$

This choice of G ensures that (2.9) is strictly between zero and one for all values of the parameters and x_j.

Logit and probit models can be derived from the underlying latent variable model

$$y^* = \beta_0 + x\beta + \varepsilon,\ y = 1\ [y^* > 0] \text{ and } y = 0 \text{ otherwise} \qquad (2.18)$$

$$\varepsilon|x \sim N(0, 1)$$

It is assumed that ε is independent of x and that ε either has the standard logistic distribution or standard normal distribution. In either case, ε is symmetrically distributed above zero for all real numbers of z. Economists tend to favor the normality assumption for ε, which is why the probit model is more popular than the logit model in econometrics (Wooldridge 2003). Besley and Case (1993) showed that the gain to farmer i of using the new technology is typically parameterized as $\gamma x_i + u_i$, where x_i are farm and farmer characteristics and u_i in an independently and identically distributed. The probit model is usually used to run this model. Garson (2006) also stated that "in practical terms, the probit model usually arrives at the same conclusions as the logistic regression. In principle, one should use the probit model if one assumes the dependent variable reflects an underlying quantitative variable. There are some issues related to using the probit model for probable response analysis, such as nonnormality of ε and hesteroskedasticity in ε. If ε does not have a standard normal distribution, the response probability will not have the probit form. If there is heteroskedasticity in ε, it means that $Var(\varepsilon|x)$ depends on x. The response probability no longer has the form $G(\beta_0 + x\beta)$ instead, it depends on the form of the variance and requires more general estimation.

2.6 Monte Carlo Model for Risk Analysis

Risk has always been a part of agriculture. Likewise, there are different types of uncertainty involved with the decision making process of a tea growing farmer. The important task of risk analysis is to determine what type of uncertainty is likely to affect the outcome of the decision (Kammen & Hassenzahl, 2001). As Romero and Redman (1989) pointed out, "traditional risk and uncertainty analysis is, by its nature, a multi-objective analysis with two objectives of profits and a measure of their variability." The nature of the risk in agricultural production in general and in tea production specifically is the variability of monetary return around its mean and the level of externality caused by production activities on the environment that affects not only sustainability of production but also farmers' health. The variability in outcomes from those which are expected poses a risk to the tea growers' ability to achieve their financial goal. According to neoclassical theory, the principle of equal marginal returns is the criterion for efficiency in resource use in the case of multi-product firms such as tea growers. In other words, the marginal revenue product (MRP) of each variable input is equal for all enterprises in which it is employed and also equal to the price of the input. Tea production depends not only on soil quality, irrigation and production inputs, such as fertilizers, labor, etc, but also on environmental variables, such as weather, weed and pest populations. The major sources of production risk in tea farming are weather, pests, diseases and interaction of technology with other farm and management characteristics as well as the quality of inputs. Since environmental variables are unknown at the time the farmer makes his/her production decisions, it can be said that he/she makes those decisions in a state of uncertainty about the outcome. If a tea grower determines whether or not he/she will convert his/her tea farm from conventional to organic production, he/she should consider the risks and uncertainty involved in this decision. For this research, certain variables are uncertain e.g., the market price of tea products (for both tea produced from conventional and tea produced from organic production practices), input costs, tea yields in different cropping and family farming conditions, etc. In the conversion period, tea farmers will face the risk of reduced tea yields due to a biological inbalance resulting from not using chemical fertilizers, pesticides and other agricultural chemical inputs. To evaluate risks is an important step in applying a new technology in agricultural production.

Roumasset (1981) shows that yield uncertainty can be represented by the stochastic production function,

$$Y = f(\theta, T) \tag{2.19}$$

where θ is a random variable between 0 and 1, and T is a vector of inputs for the proposed production technique. Simplify by postulating that fertilizer, F, is the only variable input and that θ is discrete. Production in the j th state of the environment can be expressed as

$$Y_j = f(F)$$

Ignoring price fluctuations, stochastic profits can be written as:

$$\pi_j = PY_j - C(F) \qquad (2.20)$$

where P is the price of output and C(F) is cost as a function of fertilizer (inputs).

Expected profit given by:

$$E(\pi_j) = \sum_j \pi_j P_j \qquad (2.21)$$

where P_j is the probability of the jth environmental state

High or low incidence of pest and disease problems can be associated with application of different crop protection methods from organic and conventional tea production. Roumasset (1981) also argues that "given limited knowledge, farmers may maximize expected profits only as they perceive them". Although results from the stochastic frontier analysis may show a preference for organic tea production to conventional tea production, risk analysis is still necessary to show how uncertainty and variability of their expected production and profits will affect the farm household.

There are different techniques used to model risk analysis and risk management. However, Monte Carlo analysis is commonly used. Monte Carlo simulation is a useful tool when either the problem definition is unclear or the data available are uncertain (Kammen & Hassenzahl, 2001). Monte Carlo analysis simulates multiple scenarios (trials) of the model by repeated sampling from the probability distribution of the uncertain variables and using these values in the model. In the Monte Carlo model, the risk estimate is expressed as a distribution of values with a probability assigned for each value and the distribution reflecting variability and uncertainty. The simulation results from the Monte Carlo model will provide two important parameters in determining risk and uncertainty among choices (consequence and probability).

As defined by EPA (U.S. Environmental Protection Agency) (1997), variability represents the true heterogeneity or diversity in a well-characterized population. As such it is not reducible through further study. Uncertainty represents a lack of knowledge about the population. It is sometimes reducible through further study.

Monte Carlo analysis is a probabilistic analysis technique that is a viable statistical tool for analyzing variability and uncertainty in risk management. This technique can enhance risk estimates by fully incorporating available information concerning the range of possible values that an input variable could take and weighing these values by their probability of occurrence. Since Monte Carlo analysis is a tool for combining more than two distributions, and thereby propagating more than just summary statistics. Monte Carlo analysis involves conducting and then comparing repeated trials with inputs that reflect the distributions of the system parameters. One can find many values for output this way, resulting in a range of values represents distribution of output given input choices.

According to Helton (2005), the underlying idea of sampling based approaches to uncertainty and risk analysis is that the analysis results in $Y(X) = [y_1(X), y_2(X)\ldots. y_{nY}(X)]$ are functions of uncertainty analysis inputs $X = [\ x_{1,}\ x_2\ldots. x_m]$. In turn, uncertainty in X results in uncertainty in Y(X). This leads to two questions: (i) what is the uncertainty in Y(X) given the uncertainty in X? and (ii) how important are individual elements of X with respect to uncertainty in Y(X). The goal of uncertainty analysis is to answer the first question, and the goal of sensitivity analysis is to answer the second question. After obtaining the best solution that meets a certain desired level of production efficiency for both organic tea and conventional tea, a risk analytical model using the Monte Carlo method will be developed to determine risk levels for the choices suggested. The intent is to see how values of the objective function change when values of the decision variables vary around their means and to determine whether or not converting to organic tea will be beneficial to tea growers in the Thai Nguyen province.

According to Vose (2004), the cardinal rule of risk analysis modeling is "every iteration of a risk analysis model must represent a scenario that could physically occur". Following this rule will lead to a model that is both accurate and realistic. Integral to any Monte-Carlo analysis is the generation of random numbers. Monte Carlo sampling will evaluate the probability distribution in a purely random fashion. However the randomness of this sampling suggests that, unless a very large number of iterations are performed, it is likely that over sampling for some parts and under sampling of other parts of the distribution will occur.

Conard (2005) used the Monte Carlo approach for analyzing uncertainty in an information security investment. He shows that this approach captures uncertainty in security modeling parameters and expresses its impact on the model's forecast. This approach is especially valuable for visualizing a potentially large return on an investment.

Ridlehoover (2004) used Monte Carlo analysis to evaluate the riskiness of facility location in helping determine the costs and benefits of a site. The variables are analyzed with each corresponding distribution. The result of his study shows that the use of risk factors allows the decision maker to better understand the differences of each candidate site and make a genuinely informed decision.

Although asking farmers directly about probabilities, ranges, and quartiles of profits or yield distributions may be too artificial and may not result in reliable answers. An intermediate method is to extract definitions for good, bad or medium seasons. In Monte Carlo modeling, the triangle distribution will allow us to use farmers' subjective responses for risk analysis.

Monte Carlo simulation will also be used to test the biasness of different analyses including the stochastic production frontier, mathematical programming and choice selection. Aigner, et al. (1977) suggested that in order to discover some specific information about small sample behavior of the stochastic frontier analysis estimators, they constructed two limited Monte Carlo experiments using artificial data.

2.7 Cost Benefit Analysis (CBA)

According to Kenneth (1968), the whole idea of Cost Benefit Analysis (CBA) is of enormous importance in the evaluation of social choice and even of social institutions. Nick and Jason (2005) mention that CBA presumes informed people make purposeful and consistent decisions to maximize their net gains. Relying on the rationale of CBA theory to guide environmental policy makes sense if citizens make consistent and systematic choices toward both certain and risky events (Crocker, Shogren, & Turner, 1998). Julian et al. (2000) found that in order to compare projects that have different time patterns of costs and benefits (conventional and organic tea production in this case), cost and benefit must be aggregated overtime and capital budgeting techniques, such as Net Present Value (NPV), used. Boardman et al. (2006) state that if environmental externalities lead to market distortions, the net changes in social costs (benefits) that are associated with negative (positive) environmental externalities should be added to the primary social costs (benefits). In this research, the CBA model will be used to compare NPV of the conventional and organic tea production methods for both private (using a representative tea producer) and social (for society as a whole) costs (benefits). Whether we are interested in social or private costs (benefits) does not affect the formula, however, it does determine how we measure the stream of costs and benefits.

There is a diversion between private and social costs (benefits). As Coase (1960) argues "the private product is the value of the additional product resulting from a particular activity of a business. The social product equals the private product minus the fall in the value of production elsewhere for which no compensation is paid". Arrow & Lind (1970) show that the social cost of risk-bearing will depend both upon which individual receives the benefits and pays the costs and how large each individual's share of these benefits and costs are. In calculating NPV of benefits and costs for switching from conventional tea production to organic or clean tea production, a distinction must be made between private and public benefits and costs.

2.8 Analyzing Environmental Impact

According to Ngo, et al. (2004), every year in Vietnam 30,000 to 40,000 tons of commercial chemicals were used and more than 50% of this quantity remains in the ground. Table 4 in the first section shows that 100% of the tea growers surveyed used pesticides in tea production. This use of pesticides had detrimental effects on human health and the environment. One of the obviously positive impacts of organic tea production is the reduction of pesticide and chemical residues from tea production.

According to the Vietnam Ecolink (2005) the standard for evaluating and certifying organic tea in Vietnam includes 24 different requirements and all of them are related to farming practices (Appendix G). The method of analyzing environmental impacts of organic and conventional tea production will largely be based on impacts resulting from different farming practices. Information collected from the survey will include information on quantities of pesticides and agro-chemicals applied in different farming practices (for organic and conventional tea production), types of pesticides and chemicals used, application methods and application periods, sources of pesticide suppliers, etc. Total quantities of pesticides and chemicals used will be compared to previous studies to infer what amounts are likely to remain in the soil and to the environment after one, three and to eight month periods. Soil, water and tea samples were collected on a monthly basis throughout the research period in order to analyze pesticide residues and agro-chemicals in the soil and tea products. The samples were taken separately from a conventional tea production farm and an organic tea production farm. The selected conventional tea farm is a "typical" conventional tea producer that only has a pond for catching runoff water from the conventional tea farm. For organic tea production, the samples were taken from the first year after conversion and the organic farm has a pond to catch water runoff only from the organic tea farm. The soil samples were taken using a 0-20 cm soil sampler taking soil from five to seven locations at 0-20cm depth on the diagonals of the field. The soils then were mixed to obtain about one kg of the soil sample for laboratory analysis. Water samples were also taken at the same time as soil samples. Water samples were taken using a 30cm diameter bucket from about one meter away from the edge of the pond, and then about 500ml water sample was kept in a glass jar for laboratory analysis. A sample of one kg of fresh tea was taken from each of conventional and organic tea farms (the same tea farms where soil and water samples were taken). The fresh tea samples were given to the organic tea farmer to process. The dried (processed) tea samples were brought to the laboratory at Thai Nguyen University of Agriculture and Forestry for analysis. Residues of agricultural chemical inputs were identified by using GCMS- Gas Chromatograph/Mass Spectrometer for analysis. The analytical procedure follows the GC/MS Practical Guide (McMaster & McMaster, 2007).

Charles, Brian and Donald (1992) suggested that the expenditure aversion method for valuing environmental improvement can be used to approximate economic costs. Expenditure aversion includes using the contingent valuation method (CVM) to measure the willingness to accept (WTA) of survey respondents to accept a lower yield to improve the environment. Other indirect costs of these negative environmental impacts include illness related to applying pesticides (day-offs due to sickness), buying protective equipment and clothing, paying for pesticide wastes[6] disposal, etc.

[6] For more detail see appendixes G and H.

CHAPTER III

SITE SELECTION AND EQUATIONS FOR ESTIMATION

3.1 Selection of Study Area

As mentioned in the first chapter of this dissertation, tea in Vietnam is mostly produced in the upland and middle land of northern Vietnam and the Thai Nguyen province is well known for its high quality tea. This province is also one of the first provinces selected for the project of converting tea production from the conventional production method to the organic production method. Total tea planted area in the Thai Nguyen province is 16,985 ha and accounts for 13.8% of the total tea planted area in the country, of which about 80 ha have been registered as converting to organic tea production. Therefore the Thai Nguyen province was selected for this research. Representative tea growers selected for the sample include organic tea farms, conventional tea farms and "clean tea" farms were selected from four representative communes of two tea producing districts (Dong Hy district and Thai Nguyen city) of the Thai Nguyen province for a panel discussion and an in-depth survey conducted in 2007 (the initial survey was conducted in March and a follow up survey was conducted in October). Two communes, Minh Lap and Song Cau, are in Dong Hy district and the other two communes, Phuc Xuan and Tan Cuong, are in Thai Nguyen city. The selected tea farms are representative of topographical conditions in tea production areas of the Thai Nguyen province. The other criterion for selecting these four representative tea growing communes is that all organic tea growers and most of the clean tea producers are from these four communes. From these four communes, at least two different types (e.g., conventional tea, clean or organic tea production) of tea production practices can be found.

Minh Lap commune is located about 24 km east of Thai Nguyen town (center of Thai Nguyen city) and borders the sides of the Cau river. Most of the tea farms in the Minh Lap commune are on uplands and hillsides with slopes ranging from 15% to 30%. This commune has about 27 tea growers engaged in clean tea production and eight tea growers registered for organic tea production, however, at the time of the survey there were only four registered organic tea farmers classified as organic tea producers in a total of about 2000 tea growers in the commune.

The Song Cau commune, on the other hand, is located in the northeast and about 20 km from the Thai Nguyen town. Tea farms in the Song Cau commune are similar to those in the Minh Lap commune, however, the tea farms there still administratively belong to Song Cau Tea Company (a state owned enterprise). There are 32 tea growers using the clean tea production method and four tea growers applied to become organic tea producers, however, these four tea growers did not actually using organic tea production method. There are about 60 conventional tea producers in the selected village of this commune.

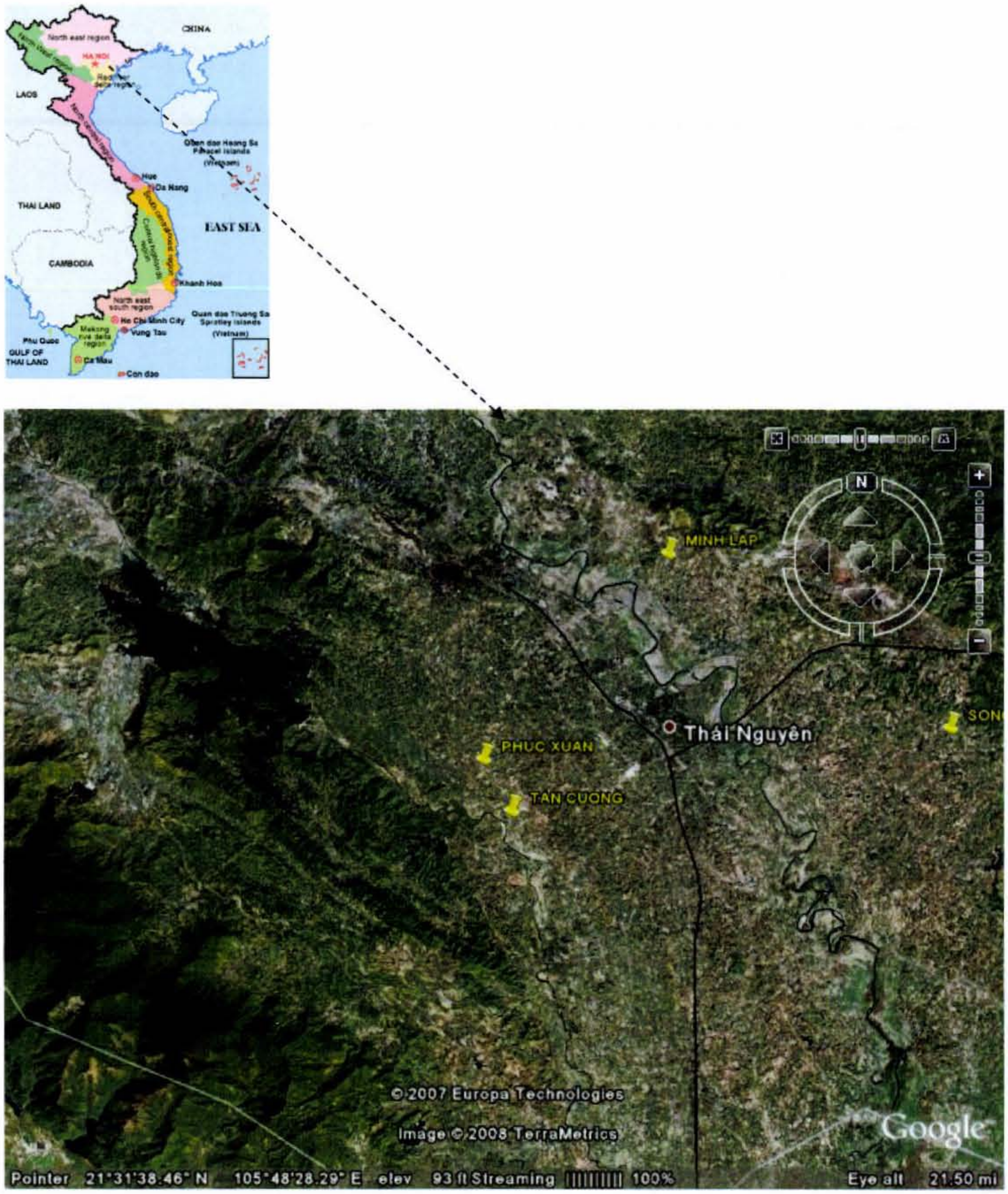


Figure 5. Study Locations in the Thai Nguyen Province

The Tan Cuong and the Phuc Xuan communes are administratively in the Thai Nguyen city. Tan Cuong is the most well-known for having the highest tea quality in Vietnam. Most of the tea farms along the sides of the Cong river where fields are flatter (with 20% slope). There are 21 tea growers in the organic tea club and registered for organic tea production and 30 are classified as clean tea producers in a total of 234 tea growers in two selected villages of this commune. Whereas, in the Phuc Xuan commune, tea is grown on hillsides and uplands and there are 43 tea growers (four of them applied to become organic tea producers but have never used this production method) who are members of the clean tea cooperative (Thanh Huong Cooperative) where tea growers share the same safety product requirements and internal monitoring system (as shown in Figure 5). There are a total of 94 tea growers in the selected village of this commune.

3.2 Sample Size Determination

Yansaneh (2007) discusses three major issues for determining the appropriate sample size for a survey considering factors such as precision, quality of the data and cost in time and money of data collection, processing and dissemination. Determining appropriate and proper sample size is the first and one of the most important steps in research. In order to obtain a statistically sound result, the following approach as described in Johnson (1980) and Yamane (1967) was used. This approach utilizes the variability of the key variable (crop yield was used for this study) to determine what would be an appropriate sample size that is representative of the population.

$$n = \left[\frac{z(\alpha/2)\sigma}{E}\right]^2 \qquad (3.1)$$

where n = sample size

α = confident level

z = the two tail z value with the corresponding confident level

σ = population standard deviation

E = precision level

The population data is on a per hectare tea output basis therefore the standard deviation of tea yields will be estimated to determine the appropriate sample size.

Since data are not continuous, the standard deviation will be estimated using the proportions formula as follows

$$\sigma = \sqrt{p\sum_{i=1}^{n}(x_i - \bar{x})^2} \qquad (3.2)$$

where p is the proportion of farms.

Agricultural research generally uses a 95 percent confident interval, this research will also adopt this confidence level. The pretest was performed using 15 tea growers, of which five were organic tea farms, five were conventional tea farms and the other five were clean tea farms. The standard deviations of tea yields for the three tea growing groups are 1.3, 1.5.and 1.6 with precision level (acceptable absolute value) of 0.09, 0.10 and 0.11 (1/15 of the estimated standard deviation) for organic tea, clean tea and conventional tea respectively. These values were then plugged in equation 3.1 using automatic calculations introduced by (Arsham, 2007), the recommended sample size of 23 organic tea producers, 67 clean tea producers and 59 conventional tea producers were recommended. Since there are only 23 tea growers registered for organic tea production, all 23 organic tea farmers were included in the survey. However, for greater statistical convenience in conducting survey analysis comparing with and without scenarios, for each organic or clean tea producer selected in the sample, one conventional tea producer was randomly selected from his/her surrounding neighbor. A total of 180 tea growers were interviewed in the survey (summing 23, 67 and 90 for organic, clean and conventional tea producers respectively). Of the 180 tea farmers interviewed, only 176 observations had complete information for the analysis which now included 23 organic tea farmers, 67 clean tea farmers and 86 conventional tea producers.

3.3 Proposed Equations for Estimation

3.3.1 Stochastic Production Frontier Equation

Assume that fresh tea is the only product produced by a tea producer and the production function follows the neoclassical production assumptions of a function being continuous, continuously differentiable and quasi-concave.

From the stochastic production frontier equation 2.1:

$y_i = f(x_i; \beta)\exp(v_i - u_i) \quad i = 1, 2, \ldots N$

where y_i represents output level for ith farm,

x_i is a vector of inputs for ith farm,

β is a vector of unknown variables,

v_i are stochastic error terms associated with the firm's specific random factors such as bad (good) weather, failure of machineries, etc., and

u_i are non-negative random variables associated with the firm's specific factors which contribute to the *i*th farm not attaining maximum efficiency.

The tea production function is assumed to be of the Cobb-Douglas form. Aigner and Chu (1968) suggested, a log-linear (Cobb-Douglas or C-D) production function for estimating efficiency since it is commonly used and has nice properties such as consistency and unbiasedness. Bhanu Murthy (2002) also argues that the Cobb-Douglas form can handle multiple inputs in its generalized form and various econometric estimation problems, such as serial correlation, heteroskedasticity and multicollinearity can be handled adequately and easily. Although it has some limitations, such as the assumption of unitary elasticity of factor substitution for all pair-wise input combinations (Olarinde & Ajao, 2001). The translog model has its own weaknesses as well, but it has also been used widely (Ali and Flinn, 1989; Wang et al., 1996).

The proposed log-linear production function for this analysis is

$$\text{Ln } y = \beta_0 + \sum_n \beta_n Lnx_{ni} - u_i \qquad (3.3)$$

where *i* is tea producer index,

x_n vector of inputs used by *i* th tea producer, and

u_i is a non-negative error component associated with production inefficiency.

The dependent variable for tea production in the Thai Nguyen province is fresh tea production (quintal).

The input vector for a tea grower in the Thai Nguyen province will include:

X_1: Labor measured in a man/ day unit (one man/day = an adult working 8 hours),

X_2: Land area (m^2),

X_3: N measured as kg/ha (pure nitrogen per hectare not commercial product),

X_4: Pesticide used in liter/ha of Bassa equivalent that may be specific for actual types of pesticides used in the research area,

X_5: Educational level of the head of a tea growing household (not completing high school, having high school, and higher education),

X_6: Irrigation (1 for having irrigation system and 2 otherwise[7]),

X_7: Distance from the household to a market place (local market, tea processing manufactures): less than 1 km, 1-3 km and more than 3 km,

X_8: Gender of the household head (1 for male and 0 for female), and

[7] Using 2 instead of 0 for more convenience when taking natural logarithms

X_9: Tea stand age (in years)

The corresponding stochastic profit frontier function is

$$\pi = py - w^T x \qquad (3.4)$$

From the dual variable profit frontier (2.12), the equation for estimating the variable profit frontier for tea production in the Thai Nguyen province is

$$v\pi = v\pi(pe^{-u}, w, z,E; \beta) = v\pi(p, w, z,E;\beta).h(p, w, z,E;\beta) \qquad (3.5)$$

where $v\pi$ is variable profit, E is a vector of environmental damage variables such as residues from agrichemicals in the soils, medical or medical- averted expenditures of tea growers; the term w is a vector of prices of variable inputs (X_1, X_3, X_4 and X_6 above) while z is a vector of quasi-fixed inputs (X_2, X_5, X_7, X_8 and X_9 above).

Consequently $h(p, w, z,E;\beta) = v\pi(pe^{-u}, w, z,E; \beta)/v\pi(p, w, z,E;\beta)$ is the ratio of maximum profit in the presence of output-oriented technical inefficiency to maximum profit or profit inefficiency. Kumbhakar and Lovell (2000) show that the normalized variable profit equation is rewritten as: $\ln\frac{v\pi}{p} = \beta_0 + \sum_n \beta_n \ln\frac{w_n}{p} + \sum_q \beta_q \ln z_q + v_\pi + u_\pi$ (3.6)

where p is output price, w is a vector of input prices, v is the normalized random effect, u is the normalized profit inefficiency, and β is a vector of technology parameters to be estimated.

3.3.2 Equation for Determining Adoption Analysis

From the binary response probability model (2.9), the proposed equation for estimating binary response probabilities is

$$P(y = 1 | x) = G(\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k) = G(\beta_0 + x\beta) \qquad (3.7)$$

where y = 1 if farmers decide to convert to organic/clean tea production and y = 0 if otherwise. The independent variables for estimating the response probabilities include:

X_1: Education level (Mid-school, high school, and college diplomat holder of the household head),

X_2: Tea farm size,

X_3: Health related expenses of the household,

X_4: Income security requirement for a household (in monetary terms),

X_5: Family labor supply (number of man/day/year),

X_6: Premium price for organic tea,

X_7: Government support program (binary variable), and

X_8: Tea stands (years).

Other variables include: gender of the household head and family size.

Hypothetical assumptions for selecting these variables as explanatory variables include the following. Tea farmers are rational decision makers and profit maximizers. Although organic tea production is not completely new to the tea growers, it requires that organic tea farmers have knowledge about the biological balance in order to apply appropriate farm management practices. A higher education level is believed to increase the understanding of problems and a more rational approach by the household head to decision making. Since organic tea production requires that the organic production area be large enough with a buffer zone separating conventional production areas from organic production areas, larger farms will have an advantage in converting to organic tea production. One of the advantages of organic tea production is the expected premium price for higher quality tea. If environmental damage caused by leaving pesticide and other agrichemical residues in the environment is paid (directly by tax or indirectly by medical costs or other adverted expenditures), the environmental cost will be a determining factor for converting to organic tea production. Like other farmers in Vietnam, most tea growers in the Thai Nguyen province have family farms, and many of them are subsistent farmers. Therefore, food security in monetary terms is a very important factor affecting the tea farmers' decision. The first priority for farmers is to generate enough income to make ends meet. Organic tea production will not appeal to poor farmers if this production system does not ensure farmers' income security even though it does produce higher quality products and is environmentally sound. Organic production usually requires more labor than conventional production for pest and weed control because labor is used to replace the use of pesticides and herbicides for controlling pests and weeds. Family farms tend to employ family labor to meet the additional labor requirement for organic tea production.

As indicated in its 10-year Strategic Plan that "organic farming especially organic tea production was encouraged by MARD" (Vinatea, 2005). Government policy promoting organic tea production would likely have impacts on farmers' decision in converting from conventional to organic tea production. Government support may include income support during the conversion period, a favorable credit policy or a price premium.

As assumed earlier, the economic life of a tea plant is 100 years. Benefits would be greatly diminished if conversion occurred at the end of the tea farms' economic life. A younger tea farm is easier to convert. The data for these variables will be obtained from a survey using questionnaires and direct interviews with individual farmers in the Thai Nguyen province.

A probit model was used to estimate with the following functional form

$$G(z) = \Phi(z) = \int_{-\infty}^{z} \phi(v)dv \qquad (3.7)$$

where G(z) takes the form of equation (3.6). The results of this estimation will provide information about what are the main factors influencing the tea growers' decision of whether or not to convert their farm from conventional to organic tea production and who are more likely to convert to organic tea production.

3.3.3 Equation for Risk and Uncertainty Analysis

As discussed in section 2.8 "traditional risk and uncertainty analysis is, by its nature, a multi-objective analysis with two objectives of profits and a measure of their variability" (Romero and Redman, 1989). The model for risk and uncertainty analysis will be simulated and compared with the variability of profits under conventional and organic/clean tea production. The outcomes from production and profit efficiency analysis and the selection analysis will be used as inputs for risk and uncertainty analysis. The efficiency analysis will provide empirical models of estimation for efficient production and profits for tea production under conventional tea production and organic tea production in the Thai Nguyen province. Selection analysis will present major factors affecting Thai Nguyen tea growers' decision for converting to organic tea production. Different distributions will be assigned to each uncertainty variable for the sensitivity analysis in order to obtain the best theoretical fit for each variable. The expected outcome of this analysis is the risk levels associated with choosing conventional tea production or organic tea production.

The adoption equation resulting from the adoption analysis will also be used as an objective function for the risk analytical model to determine how different factors affect the probability to adopt new tea production methods (e.g., organic and clean tea production).

3.3.4 Measurement of Costs and Benefits (CBA)

Net Present Value (NPV) calculates net returns or net benefits overtime, streams of benefits and costs of different tea production methods (conventional and organic tea production methods) as expressed as follow:

$$\text{NPV} = \sum_{j=0}^{\infty}(B_j - C_j)/(1+i)^j \quad (3.8)$$

where B_j is benefits for the j th period after the conversion, C_j is the costs for the j th period after the conversion, and i is the discount rate. Based on data collected for the 2007 crop year and three previous crop years (2004, 2005 and 2006), CBA will be carried out twice for a representative tea growing household for each tea production method and for both private and social perspectives. For private CBA, costs and benefits will be measured using the monetary valuation method (direct or indirect market operations and farmers' accounting records). For social CBA, the measurement of costs and benefits is more complicated.

As Pearce & Howarth (2000) pointed out, the practical problem with economic valuation is deriving credible estimates of people's values based on either markets or very imperfect markets. In this research, several valuation techniques will be used to evaluate economic parameters for private and social CBA as follow:

(i) Revealed preference technique (market based information): most of the economic data will be collected using this method e.g., tea production, tea price, all input quantities and prices (including labor), tea planting areas etc. using this technique, environmental values will be inferred from markets in which environmental factors have an influence, such as the higher price for organic tea products, reducing health care related costs of organic tea growers, health related problems for those who were in direct or indirect contact with pesticides, etc.

(ii) Replacement cost: this technique uses the cost of cleaning pesticide residues and other chemical inputs in the soil, in the surface water and in tea products for conventional tea production. The results from tea, water and soil sample analyses could be used for this determination. However, due to the sample and replicate limitations, the preliminary results of soil, water and tea sample analyses in this study were not used in NPV analysis.

(iii) Sensitivity analysis will be applied to determine the effects of tea growers switching from conventional to organic production. In particular, the effects on the costs of risk-bearing computed in terms of private and social CBA. As Dinwiddy and Teal (1996) discussed, there are two discount rates used for evaluating public sector projects: the consumption rate of interest and the social discount rate.

In this research to calculate NPV, the prevailing interest rate in the market (annual interest rate from the Agricultural Development Bank is 10.8%) will be used as the private discount rate. The prevailing interest rate of the Bank for the Poor (considered as the opportunity cost for social development with an annual interest rate of 7.2%) will be used as the social discount rate.

CHAPTER IV

PRODUCTION EFFICIENCY

Availability of accurate data is essential to conduct any socio-economic study involving quantitative analysis. This research aims to examine production and profit efficiency of three different tea production methods, to evaluate factors affecting adoption of organic or clean tea production, to evaluate risks from changing the adoption probability and facing loses as different decision variables vary, and to analyze present value of net benefits for different tea production methods during the transition period (5 year span). For this study, the farm level cross-sectional data were collected for the production years from 2003-2007. Since farmers in Vietnam do not have to record all flows of outputs and inputs on their farms for tax filing purposes, it is difficult to have them recall detailed information for years prior to 2006. The available data are for the tea production year 2006 and the year when their tea farms were converted (for organic tea or clean tea production). Therefore, available data collected in this research involves the production years 2006, 2007 and data recalled when farms were converted to a new tea production practice. All economic data were then deflated to 2007[8] monetary values. The quantitative data for different inputs (e.g., labor, fertilizer, pesticide and herbicide, etc.) were computed based on the total amount of money used to purchase this input divided by its price. For example, the quantity of fertilizer equals the total amount of money spent for different types of fertilizers divided by urea (46% N) price (VND 4,900/kg) to get nitrogen equivalent quantity (in kg). Capital was obtained by the total value of machinery used for tea production (FAO, 2003; Kolawole, 2006; Sharma, Leung, & Zaleski, 1997; Shuwu, 2006) in VND1,000 (th.VND)

[8] CPI for 2007 is 7.7% (GSO, 2008)

4.1 Descriptive Data for Production Efficiency Analysis

4.1.1 Household Characteristics

In order to control for data reliability and validity, measurement and sampling errors, a number of tests and measurements were used. After the data were collected, a number of tests were employed to ensure obtaining unbiased estimates. These tests included testing for normality of residuals using the One Sample Kolmogorov-Smirnov test. The results suggest that some variables did not conform to the assumption of the regression analysis such as normality of the data. The data that violated the normality assumption were transformed by use of natural logarithms (Sheskin, 2004). Outliers "whose observations had large residuals were removed from the analysis such that cases with studentized residuals greater than absolute value of 2 were excluded" (Shuwu, 2006). In this research, Hadi (1992) method was used to identify outliers at the 5% level of significant (default in Stata. 9). The Variance Inflation Factor (VIF) procedure was used to detect multicollinearity and was preferred over the correlation coefficient method which fails to yield conclusive results (Pindyck and Rubinfield, 1981). If the VIF is greater than 10, then there is a potential multicolliearity problem (Neter, Wasserman, & Kutner, 1989). No serious collinearity problem among the independent variables was detected by the test.

Table 5. Household Characteristics

Statistics	Production method	Variables[9]					
		Age	Family size	Ethnicity	Education	Tea exp.	Distm.
Mean	Organic	43.2	4.1	1.7	2.3	19.1	1.6*(c)
	Clean	44.6	4.3	1.2** (a,b)	2.1	21.0	1.9
	Conventional	46.1	4.4	1.6	2.2	22.1	2.0
Standard Deviation	Organic	9.2	1.2	0.9	0.8	7.1	0.8
	Clean	10.6	1.1	0.5	0.5	8.2	0.7
	Conventional	9.3	1.1	0.9	0.6	10.1	0.8
Max	Organic	64.0	7.0	3.0	4.0	30.0	3.0
	Clean	75.0	10.0	3.0	3.0	43.0	3.0
	Conventional	65.0	8.0	3.0	3.0	50.0	3.0

** = statistically significant at the 5% level, * = statistically significant at the 10% level, (a): compared to organic tea; (b): compared to clean tea and (c): compared to conventional tea production.

[9] Distm is a distance from home to a closest local market = 1 if < 1 km, = 2 if from 1-2 km, = 3 if > 3 km; Age: age of the household head (years); Ethnicity: = 1 if Viet (majority), = 2 if Tay and = 3 otherwise; Education level of the household head: = 1 if elementary,= 2 if middle, = 3 if High school graduate and = 4 if higher; Tea exp is tea farming experience in years

Table 5. (Continued) Household Characteristics

Min	Organic	26.0	2.0	1.0	1.0	8.0	1.0
	Clean	27.0	2.0	1.0	1.0	5.0	1.0
	Conventional	21.0	2.0	1.0	1.0	5.0	1.0
Skewness	Organic	0.3	0.5	0.6	-0.1	0.3	0.8
	Clean	0.5**	0.7	3.1	0.4	0.3**	2.3
	Conventional	-0.04	0.5	0.8	0.1	0.3	0.04
Kurtosis	Organic	2.9	2.8	1.4	2.3	1.9	2.1
	Clean	2.9	4.2	10.6	4.6	2.7	2.3
	Conventional	2.7	3.8	1.7	2.9	2.5	1.8
Percentile	Organic	90% (30-60)	25%(4-5)	62% (=1)	90%(≥2)	95%(>10)	25%(≥2)
	Clean	90% (30-60)	50%(4-5)	89% (=1)	90%(≥2)	95%(>10)	50%(≥2)
	Conventional	85% (30-60)	50%(4-5)	65% (=1)	90%(≥2)	90%(>10)	50%(≥2)

** = statistically significant at the 5% level, and *** = statistically significant at the 1% level

Table 6. Tea Farm Characteristics

Statistics	Production method	Variables[10]				
		Tea stand	Distf.	Tea area	Irrigation	Capital
Mean	Organic	15.7	1.3	1,545***(b,c)	1.2**(c)	76,986***(b,c)
	Clean	16.7	1.3	3,763***(a,c)	1.2**(c)	8,878***(a,c)
	Conventional	16.9	1.3	2,569	1.4	20,719
Standard Deviation	Organic	6.9	0.5	762	0.4	69,820
	Clean	7.1	0.6	2,105	0.4	8,263
	Conventional	7.2	0.6	2,505	0.5	33,988
Max	Organic	32.0	2.0	4,000	2.0	255,675
	Clean	34.0	4.0	10,100	2.0	55,671
	Conventional	35.0	3.0	20,000	2.0	208,304

*** = statistically significant at the 10% level; ** = statistically significant at the 5% level, * = statistically significant at the 1% level, (a): compared to organic tea; (b): compared to clean tea and (c): compared to conventional tea production.

[10] Distf is a distance from home to the tea farm = 1 if < 200m, = 2 if 200m - <500m, = 3 if 500m -1000m, = 4 otherwise; tea stand = age in years; tea area (m^2); Irrigation = 1 tea farm is irrigated, = 2 otherwise; Capital is total value of machinery used for production/ha (th.VND).

Table 6. (Continued) Tea Farm Characteristics

Min	Organic	3.0	1.0	750	1.0	0.0
	Clean	3.0	1.0	720	1.0	0.0
	Conventional	3.0	1.0	450	1.0	0.0
Skewness	Organic	0.5	0.8	1.9**	1.3	0.5
	Clean	0.3	2.1	1.33**	1.4	2.2*
	Conventional	0.4	1.85	4.4**	0.3	2.7
Kurtosis	Organic	2.9	1.7	6.7***	2.8	2.6
	Clean	2.6	8.1	4.3**	3.4	7.6***
	Conventional	2.5	5.4	29.3***	2.0	11.1
Percentile	Organic	95% (8-32)	50%(=1)	75% (≥1000)	75%(=1)	80%(≥5000)
	Clean	90% (8-34)	75%(=1)	90% (≥1000)	75%(=1)	65%(≥5000)
	Conventional	90% (8-35)	50%(=1)	85% (≥1000)	50%(=1)	72%(≥5000)

** = statistically significant at the 5% level, and *** = statistically significant at the 1% level

The test for homogeneity of variance was conducted using the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity (Stata., 2007) and the null hypothesis of constant variances of the residuals was accepted ($p > 0.000$).The Ramsey test was conducted to test for omitted variables. The null hypothesis of no omitted variables was accepted. In addition to the Komogrov-Smirnov (K-S) test, the variables were corrected for normality using the skewness test as shown in Table 5. Descriptive statistics for the tea producing households in the research areas are presented in Table 5.

The results in Table 5 show that household characteristics are distributed evenly among three different tea producing groups. The means for age and education level of the household head, family size and ethnicity are insignificant among three different tea producing groups. On average, the household heads in the organic tea producing group have less tea farming experiences and their homes are closer to a market than those in the clean and conventional tea producing groups. There are only 25% of organic producers whose distance to a local market is greater than 1 km, whereas, there are 50% for clean and conventional tea groups. In terms of ethnicity, there are a higher percentage of Viet[11] people participating in clean tea production than other ethnic groups (75%) while the ratio of Viet people in organic and conventional tea groups are the same at 50%. Almost all (90%) of the heads of tea producing households are in their productive ages (from 30-60), have a middle school education (2), and with more than 10 years of experience in tea farming.

The Komogrov-Smirnov (K-S) test results show that age and tea farming experiences of the household heads for clean tea group were statistically skewed

[11] Viet is a majority ethnic group in Vietnam and accounts for about 86% of the total population (GSO, 2001)

distributions but not statistically significant for the Kurtosis test. As suggested by Sheskin (2004), translog forms will be used to correct skewedness problem. The results of the Komogrov-Smirnov (K-S) test for the translog form shows no presence of skewness for these mentioned variables. Since ethnicity, education and distm variables take only discrete values (e.g., 1, 2, 3 and 4) normality test for those variables is not applicable.

4.1.2 Tea Farm Characteristics

Tea farm characteristics, such as tea stand, irrigation status etc., are important factors considered as production efficient variables in production efficiency analysis Table 6 shows that, average tea stand in the sample is quite young (around 16 years). According to Do and Le (2000), the most productive period of the tea stand's life is from 10 to 30 years old. The 90% tea in the sample had stands ranging from 8-34 years old suggesting that most surveyed tea farms are in the most productive period. The average age for tea stand is also the same for all three tea production groups. The distance from home to the tea farm is also relatively short (percentage of tea growers having less than 200 m to travel between home and their tea farms are 50%, 75% and 50% for organic, clean and conventional tea producers respectively). A higher percentage of organic and clean tea farmers irrigate their tea crop than conventional tea growers in the sample. On average, organic tea growers have smaller tea farms (1545 m^2, 3763 m^2 and 2569 m^2 for organic, clean and conventional tea producers respectively) and have higher machinery investment for tea production than clean and conventional tea growers do.

The results of the Komogrov-Smirnov (K-S) test for normality of tea stand age, tea farm size and investment in capital with accompanying levels of significance (e.g. ** for significant at the 5% level and *** for significance at the 1% level) in Table 6 show that the data for tea farm size were skewed positively for all three tea producer groups. The distribution of data for tea farm size (in all three groups) is also statistically significant. For tea production and capital investment, the Komogrov-Smirnov (K-S) test shows that there is statistically significant appearance of a leptokurtic distribution (positive kurtosis value). To correct for skewness and kurtosis, translog forms were used in later analytical models as suggested by Sheskin (2004). The Komogrov-Smirnov (K-S) test for the trans-log form found these variables were not statistically significant in detecting the presence of neither skewness nor kurtosis.

4.1.3. Tea Production Characteristics

The descriptive statistics presented in Table 7 illustrate characteristics of important tea production variables for the farm sample. The data were collected from 23 organic producers, 67 clean tea producers and 86 conventional tea producers (after outliers and incomplete observations were excluded). Since farmers in the research areas face the same input prices, input quantities used were obtained by dividing total expenditures to purchase that input by its market price.

Statistically, organic tea production has a significantly lower yield than clean and conventional tea production. This result is also consistent with information gathered by organic tea growers i.e., organic tea yield is about 70% of conventional tea yield. A frequent reason given by organic tea producers was that during the transition period (switching to organic tea production) pests and diseases were primary causes of reductions in tea yields. Another explanation is nutrient deficiency due to terminating use of chemical fertilizers and tea grower inability to substitute organic manures in order to satisfy nutrient requirements of the plants. Approximately, half of the total organic tea producers have yields less than 80 quintals/ha while only 10% of the clean and conventional tea producers fall in this lower yield range. Organic tea producers also used much less fertilizers and pesticides (especially herbicides) as compared to clean and conventional tea producers. One of the reasons organic tea producers did not use herbicide is that there were no herbal or bio-herbicides available and organic tea producers are not allowed to use chemical inputs. Also, clean tea producers applied significantly less pesticides than conventional tea producers. The Komogrov-Smirnov (K-S) test shows the presence of a statistically significant negatively skewed distribution for tea yield and a positively skewed distribution for herbicide use for clean and conventional tea producer groups. Conventional tea production has both skewness and kurtosis problems for all inputs except labor. After using the translog-forms to correct these problems, a kurtosis problem still remained for pesticide and herbicide variables in the case of the conventional tea producer group.

Table 7. Tea Production Characteristics

Statistics	Production method	Variables[12]				
		Tea yield	Labor used	Fertilizer used	Pesticide used	Herbicide used
Mean	Organic	79.4***(b, c)	1291	858.9**(b,c)	23.1*** (b,c)	0***(b,c)
	Clean	94.2	1236	1195	68.9** (c)	4.9
	Conventional	93.5	1215	970.2	91.9	4.7
Standard Deviation	Organic	13.5	352	667.6	20.9	0
	Clean	12.4	461	568.4	28.3	7.6
	Conventional	15.6	493	667.2	75.6	7.8
Max	Organic	98.3	2004	2878.0	81.0	0
	Clean	114.1	2539	2828.0	171.1	32.8
	Conventional	115.7	2347	3894.0	415.0	32.0

*** = statistically significant at the 10% level, ** = statistically significant at the 5% level, * = statistically significant at the 1% level, (a): compared to organic tea; (b): compared to clean tea and (c): compared to conventional tea production.

[12] Unit for tea yield = quintal/ha; Labor= man day/ha; Fertilizer = kg of Urea equivalent/ ha, Pesticide = liter of Bassa equivalent/ha and Herbicide = kg of Lypoxin equivalent/ha

Table 7. (Continued) Tea Production Characteristics

Min	Organic	53.8	518	122	0	0
	Clean	42.9	424	193	7	0
	Conventional	42.5	332	0	0	0
Skewness	Organic	-0.3	0.2	0.2	0.9	N/A
	Clean	-1.6**	0.4	0.5	0.5	1.8***
	Conventional	-1.2**	-0.7	1.3**	1.4**	1.6***
Kurtosis	Organic	2.2	2.9	4.8**	3.5**	N/A
	Clean	6.7	2.8	2.8	2.3	5.8 ***
	Conventional	4.7**	2.2	6.3***	5.6***	4.9**
Percentile	Organic	50% (<80)	75%(≥1000)	75% (≥1000)	75%(< 35)	99% (0)
	Clean	10% (<80)	75%(≥1000)	75% (≥1000)	25%(< 35)	50% (0)
	Conventional	10% (<80)	75%(≥1000)	50% (≥1000)	25%(< 35)	75% (0)

** = statistically significant at the 5% level, and *** = statistically significant at the 1% level

4.2 Production Efficiency Analysis

4.2.1 Factors Affecting Production Efficiency

As presented earlier, three primary groups of variables affect production efficiency: household characteristics, tea farm characteristics and tea production characteristics. As discussed in section 3.4.1, all proposed variables influencing production efficiency were tested to determine their conformity to the normality assumption. The variables, after correcting for normality (i.e., skewness and kurtosis) see discussion in section 4.1, were regressed and checked for heteroskedasticity. The results of the Breusch-Pagan /Cook-Weisberg test are shown in Table 8.

Table 8. Results of Breusch-Pagan /Cook-Weisberg Test for the Production Model

	Organic tea		Clean tea		Conventional
Statistics	Before[a]	2006	Before	2006	2006
Chi^2	0.17	0.35	39.78***	58.62***	25.56***
Pro $Chi^2 > Chi^2$ bar	0.678	0.555	0.000	0.000	0.000
Test for H_0: constant variance					

[a] Before refers to data collected in the year before conversion occurred, and 2006 refers to data for the 2006 tea production year.

*** = statistically significant at the 1% level.

The test results in Table 8 showed the absence of heteroskedasticity in both data subsets of organic tea production. However, there were heteroskedasticity problems in the data subsets for clean tea production and conventional tea production. The correction for heteroskedasticity involves standardizing variables (dividing every variable by its standard deviation) as suggested by Varian (1984) and Kuosmanen et al. (2007), before doing the actual production efficiency analysis.

The empirical model developed for estimating tea production is:

$\ln yld = \beta_o + \beta_1 \ln labor + \beta_2 \ln fer + \beta_3 \ln tare + \beta_4 \ln pest + \beta_5 \ln stand + \beta_6 \ln texp + \beta_7 \ln capt + \beta_8 \ln age + \beta_9 distf + \beta_{10} ir + \beta_{11} fsiz + \beta_{12} eth + \beta_{13} edu + v + u$

where yld is tea yield (quintal/ha), labor is labor used (man day/ha), fer is fertilizer applied (kg of Urea equivalent/ ha), pest is pesticide applied (liter of Bassa equivalent/ha), distf is the distance from home to tea field (=1 if < 200m, = 2 if 200m-<500m, = 3 if 500m-1000m, = 4 if otherwise), stand is the age of the tea stand (years), tare is tea growing area (m^2), ir is irrigation status (= 1 if tea farm is irrigated, = 2 if otherwise), Capt is capital (values of machineries used for tea production ha), age is the age of the household head (years), eth is the ethnicity of the tea grower(= 1 if Viet, = 2 if Tay and = 3 if otherwise), edu is the education level of the household head (=1 if elementary,= 2 if middle, =3 if high school graduate and = 4 if higher), and Texp is tea farming experience (years)

4.2.2 Organic Tea Production

Results of the production efficiency analysis presented in Table 9 were based on the stochastic frontier function analysis (SFA) assuming that tea production can be approximated by a Cobb-Douglas production function as discussed in section 3.4.1 earlier.

Table 9. Statistics of Production Efficiency Analysis for Organic Tea

Variables	Before conversion		2006 production year	
	Coefficient	Prob. |t| > t	Coefficient	Prob. |t| > t
Constant	2.344***	0.010	2.783*	0.063
Labor	0.265**	0.028	0.243*	0.066
Fertilizer	0.0008	0.811	0.082	0.215
Pesticide	0.013*	0.051	0.0006	0.906
Capital	0.0012	0.761	0.009**	0.042
Tea farm size	-0.041	0.644	-0.064	0.480
Tea stand	0.047	0.384	0.204***	0.002
Distance to fields	-0.138**	0.043	-0.089	0.228
Irrigation	0.029	0.802	0.0005	0.997
Tea farming experience	-0.011	0.884	-0.124	0.148
Age of HH head	0.106	0.458	-0.159	0.277
Ethnicity	-0.067	0.215	-0.0008	0.989
Education	0.042	0.461	-0.059	0.461
Family size	0.068***	0.007	0.095***	0.001
Lnsigma^2_v	-4.618***	0.000	-4.492***	0.000
Lnsigma^2_u	11.413	0.938	-12.113	0.965
Wald chi^2(11)	30.86***	0.002	40.50***	0.000
R^2 of production function	0.59		0.64	

* = statistically significant at the 10% level, ** = significant at the 5% level,

*** = significant at the 1% level and n=23; Source: Computed from field data survey

The results of the variance analysis (Lnsigma^2_v for random effect and Lnsigma^2_u for production inefficiency effect) show that organic tea farmers are very production efficient.

The random effects for production efficiency in both cases, before conversion to organic production and the 2006 production year, are statistically significant at the 1 % level whereas inefficiency effects are not significant for both cases (p values = 0.94 and 0.96 for before conversion and for the year 2006 respectively). Among production factors, only labor has significant effects on tea production efficiency for both cases, (before conversion to organic tea production and for the 2006 production year). These results reflect typical family tea farms with labor intensive, whereas, the capital investment in tea production has positive and significantly effects on tea production efficiency for only organic tea production in 2006. As required by organic production procedures (IFOAM, 2005), no chemically synthetic inputs are allowed, tea growers tend to substitute chemical inputs with labor and capital inputs, especially for weed and pest control. This is illustrated by the labor and capital coefficients where both have significant effects on production efficiency for organic tea production while labor and pesticide have positive and significant effects on production efficiency before the conversion. Fertilizers and pesticides do not show significant effects on tea production efficiency for organic tea production in 2006.

The tea stand variable has a positive and significant effect on tea production efficiency for organic tea production in the year 2006. According to Do and Nguyen (1977), the tea stand of age 10-30 years is in its most productive period for tea plants, For the surveyed organic tea farmers, the average age of their tea stands was 15.7 years (section 4.1.2) . Older tea fields imply higher production efficiency (as shown by the significant tea stand coefficient) for the 2006 production year. Since organic production is accomplished by using biological and mechanical methods (Codex Alimentarius Commission, 2004) the mature tea farm will be more production efficient. For factors affecting efficiency, only family size has a statistically significant effect on the production efficiency of organic tea production before conversion and for the 2006 production year. The positive effect of family size on tea production efficiency for organic tea production is consistent with high family labor required and the substitution of family labor for other chemical inputs as shown and discussed earlier. Before conversion, the negative and significant effect of distance to fields (i.e., from home to tea fields) on production efficiency in the before conversion case implies that farther fields are less production efficient. This reflects the fact that closer tea fields generally receive more intensive care and management, especially for pest and disease controls than those fields farther from home.

4.2.3 Clean Tea Production

The results in Table 10 illustrate the influences of different production and inefficiency variables on production efficiency for clean tea producing farms. As defined by VTA (2004), clean tea production is a tea farming practice that minimizes usage of pesticides and other chemical inputs and by adopting Integrated Pest Management (IPM) pest and disease control strategy for tea production. The products from the clean tea production method are free of pesticide and chemical residues but are not certified as organic. Unlike the results for organic tea production efficiency analysis shown earlier, there are a few differences in terms of coefficient magnitudes and signs of coefficients of different production variables. Among production factors, only pesticide has a significant and negative effect on production efficiency of clean tea production for both before conversion and the 2006 production year. The effect of pesticide on production efficiency can be explained by the fact that their use recommended only as part of an IPM strategy for pest and disease controls. Also, for clean tea production, use of pesticide was not prohibited as in organic tea production. Before joining clean tea production program, most clean tea producers belonged to IPM clubs where they were trained in how to control pests without or by minimizing the application of pesticides. Therefore, for clean tea production, those farmers applying pesticides are not efficient farmers (as shown by the negative coefficient). Similar to the organic tea production results, the age of the tea stand also has a significant effect on clean tea production efficiency.

Among technical inefficiency factors, only family size has a statistically significant effect on production efficiency for clean tea farms. The negative relationship between family size and tea production efficiency is probably due to chemical input use not being strictly controlled. Therefore, clean tea production does not require more labor intensive practices than organic tea production and larger family size may lead to a surplus of family labor supply, hence, lower efficiency.

Results from the variance analysis for random errors (lnsigma^2_v) and inefficiency (lnsigma^2_u) show the significant presence (at the 1% level) of production inefficiency in clean tea production. For farms before conversion and in 2006, it appears that almost the same influence on production inefficiency exists both before conversion and in the year 2006 for clean tea farms (lnsigma^2_u = -3.104 and -3.183 for before conversion and for the year 2006 respectively).

Table 10. Statistics of Production Efficiency Analysis for Clean Tea

Variables	Before conversion		2006 production year	
	Coefficient	Prob. |t| > t	Coefficient	Prob. |t| > t
Constant	2.073***	0.000	2.252***	0.000
Labor	0.115*	0.052	0.068	0.261
Fertilizer	0.084	0.123	0.040	0.259
Pesticide	-0.047*	0.061	-0.042*	0.080
Capital	-0.012	0.121	-0.003	0.654
Tea farm size	-0.027	0.442	-0.009	0.809
Tea stand	0.067**	0.049	0.014*	0.052
Distance to fields	-0.004	0.916	-0.006	0.901
Irrigation	0.026	0.707	-0.018	0.776
Tea farming experience	0.021	0.783	-0.064	0.219
Age of HH head	0.007	0.939	0.069	0.372
Ethnicity	-0.085	0.292	-0.134	0.115
Education	-0.036	0.472	-0.024	0.671
Family size	-0.002	0.924	-0.029*	0.081
Lnsigma^2_v	-37.143	0.950	-37.494	0.959
Lnsigma^2_u	-3.104***	0.000	-3.183***	0.000
Wald chi^2(11)	68.62***	0.000	37.97***	0.000
R^2 of production function	0.36		0.38	

* = statistically significant at the 10% level, ** = significant at the 5% level,

*** = significant at 1% level and n = 67; Source: Computed from field survey data.

4.2.4 Conventional Tea Production

Table 11 shows the results of the production efficiency analysis for conventional tea production. The statistically negative and significant coefficients of Lnsigma^2_u (inefficiency error) and Lnsigma^2_v (random error term) illustrate significant presence of production inefficiency and random effects in conventional tea production in the research areas.

Similar to organic tea production before conversion, only labor and pesticide played statistically significant roles in improving production efficiency for conventional tea production farms (positive coefficients of 0.104 and 0.007 for labor and pesticide respectively). The significant and negative effect of farm size on production efficiency for conventional tea production reflects inconsistency in labor intensive tea farming practices. This implies that smaller farms will be managed more efficiently. For inefficiency parameters, tea stand has a positive and significant effect on tea production efficiency for conventional tea production (similar to clean and organic tea production). This observation is consistent with what was discussed earlier about the role of tea stand age contributing to tea production efficiency.

Unlike organic tea production, for conventional tea production the distance from home to tea farms has a significant and positive relation to tea production efficiency (farther tea farms are more efficient). One explanation is conventional tea farmers tend to reduce pesticide applications on tea fields closer and surrounding their homes. This together with the positive effect of pesticides on tea production efficiency helps explain why tea farms close to farmers' homes are less efficient.

Table 11. Statistics of the Production Efficiency Analysis for Conventional Tea

	2006 production year	
Variables	Coefficient	Prob. |t| > t
Constant	3.863***	0.000
Labor	0.104*	0.092
Fertilizer	-0.002	0.642
Pesticide	0.007*	0.093
Capital	0.002	0.372
Tea farm size	-0.003	0.914
Tea stand	0.003	0.914
Distance to fields	0.061**	0.017
Irrigation	-0.097**	0.048
Tea farming experience	0.013	0.687
Age of HH head	-0.019	0.823
Ethnicity	0.008	0.732
Education	-0.004	0.413
Family size	0.028**	0.043
$Lnsigma^2\_v$	-5.610	0.000
$Lnsigma^2\_u$	-3.219***	0.000
Wald $chi^2(11)$	40.51	0.000
R^2 of production function	0.55	

* = statistically significant at the 10% level, ** = significant at the 5% level,
*** = significant at the 1% level and n = 86; Source: Computed from field survey data.

The statistically significant and positive effect of the family size variable on production efficiency for conventional tea production suggests that farms with larger family sizes tend to be more efficient given the labor intensiveness of family farming operations. The negative and statistically significant effect of irrigation status suggests that irrigated tea farms are more production efficient. Although tea is an upland crop, it still favors warm and humid growing conditions. Irrigation becomes more essential for tea production in the Northern areas of Vietnam during the dry months (September to December) of the year (Do and Le, 2000). Therefore, irrigated tea fields are more production efficient.

4.2.5 Mean Comparison of Production Efficiency

- Temporal Comparison

Table 12. Temporal Comparison of Mean Production Efficiency

	Organic tea production		Clean tea production	
Statistics	Before conversion	In 2006	Before conversion	In 2006
Mean	0.997	0.998	0.869	0.879
Sdv. of mean	0.00004	0.00002	0.11312	0.11259
Prob. $\|t\| > t$				
H_0: diff.=0	0.000***		0.293	

*** = significant at the 1% level

The temporal mean comparison results for production efficiency presented in Table 12 show that organic tea producers are very production efficient. Although there is a higher mean production efficiency (0.998) for organic farms in 2006 as compared to before conversion to organic tea production (0.997), the difference is very small but the difference in means is statistically significant. There are no statistically significant differences between means for the case of clean tea production (comparing before conversion with production in 2006). By definition (VAT, 2005), the main differences in terms of input use for these two cases were the reduced usages of pesticides and applying fertilizers more adequately.

- *Mean Comparison Cross Different Tea Production Methods*

The results shown in Table 13 are results from comparing mean (average) value of production efficiency for the three different tea production methods (e.g., organic, clean and conventional tea production). The results show the highest production efficiency (0.998) is obtained from organic tea production which also has the smallest standard deviation (0.00002). While, conventional tea production has the lowest mean production efficiency (0.859) and the largest standard deviation (0.11596). Also, organic tea producers have significantly higher production efficiency than either clean tea producers or conventional tea producers. Whereas, there are no statistically significant differences in mean production efficiency levels between clean tea producers and conventional tea producers. This result is also consistent with findings in Table 10 showing no significant difference between the production efficiency before conversion to clean tea production and tea production for the year 2006. Furthermore, combining this result with the production efficiency performance of organic tea producers before they converted to organic tea production it can be inferred that farmers who adopt organic tea production are very efficient farmers.

Table 13. Cross Comparison of the Means of the Production Efficiency in 2006

	Statistics		
Pair-comparison	Mean	Standard deviation	Prob. $\|t\| > t^a$
Organic tea v.s.	0.998	0.00002	0.000***
Clean tea	0.879	0.11259	
Organic tea v.s.	0.998	0.00002	0.000***
Conventional tea	0.859	0.11596	
Clean tea v.s.	0.879	0.11259	0.285
Conventional tea	0.859	0.11596	

[a] H_0: No difference in means, *** = significant at the 1% level.

Source: data computed from field survey data in 2007.

CHAPTER V

PROFIT EFFICIENCY ANALYSIS

5.1 Descriptive Data for Profit Efficiency Analysis

According to production theory, a farmer is assumed to choose a combination of variable inputs and outputs that maximize profit subject to technology constraints (Sadoulet & de Janvry, 1995). Tea profit efficiency as defined in this study is the profit gains from operating on the profit frontier taking into consideration farm specific prices and factors. A tea farm is assumed to operate by maximizing profit subject to perfectly competitive input and output markets and a given output technology. Tea farm profit is measured in terms of Gross Margins that equal total revenue (TR) minus total variable cost (TVC) (Kolawole, 2006; Shuwu, 2006; FAO, 2003; Coelli, 1998; Ali and Flinn, 1989). It is currently possible to incorporate institutional and environmental factors, such as quality of soils, water and rainfall as shown by (Ali and Flinn, 1989; Coelli ,1995). Regularity conditions require that the function be non-negative, monotonically increasing in output, convex and homogeneous of degree zero in all prices. To minimize problems from using different measurement units and to comply with "regularity conditions", Thompson and Mark (1989), Goyal and Berg (2004), FAO (2003), Kolawole (2006) used a normalized profit function, which is, dividing profit, input prices, and other factors by output price(s). The descriptive statistics presented in Table 14 are for normalized variables.

The Cobb-Douglas form of the profit function was described in the equation 3.6 earlier.

$$\ln\frac{v\pi}{p} = \beta_0 + \sum_n \beta_n \ln\frac{w_n}{p} + \sum_q \beta_q \ln z_q + v_\pi + u_\pi \qquad (5.1)$$

where v_{it} represents the random effect and u_{it} represents the inefficient effect which includes age of household heads, education level, tea farming experience, distance from home to the closest local market, and tea farm size. These socio-economic variables are included in the analytical model to determine their possible influence on profit inefficiency for tea production. Conformity to Hotelling's Lemma we would expect negative signs for input cost and input price coefficients (Coelli, Prasada Rao, & Battese, 1998). It is hypothesized that the cost of inputs negatively affects profit efficiency (Ali and Flinn, 1989; Shuwu, 2006). Sigma^2_v (σ^2_v) and sigma^2_u (σ^2_u) are the variances of the random effect and of the inefficient effect used to measure variation of profit from the frontier that can be attributed to profit inefficiency (Battese & Corra, 1977). In this research, lnsigma^2_v and lnsigma^2_u will be used to replace σ^2_v and σ^2_u as suggested by Battese and Coelli (1993).

The model for estimation is

$$\ln(profit/p) = \beta_0+\beta_1\ln(plabor/p)+\beta_2\ln(pfer/p)+\beta_3\ln(pecost/p)+\beta_4\ln(hcost/p)+\beta_5\ln(ocost/p)$$
$$+\delta_1\ln texp+\delta_2\ln age+\delta_3\ln tare+\delta_4 distm+\delta_5 edu \quad (5.2)$$

where profit is net returns (th.VND), plabor is the price of labor[13] (th.VND/man day), pfer is the price of fertilizer (th.VND/ kg of nitrogen equivalent), pecost is the expenditure for pest and disease control[14] (th.VND), hcost is the expenditure for health care and hospitalization (th.VND) as an indirect measurement of environmental cost, ocost is other variable costs in th.VND (fuel, irrigation fee etc.,) texp is tea growing experience (years), age is the age of the household head (years), tare is the tea farm size

[13] Labor in this research was treated as aggregated variable consisting of family labor and hired labor for tea production per hectare (Lau and Yotopoulos, 1971; Sharma et al., 1999).
[14] For organic tea production, pesticide use is not allowed. Given this requirement, total expenditure for pest and disease control is used to replace pesticide and herbicide prices.

(m^2), distm is the distance from home to the closest local market (= 1 if < 1km, = 2 if from 1-2 km, = 3 if >3 km), and edu is the education level of the household heads (= 1 if elementary education,= 2 if middle school education, = 3 if high school graduate and = 4 if higher).

All variables in the model were corrected for normality problems (skewness and kurtosis) by using the translog form as discussed in section 4.1. Equation 5.2 was estimated and to checked for heteroskedasticity. The results of Breusch-Pagan /Cook-Weisberg test are shown in Table 14.

Table 14. Results of Breusch-Pagan /Cook-Weisberg Test for Profit Model

	Organic tea		Clean tea		Conventional
Statistics	Before[a]	2006	Before	2006	2006
Chi^2	0.03	0.30	4.69**	51.38***	27.53***
Pro $Chi^2 > Chi^2$ bar	0.871	0.585	0.030	0.000	0.000

H_0: constant variance.

** = significant at the 5% level, and *** = significant at the 1% level.

[a] Before refers to data collected in the year before conversion.

The test results in Table 14 showed an absence of heteroskedasticity in the data subsets for organic tea production. However, there were heteroskedasticity problems in the data subsets for clean tea production and conventional tea production. Similar to what was done in section 4.1 of the analytical model for production efficiency, a correction for heteroskedasticity was done by standardizing variables (dividing every variable by its standard deviation) as suggested by Varian (1984) and Kuosmanen et al. (2007) before running the actual profit efficiency analytical model.

As discussed in section 4.1, following data collection a number of tests were conducted to ensure that theoretical assumptions for the model were not violated and the estimates were unbiased. These tests include tests for normality, an outlier test, a test for omitted variables and a test for variance homogeneity. The latter test for homogeneity was conducted using the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity (Stata, 2007) and the null hypothesis of constant variances for residuals was accepted ($p > 0.000$). The Ramsey test was conducted to test for omitted variables. The null hypothesis of no omitted variables was accepted. In addition to the Komogrov-Smirnov (K-S) test, the variables were corrected for normality by using the skewness test for variables included in the profit efficiency analytical model shown in Table 15. The descriptive statistics in Table 15 show that organic farmers face the lowest normalized prices (price ratios for each input). Since the market for agricultural inputs are very competitive and farmers in the research areas face almost identical input prices, low price ratios (normalized input prices) can be attributed to the higher output price received by organic tea farmers. There is a significant reduction in health care costs for organic tea farmers as compared to those in clean tea and conventional tea production. By contrast, conventional tea farmers face the highest normalized input prices. Although actual input prices in the market are almost the same, conventional tea producers have to deal with the highest normalized input prices and receive the lowest output prices. Conventional tea growers also paid higher health care costs, pest control costs and other variable costs as compared to organic and clean tea farmers.

The Komogrov-Smirnov (K-S) test results shown in Table 15 indicate that health care related cost data for clean tea and conventional tea production have positively skewed and leptokurtic (positive kurtosis) problems while other cost data for conventional tea production only has the leptokurtic problem. Note that organic tea production problems deal with kurtosis but not skewedness. Pest control cost for clean and conventional tea production has positive kurtosis but not skewedness. A correction procedure is to transform these variables to natural logarithms before running the analytical model.

5.2 Profit Efficiency Estimation

Profit efficiency for different tea production methods can provide important information to tea growers contemplating switching production methods. Profit efficiency is also of interest to policy makers interested in developing government intervention programs. The dual method applied in this research to analyze tea profit efficiency provides information about factors influencing profit efficiency and the estimated magnitudes of these effects.

5.2.1 Profit Efficiency of Organic Tea Production

The results from the profit efficiency estimation for organic tea production are presented in Table 16. These results are based on the stochastic frontier profit efficiency analysis and on the assumption that tea production can be approximated by a Cobb-Douglas production function (as discussed in section 5.1). The results from the variance analysis (Lnsigma^2_v for random effect and Lnsigma^2_u for profit inefficient effect) show that although in the production efficiency analysis, the random effects for production efficiency both before conversion to organic production and also for the year 2006 are statistically significant at the 1 % level, random effects for profit efficiency are only statistically significant before conversion. Whereas, the inefficient effect for profit efficiency is not significant before conversion but statistically significant for the 2006 production year. Before conversion to organic tea production, only labor price is a statistically significant effect on profit efficiency. The negative effect of labor price on profit efficiency is theoretically expected (Ali and Flinn (1989) and Shuwu (2006). The negative and significant effect of the pest and disease control costs for organic tea production in the 2006 production year conforms with theoretically hypothesized theory and observations made earlier by Ali and Flinn (1989), Kolawole (2006), Abdulai and Huffman (2000). This reflects the fact that for organic tea production pest control costs contribute significantly to reduced profit due to applying higher cost pest control measurement to substitute for synthetic pesticide. The positive and significant effects of the tea growing experience variable for organic tea production in the 2006 production year imply that more experience in tea growing will reduce tea profit inefficiency. These results are consistent with Ali and Flinn (1989), Abdulai and Huffman (2000) and Shuwu (2006). The positive coefficient of tea growing experience implies that experienced tea farmers are better performers than those without experiences. This result is similar to the result reported by Ali and Byerlee (1991), and Sharma et al., (1999). Note that labor and fertilizer prices do not have statistically significant effects on profit efficiency for organic tea production in 2006. They also reflect the fact that most of organic tea farms using family labor and applying domestic animal manures to substitute for chemical fertilizers. Therefore, changes in the price of hired labor and chemical fertilizer price do not entail significant changes in profit efficiency

Table 15. Descriptive Statistics of Variables for Profit Efficiency Analysis (2006)

Statistics	Production method	Variables[15] (Normalized variables)					
		profit	plabor	pfer	pecost	hcost	ocost
Mean	Organic	4510	2.25** (b,c)	1.19**(b,c)	111***(b,c)	83***(b,c)	799(c)
	Clean	4632	2.69	1.43	415***(c)	174	736
	Conventional	3459	3.46	1.84	646	331	1163
Standard Deviation	Organic	1687	0.41	0.22	92	112	483
	Clean	1631	0.47	0.25	271	286	380
	Conventional	1742	0.98	0.53	501	1013	771
Max	Organic	7201	2.9	1.5	283	526	1769
	Clean	7400	3.6	1.9	1282	1808	1941
	Conventional	6295	6	3.2	2333	8930	4744

* = statistically significant at the 10% level, **= significant at the 5% level, *** = significant at the 1% level.

(a): compared to organic tea; (b): compared to clean tea and (c): compared to conventional tea production.

[15] Profit denotes normalized profit, plabor is normalized price of labor, pfer is normalized price of fertilizer, pecost is normalized pest control costs, hcost is normalized health care costs, and ocost is normalized other variable costs (fuel, irrigation etc.,)

Table 15. (Continued) Tea Farm Characteristics

Min	Organic	214	1.5	0.8	0	0	0
	Clean	142	1.9	1	56	0	0
	Conventional	0	2.1	1.1	0	0	0
Skewness	Organic	-0.63	-0.30	-0.46	-0.42	2.76	0.19
	Clean	-0.74	0.12	0.08	0.13	4.39**	0.67
	Conventional	-0.49	0.57	0.57	1.19	7.46***	1.58
Kurtosis	Organic	2.89	2.56	2.36	1.92	11.60***	2.59
	Clean	3.44*	1.73	1.76	1.91**	23.44***	3.35**
	Conventional	2.24	2.40	2.36	4.09**	62.74***	7.81***
Percentile	Organic	57%>5000	75%<2.5	99%<1.5	75%< 190	25%> 105	71%>1000
	Clean	50% >5000	48%< 2.5	68% < 1.5	24% < 190	50%> 105	81%> 1000
	Conventional	23%>5000	25< 2.5	28% < 1.5	20% < 190	41%> 105	51%> 1000

* = statistically significant at the 10% level, ** = significant at the 5% level, *** = significant at the 1% level,

Table 16. Profit Efficiency Estimation for Organic Tea Production

	Before conversion		2006 production year	
Variables	Coefficient	Prob. |t|>t	Coefficient	Prob. |t|>t
Constant	10.783	0.000	7.5110	0.000
Labor price	-0.737**	0.021	-0.497	0.858
Fertilizer price	-0.065	0.378	0.403	0.861
Pest control cost	-0.073	0.270	- 0.023*	0.057
Health care cost	-0.051	0.298	-0.005	0.186
Other variable costs	-0.014	0.885	-0.007	0.583
Tea farm size	0.012	0.527	-0.164	0.542
Distance to market	-0.027	0.789	-0.049	0.747
Tea growing experience	0.099	0.717	0.796**	0.012
Age of HH head	0.014	0.959	-0.392	0.141
Education	0.016	0.863	0.320	0.425
Lnsigma^2_v	-3.541***	0.001	-32.797	0.967
Lnsigma^2_u	-3.442	0.183	-0.667**	0.024
Wald chi^2(11)	15.02*	0.059	2.6e+07***	0.000
R^2 of profit function	0.51		0.53	

* = statistically significant at the10% level, ** = significant at the 5% level,

*** = significant at the 1% level and n = 23; Source: Computed from field data survey

5.2.2 Profit Efficiency of Clean Tea Production

The results in Table 17 show the influences of different input prices and inefficiency variables on profit efficiency for clean tea production farms. As defined by VTA (2004), clean tea production is a tea farming practice that minimizes usage of pesticides and other chemical inputs and adopts Integrated Pest Management (IPM) for pest and disease control in tea production. The products from clean tea production are free of pesticides and chemical residues but are not certified as organic. This can be thought of as an intermediate tea production method between the conventional and organic tea production methods.

Unlike the results of organic tea profit efficiency shown previously, fertilizer price has a statistically negative and significant effect on profit efficiency for clean tea production in both cases, before conversion and the 2006 production year. This negative fertilizer price coefficient conforms to the theoretical hypothesis shown in 5.1. Similar results were reported earlier by Ali and Flinn (1989), Abdulai and Huffman (2000), Kolawole (2006) and Shuwu (2006).

The positive and significant effects of education and tea growing experience variables on profit efficiency are expected as discussed in section 5.1.1. These effects imply that higher education and more tea growing experience enable farmers to reduce profit inefficiency. These results are consistent with Ali and Flinn (1989), Abdulai and Huffman (2000) and Shuwu (2006). Thus, more education to organic tea farmers in particular would be very beneficial in terms of reducing profit inefficiency. The positive coefficient of tea growing experience implies that experienced tea farmers are better performed than those without experience. This result is similar to earlier studies reported by Ali and Byerlee (1991), and Sharma et al., (1999).

The negative effect of distance (from home to the local market) for 2006 indicates that being farther away from the market tea farmers will incur larger transportation costs. The positive and significant effects of the farm size variable for 2006 is similar to results reported by Ali and Byerlee (1991), Abdulai and Huffman (1988) and Kolawole (2006). Namely, larger farm size enable farmers to take advantage of the economies of size and scale to improve profit (Mathijs & Swinnen, 2001).

Although the positive and significant effect of the labor price variable on profit efficiency for clean tea production before conversion is hypothetically unexpected, Kolawole (2006) and Shuwu (2006) reported similar results for rice production in Nigeria and Uganda respectively. Note that before conversion, all clean tea farmers were already in IPM (Integrated Pest Management) clubs where they were trained with IPM techniques to control pests. The IPM production method requires more family labor to manage tea fields, protect pest enemies and control pests, which could explain the positive effect of labor cost on profit efficiency as discussed in section 5.2.1.

The positive and significant effects of education and tea growing experience variables on profit efficiency are expected as discussed in section 5.1.2. These effects imply that more tea growing experience enable farmers to reduce profit inefficiency. These results are consistent with Ali and Flinn (1989), Abdulai and Huffman (2000) and Shuwu (2006).

Results of the variance analysis for the random error (lnsigma^2_v) are statistically insignificant for both cases, before conversion and in 2006. The inefficient elements

($lnsigma^2$_u) are significant (at the 1% level) for both cases. Also note that the coefficient of determinant for these profit equations in both cases is low ($R^2 = 0.35$ and 0.36 for before conversion and 2006 respectively).

Table 17. Profit Efficiency Estimation for Clean Tea Production

Variables	Before conversion		2006 production year	
	Coefficient	Prob. |t| > t	Coefficient	Prob. |t| > t
Constant	10.013***	0.000	11.910***	0.000
Labor price	0.553***	0.000	0.099	0.740
Fertilizer price	-0.194***	0.000	-0.397***	0.001
Pest control cost	-0.035	0.269	-0.048	0.359
Health care cost	0.021	0.472	-0.006***	0.000
Other variable costs	-0.047	0.463	-0.009	0.688
Tea farm size	-0.018	0.692	0.164**	0.031
Distance to market	0.035	0.227	-0.121***	0.005
Tea farming experience	0.105**	0.018	0.064***	0.000
Age of HH head	-0.239***	0.000	-0.062	0.747
Education	0.080***	0.000	0.085	0.121
$Lnsigma^2$_v	-36.698	0.958	-34.885	0.964
$Lnsigma^2$_u	-2.041***	0.000	-0.735***	0.000
Wald $chi^2(11)$	11510***	0.000	3.2e+08***	0.000
R^2 of profit function	0.35		0.36	

* = statistically significant at the 10% level, ** = significant at the 5% level,

*** = significant at the 1% level and n = 67; Source: Computed from field data survey.

Table 18. Profit Efficiency Estimation for Conventional Tea Production

	2006 production year	
Variables	Coefficient	Prob. |t|>t
Constant	8.298***	0.000
Labor price	2.684	0.576
Fertilizer price	-4.194**	0.004
Pesticide price	-0.053***	0.000
Health care cost	0.007	0.180
Other variable costs	-0.006	0.699
Tea farm size	0.516	0.248
Distance to market	0.031	0.706
Tea farming experience	-0.456	0.457
Age of HH head	0.338	0.711
Education	0.047	0.248
$Lnsigma^2\_v$	-28.23	0.904
$Lnsigma^2\_u$	3.90***	0.000
Wald $chi^2(11)$	4.8e+06***	0.000
R^2 of profit function	0.35	

* = statistically significant at the 10% level, ** = significant at the 5% level,

*** = significant at the 1% level and n = 86; Source: Computed from field survey data.

5.2.3 Profit Efficiency of Conventional Tea Production

Table 18 shows the results from profit efficiency estimation for conventional tea production. The coefficient of Lnsigma^2_v (random error) is not statistically significant implying a non-significant presence of random factors in conventional tea production for the sample. However, the variance for the inefficiency effect (Lnsigma^2_u) is statistically significant at the 1% level implying a significant presence of inefficiency on tea profit efficiency for conventional tea production in the sample.

Among input price variables, fertilizer and pesticide have statistically significant effects on profit efficiency. However, the negative signs for the coefficients of fertilizer price and pest control costs (expected signs as discussed in section 5.1) showing that as the price of fertilizer and pest control costs increase, profit efficiency will decrease. These results conform to previous work done by Ali and Flinn (1989), Abdulai and Huffman (2000), Kolawole (2006) and Shuwu (2006). Conventional tea production in the Thai Nguyen province is very typical and resembles an intensive farming practice where synthetic inputs are used intensively (Gwenaelle & Alberik, 2001). The negative and large coefficient of fertilizer price illustrates a large dependency of conventional tea production on chemical inputs. The intensive use of fertilizers and pesticides led to increased fertilizer and pesticide costs. To halt use of chemical inputs and pesticides will likely cause a large reduction in tea yield and, hence, tea production profit.

5.2.4 Mean Comparison for Profit Efficiency Analysis

- Temporal Comparison

Table 19. Temporal Comparison for the Mean of Profit Efficiency

	Organic tea production		Clean tea production	
Statistics	Before conversion	For 2006	Before conversion	For 2006
Mean	0.733	0.836**	0.487***	0.747
Sdv. of mean	0.263	0.092	0.344	0.232
Prob. |t| > t				
H_0: diff.=0	0.037		0.000	

*** = significant at the 1% level,

Temporal comparison for the mean of profit efficiency presented in Table 19 show that organic tea producers are high profit efficient farmers. The difference between means test is statistically significant for organic tea production with a 0.836 average, efficiency level in 2006 compared to a before conversion of 0.733. Also there is statistical significant difference between the mean of profit efficiency for clean tea production comparing before conversion with clean tea production in 2006 (0.487 for before conversion as comparing to 0.747 for 2006). By definition (VAT, 2005), the main differences in terms of input uses between conventional tea (in this case, tea farms before conversion to clean tea production) and clean tea production were using less pesticides and applying fertilizers more judiciously (balancing of macro nutrients for tea) when switching to clean tea. As observed in section 5.2.1, there may be some tradeoff between the effects from different inputs used and greater efficiency in using chemical inputs.

Therefore, there is an obvious improvement in tea profit efficiency level for clean tea production comparing before conversion and the 2006 production year ,

Table 20. Cross Comparison of the Means of Profit Efficiency for 2006

	Statistics		
Pair-comparison	Mean	Standard deviation	Prob. |t| > t*
Organic tea v.s.	0.836	0.092	0.011**
Clean tea	0.747	0.232	
Organic tea v.s.	0.836	0.092	0.000***
Conventional tea	0.454	0.285	
Clean tea v.s.	0.747	0.232	0.000***
Conventional tea	0.454	0.285	

H_0: No difference in means, *** = significant at the 1% level

Source: data computed from field survey data in 2007.

The results shown in Table 20 illustrate the mean comparison of profit efficiency for three different tea production methods (e.g., organic, clean and conventional tea production) using the Stochastic Profit Frontier Analysis (SFA). The results show that the highest profit efficiency (0.836) is obtained from organic tea production with a small standard deviation (0.092). Conventional tea production has the lowest mean profit efficiency (0.454) and the largest standard deviation (0.285). Organic tea producers have significantly higher production efficiency and profit efficiency than that of clean tea and conventional tea producers. Also, clean tea producers have a significantly higher mean profit efficiency level as compared to conventional tea producers although there is no significant difference between the mean production efficiencies of clean tea and conventional tea production.

Results of the production and profit efficiency analyses for three different tea production methods in the Thai Nguyen province indicate that organic tea farmers have the highest efficiency levels for both production and price analyses. Although there is no difference in terms of the production efficiency, there is higher profit efficiency for clean tea production than for conventional tea production. Also, the results show a very low profit efficiency level for conventional tea producers (an average of 0.45).

CHAPTER VI

ADOPTION ANALYSIS

Although organic tea production is not a newly invented technology, conversion to organic tea production requires strict compliance with organic producing requirements which entail possible risks to tea growers. Adoption analysis will help identify primary factors which influence tea growers' decision for switching to organic tea production. Numerous theories have been put forward to interpret patterns of new technology adoption. The technology adoption elements highlighted by these theories include: the role of information and time; the cost-performance of new technology relative to other production factors; the influence of individual characteristics, such as size, age or ownership and managerial and labor qualities; product and market factors; spatial agglomeration and proximity and economic conditions and institutional and policy environment (Sweeney, 1987; Tornatzky, Fleisher, & Chakrabarti, 1990). This study is based on primary data collected from field surveys in the Thai Nguyen province and literature suggested by Sweeney (1987), Tornatzky and Chakrabarti (1990) and Mendola (2007) to form the adoption model for analysis.

6.1 Descriptive Data of Independent Variables for Analytical Model

6.1.1 Descriptive Data for Organic Tea Adoption Analysis

To analyze the adoption of organic tea production as a new technology (see discussion in section 3.2) it is assumed that the new technology adopted (e.g., organic tea production) is a function of a wide range of household characteristics (Mendola, 2007). Table 21 reports descriptive statistics for the adoption status of 176 surveyed households in the research areas of the Thai Nguyen province. Some of these characteristics will be used as explanatory variables in the estimated models presented later. The selection of explanatory variables for the estimated models is based on the theoretical discussion below.

It was observed that there is a statistically significant difference between health care related costs for adopters and that of non-adopters (see Table 21). This perhaps suggests that the intensive use of chemicals and pesticides is an environmental and health hazard. The statistically difference in tea yields between adopters and non-adopters verifies the concern about the loss in tea yield from organic tea production. This loss in yields is directly translated into lower income and makes tea producers hesitant in adopting organic tea production (OTP). However, the lower tea yield from organic farming is viewed as an important effect from adopting organic tea production rather than the concern influencing the decision to adopt. The premium tea price for high quality tea (organic tea) and outside support for organic tea production are statistically very different between adopters and non-adopters suggesting that these two factors may be important factors affecting farmers' decision to adopt OTP. The capital invested in tea production (mostly for tea processing machinery) is significantly higher for adopters than for non-adopters indicating that machinery as a mechanical substitute for chemical input may influence the decision to adopt OTP. The other behavioral factor, self-expressed willingness to accept (WTA) the loss in tea yield or profit in order to have a "chemical and pesticide free" environment or a "better" environment does differ between adopters and non-adopters suggesting that WTA is also a good candidate as an explanatory variable in the model. Premium price for organic production is a significant incentive to adopt organic tea production.

For family size and education level of the household head, these two characteristics had mean values that were not statistically different between adopters and non-adopters (see Table 21). Consequently, these variables may not affect the decision to adopt. Likewise, there is no statistically significant difference in average age of the household head. This variable, like family size and education level, may not influence the decision to adopt organic tea production. Farm size and tea stand age also did not have mean values that differed between adopters and non-adopters. This is consistent with previous production efficiency analysis that adoption of new technology is not affected by farm size (Mendola, 2007). Also irrigation status and distance from home to the tea farms are not statistically different between adopters and non-adopters suggesting that they may not affect the decision to adopt organic tea production. Finally, the self-evaluated probability of reducing tea yield when switching to organic tea production (score from 1 to 5 with the lowest probability = 1 and the highest probability = 5) does not differ between the two groups suggesting that a reduction in yield of organic tea is consistently expected.

Table 21. Characteristics of Adopters and Non-adopters of Organic Tea Production

Variable[16]	Adopters	Non-Adopters	Difference (%)
Number of observations	23	153	
Farm and household characteristics			
-Family size (person)	4.1	4.3	5.0
- Family Labor (≈ # of adult)	2.1	2.4	14.0**
- Age (years)	43.2	45.4	5.0
- Education	2.3	2.1	-9.0
- Tea farming experience (yrs)	19.1	21.6	13.0
- Health care costs (th.VND/yr)	725	1,614	123**
- Farm size (m^2)	1,545	3,083	100
- Tea yield (quintal/ha)	79.4	93.8	19.0***
- Tea stand (yrs)	15.7	17.1	9.0
- Irrigation (=1 irrigated, =2 otherwise)	1.2	1.3	8.0
- Capital (th.VND)	76,986	15,534	-80***
- Distance to tea field	1.3	1.3	0.0
Market/institutional characteristics			
-Tea price (th.VND/kg of fresh tea)	9.2	6.9	-25.0***
-WTA (% accepted yield reduction)	30.8	21.7	-30.0***
- Outside support	1.9	1.2	-37.0***
- Probability to reduced income	3.9	4.4	13.0

* = significant at the 10% level, ** = significant at the 5% level, *** = significant at the 1% level.

[16] Distance from home to the tea farm = 1 if < 200m, = 2 if 200 - 500m and = 3 if 500m -1000m and , support: = 1 if government, = 2 if NGO and = 3 if more than 2, probability to reduced income measured by score (the lowest = 1 and highest = 5).

6.1.2 Descriptive Data for Clean Tea Adoption Analysis

Similar to the adoption analysis for organic tea production, the adoption analysis for clean tea production assumes the new technology adoption (i.e., clean tea production) is a function of a wide range of observable characteristics of the household (Mendola, 2007). Clean tea production as defined in section 4.1.2 is an intermediate or transitioning tea production method between conventional and organic tea production. Table 22 reports descriptive statistics for the adoption status of 153 surveyed households in the research areas of the Thai Nguyen province (organic farms were excluded from the sample). Some of these characteristics will be used as explanatory variables in the estimated models.

As in organic tea production, it is observed that there is a statistically significant difference between health care related costs for adopters and for non-adopters. This suggests that health concerns influence the adoption decision. The tea price and outside supports for clean tea production (CTP) are statistically different between adopters and non-adopters suggesting that these two factors are very important factors affecting farmers' decision to adopt CTP. Unlike organic tea production, the capital investment in machinery for clean tea production is significantly lower for adopters than non-adopters reflecting the fact that almost all of the clean farmers in the Song Cau commune and a portion from the Minh Lap commune sell their fresh tea directly to tea processing factories in the region instead of processing themselves. The other factor, the self-evaluated probability of reducing tea yield when switching to clean tea production is statistically higher for clean tea adopters than for non-adopters suggesting that adopters perceived higher risk from not using pesticides and chemical inputs in tea production.

With clean tea production, receiving a premium price still plays an important role in the decision to adopt.

As in organic tea production, family size, education level and age of the household head did not have mean values that differed significantly between the two groups. This suggests that family size, education level, and age probably do not affect the decision to adopt CTP. Also, there is no difference in tea stand age between the two groups which is consistent for all tea production methods. Also, tea farming experience did not have a significant difference in mean values between adopters and non-adopters suggesting that tea farming experience does not influence the adoption decision for clean tea production.

Unlike organic tea, the farm size and irrigation variables did differ significantly between the two groups. For smaller farms using irrigation, incorporating IPM methods to replace chemical and pesticide applications may not be viewed as complicating management rather, emphasizing the benefit of a cleaner environment.

These results and discussions help select the explanatory variables for the empirical adoption models for organic and clean tea production presented next.

Table 22. Characteristics of Adopters and Non-adopters of Clean Tea Production

Variable[17]	Adopters	Non-Adopters	Difference (%)
Number of observations	67	86	
Farm & household characteristics			
-Family size (person)	4.3	4.4	2.0
- Family Labor (≈ # of adult)	2.2	2.5	14.0*
- Age (years)	44.6	46.1	3.0
- Education	2.2	2.1	-5.0
- Tea farming experience (yrs)	21.0	22.1	5.0
- Health care costs (th.VND/yr)	1,258	1,891	50*
- Farm size (m^2)	2,568	3,743	46***
- Tea yield (quintal/ha)	93.7	92.8	-0.9
- Tea stand (yrs)	17.7	17.6	-1.0
- Irrigation (=1 for irrigated, 2 otherwise)	1.2	1.4	8.0**
- Capital (th.VND/ha)	8,878	20,719	130***
- Distance to tea farm	1.3	1.3	0.0
Market/institutional characteristics			
-Tea price (th.VND/kg of fresh tea)	7.7	6.2	-19.0***
-WTA (% accepted yield reduction)	21.3	22.0	3.0
- Outside support	1.9	0.7	-63.0***
- Probability to reduced income	4.7	4.1	- 13.0 ***

* = statistically significant at the 10% level, ** = significant at the 5% level, *** = significant at the 1% level.

[17] Distance from home to the tea farm = 1 if < 200m, = 2 if 200m - 500m and = 3 if 500m - 1000m and = 4 if > 1000m, support: = 1 if government, = 2 if NGO and = 3 if more than 2 and evaluated probability to reduced income measured by score (the lowest = 1 and highest = 5)

6.2 Empirical Adoption Models

6.2.1 Empirical Adoption Model for Organic Tea Production

The proposed model (equation 3.6) developed in section 3.3.2 can be expanded as:

$$P(y = 1 | x) = G(\beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k) = G(\beta_0 + x\beta)$$

Based on the discussion and assumptions in section 6.1.1, a set of explanatory variables (x_i) were selected for the probit model that will be used to analyze the effects of different factors on the response probability for adopting the organic tea production method in the Thai Nguyen province. The independent variables were selected based on the discussions in section 6.1.1. As discussed in section 4.1.1, tea yield is a function of different production and socio-economic parameters, it is not an exogenous variable therefore it is treated as an endogenous variable in the estimated model by using the instrumental probit procedure (Wooldridge, 2003).

Table 23 reports the results of the adoption analytical model estimated using the instrumental probit method. We observe from Table 23 that there are positive and statistically significant relationships between the response probability to adopt organic tea production and variables involving the premium price for organic tea, capital invested in machinery for tea production per hectare, tea yield per hectare, outside support and percentage of expressed willingness to accept reduced yields for pesticide and chemical free input tea production. As discussed in section 6.1.1, the loss in tea yields for organic tea production is the major concern. If organic tea yields increase so will the adoption of organic tea production. This result suggests that in order to promote switching to organic tea production, development of agricultural technologies that can improve organic tea yield should be considered. As mentioned earlier, mechanization is partly used as a substitute for chemical input in organic tea production, therefore, those who can afford machinery are more likely to adopt. There is some consistency with the results observed in the earlier section, i.e., capital has a positive relationship with organic tea production efficiency. Since organic tea yields are lower, conventional tea farmers are often hesitant in adopting the organic tea production method. The higher premium price for organic products is the only economic incentive motivating adoption. The self-expressed willingness to accept reduced tea yields is an indirect measurement of the environmental benefit from organic tea production. Those farmers who are concerned and are strongly in favor of a "better" environment are more likely to adopt organic production method. The positive and significant relationship between this response probability to adopt organic tea production and outside support reflecting the fact that all 23 organic tea farmers have been receiving outside support from the government agencies and NGO in the form of extension services, technical training, and payment of certification costs, etc. The outside support for organic tea production plays an important role for increasing adoption rates.

The probit model results (see Table 23) also show a negative relationship between response probabilities to adopt organic tea production and health related costs (as an environmental cost). The negative relationship between the probability to adopt organic tea production and health care related costs reflect a consistent observation with the earlier that organic tea growers paid less health care related costs than non-organic tea producers. Theoretically, it is expected that health care cost should have a positive effect on the adoption rate for organic tea production suggesting that when health care related costs associated with tea production increase, tea farmers are likely to switch to organic tea production where a pesticide and chemical free working environment would reduce health care costs.

Table 23. Adoption Analysis for Organic Tea Production

Variable	Coefficient	Std. Error	P>|z|
Tea yield	0.06425***	0.00698	0.000
Health care costs	-0.00003**	0.00001	0.011
Capital	0.00001**	2.6e-6	0.034
Family labor	-0.10664	0.10832	0.325
Family size	-0.01232	0.08101	0.879
Education	-0.01024	0.02496	0.652
Age of the household head	-0.01613	0.01014	0.112
Irrigation status	0.93851	1.28602	0.238
Support	0.36672***	0.13027	0.005
Evaluated prob. score	-0.05818	0.08227	0.480
WTA	0.01555**	0.00738	0.035
Tea price	0.13981**	0.04689	0.048
Distance from home to tea field	-0.18906	0.18036	0.295
Constant	-7.97877***	1.09203	0.000

Instrumented (endogenous variable): tea yield; n: 176.

Instruments: farm size, tea farming experience, tea stand and other exogenous variables in the model.

* = statistically significant at the 10% level, ** = significant at the 5% level,

*** = significant at the 1% level.

Wald $Chi^2(13)$ = 188.22; Prob > Chi^2 = 0.0000.

The negative and significant effect of health care related costs on the response probability for adopting organic tea suggests that increases in health care related costs will decrease the probability of adopting organic tea production. An explanation for this could be that survey respondents interpreted health care costs as health care expenditures for the family and made no distinction between health costs from tea production and health care costs incurred for other reasons. Therefore, the health care cost variable may misrepresent the actual relationship of health costs and tea production methods.

6.2.2 Empirical Adoption Model for Clean Tea Production

Similar to the adoption analysis for organic tea production, results in Table 24 show the adoption analysis for clean tea production. The key results include the positive and statistically significant influence of the premium tea price, outside support and the willingness to accept reduced tea yields for pesticide and chemical free input tea production on response probabilities to adopt clean tea production. These results suggested that the premium price for clean tea products and the outside supports play key roles to increase adoption rates in the Thai Nguyen province. However, as it was observed from discussion in section 6.1.2 that there are no significant differences in mean values for tea yields between adopters and non-adopters. Consistent with this finding, tea yield shows no statistically significant effect on the response probability to adopt clean tea production (Table 24). In fact, the switch to clean tea production did not cause a significant reduction in yields in the Thai Nguyen province. Also, similar to organic tea production, self-expressed willingness to accept reduced tea yields (WTA) is an indirect measurement of the environmental benefit from clean tea production. Those farmers who are highly concerned about the environment are more likely to adopt clean tea production as a way to reduce the environmental hazard. Though clean tea production does not prohibit tea farmers from using chemical inputs and pesticides, rather it does promote reductions in pesticide use (IPM) and appropriate fertilizer application. Therefore, clean tea production does not necessarily require use of more labor. This is shown by the negative and significant relationship between family labor supply and the probability to adopt clean tea production.

Table 24. Adoption Analysis for Clean Tea Production

Variable	Coefficient	Std. Error	P>|z|
Tea yield	-0.00899	0.03078	0.770
Health care costs	0.00003	0.00002	0.157
Capital	-0.00001	9.50e-06	0.190
Family labor	-0.46071*	0.24948	0.065
Family size	-0.02515	0.14811	0.865
Education	-0.20870	0.35863	0.561
Age of the household head	-0.00073	0.01434	0.959
Irrigation status	-0.12192	0.49847	0.807
Support	1.35443***	0.43559	0.002
Evaluated prob. score	0.29368	0.21632	0.175
WTA	0.03341**	0.01435	0.020
Tea price	0.43286***	0.10634	0.000
Distance from home to tea field	0.94834	0.80863	0.131
Constant	-5.76497	4.88546	0.238

Instrumented (endogenous variable): tea yield; n=153

Instruments: farm size, tea farming experience, tea stand and other exogenous variables in the model.

* = statistically significant at the 10% level ** = significant at the 5% level,

*** = significant at the 1% level.

Wald $Chi^2(13) = 71.55$; Prob > $Chi^2 = 0.0000$.

CHAPTER VII

RISK ANALYSIS

7.1 Risk Analysis and Probability of Adoption

The findings presented in the two previous sections identify factors affecting production efficiency and profit efficiency for different tea production methods as well as factors that affect tea growers' decision of whether or not to switch from conventional tea production to organic tea production or clean tea production. However, in reality, factors keep changing dynamically and over time. This chapter deals with risk analysis and is designed to examine how changes in key variables affect profit and the adoption rate of a new tea production method (i.e., either organic or clean tea production). For the small and family type tea farms in the Thai Nguyen province, tea growers are concerned about gains or losses from switching to organic or clean tea production. Policy makers, tea promoters and tea producers are also interested in the effects on the organic tea adoption rate from changes in factors of production, government intervention, and environmental policies/regulations. The following section will provide some insight into these concerns.

7.1.1 Changes in the Adoption Rate Without Premium Price

As discussed in section 6.2.1, there are six major factors that have statistically significant effects on the adoption rate for organic tea production: premium price, yield reduction for organic tea, capital investment in tea production, outside support, WTA, and environmental costs (health related in this model). As in section 6.2.2, there are four major factors that have statistically significant effects on the adoption rate for clean tea production: family labor, the premium price, outside support and WTA. However, changes in the premium prices for organic tea and clean tea products and outside support are partly controllable and observable. It would be interesting to see what happens to the adoption rates of organic and clean tea production when these variables are allowed to change. Therefore, the risk model describing the adoption of organic tea production and clean tea production will focus on these two variables.

The objective function (equation) for the adoption of organic tea production is taken from Table 23. In equation form, this can be written as:

$$P(y=1|xi) = \phi(-7.979 + 0.0643\,yld - 0.00003hcost + 0.00001\,capt - 0.1066flab - 0.0123fsiz - 0.0102edu - 0.0161age + 0.9385\,ir + 0.3667\,sport - 0.0582\,prob + 0.0155WTA + 0.1398\,tprice - 0.1891distf \quad (7.1)$$

The objective function (equation) for the adoption of clean tea production is taken from Table 24. In equation form, this can be written as:

$$P(y=1|xi) = \phi(-5.765 - 0.00889\,yld - 0.00003hcost + 0.00001\,capt - 0.4607flab - 0.0252fsiz - 0.2087edu - 0.0007age + 0.1219\,ir + 1.3544\,sport + 0.2939\,prob + 0.0334WTA + 0.4329\,tprice + 0.9483distf \quad (7.2)$$

where P is the response probability to adopt organic tea production, ϕ is the standard normal distribution function, yld is fresh tea yield (quintal/ha), hcost is health care related costs (th.VND[18]), capt is value of machinery for tea production/ha (th.VND), flab is the adult equivalent in a family (man), fsiz is the family size (persons), edu is the education level of the household head (= 1 for elementary school education, = 2 for middle school education, = 3 for high school education, = 4 for college education or above and = 0 if otherwise), age is the age of the household head (years), ir is the irrigation status of a farm (= 1 if irrigated and = 2 otherwise), sport represents outside support (= 1 if from the government, = 2 if from NGO, = 3 if more than 2 and = 0 if otherwise), prob is self-

[18] The exchange rate from Vietnam Commercial Bank is $1=15,966 VND (February 4, 2008)

evaluated score for the probability of reduced tea yields or profits when switching to organic tea production (from 1 to 5 where 1 for the lowest), WTA is the self-expressed willingness to accept reduced tea yields to be free of pesticides and chemicals in the farming environment (%), and tprice is the tea price (th.VND), and distf is distance from home to the tea farm (= 1 if < 200m, = 2 if 200m - 500m and = 3 if 500m - 1000m and = 4 if > 1000m).

Results illustrated in Figure 6 were simulated by using the adoption equations presented in Tables 23 and 24. In these simulations, the variables are valued at their mean values for the sample. Tea prices will be varied as the regular tea price in the market (no premium price for organic tea or clean tea scenarios).The graphs depicted in Figure 6 are the cumulative probability density functions for response probabilities to adopt organic and clean tea production (i.e., ___ for clean production and ---- for organic tea production). The simulations were done by using the @RISK 4.5 program to run a total of 100 trials. As shown in equation 3.7 in section 3.3.2, if the response probability is less than or equal to 0.5 (the 0.5 delimiter), the probability of adopting organic or clean tea production will be zero (the portion of the graph falling on the right hand side of the 0.5 delimiter represents the adoption rates of organic and clean tea production). The graph shows that holding other production and economic conditions as they are now, removing the premium price will result in the probability for adopting organic tea production equal to zero. As discussed earlier, the premium price for organic tea is the major economic incentive for organic tea producers. Varying the premium price for organic tea will have an important effect on the adoption rate for organic tea production. In fact, later analysis will show that tea farmers start adopting organic tea production if the premium price for organic tea products is at least 20% higher than the regular tea price in the market.

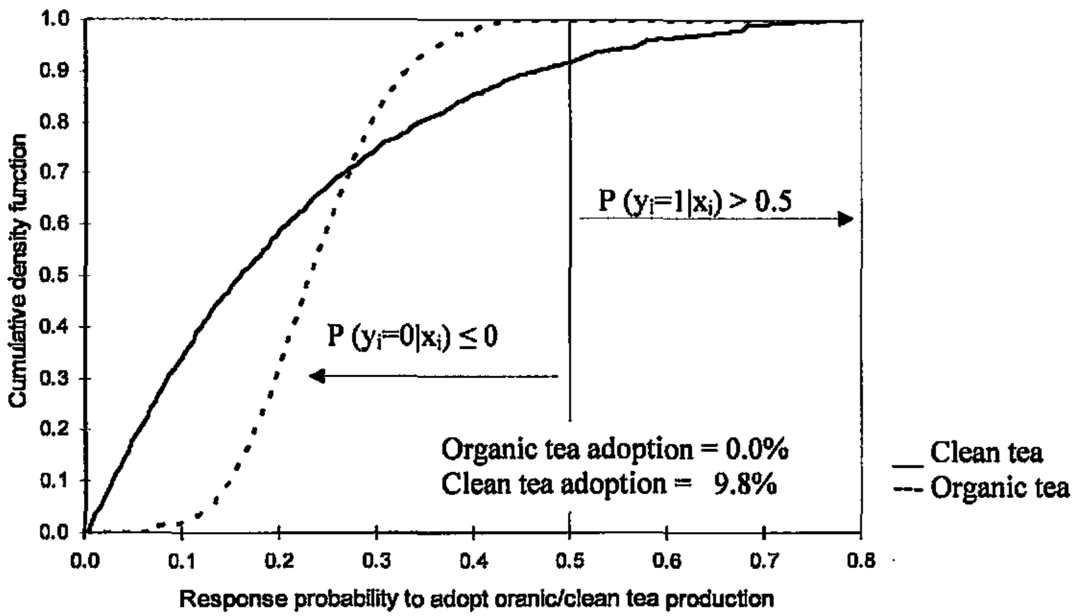


Figure 6. Adoption Rates for Organic and Clean Tea Production without Premium Price

Also, Figure 6 illustrates the cumulate probability density function for clean tea adoption. The clean tea graph shows that holding other production and economic conditions constant, if the premium price for the clean tea product is removed, the probability of adopting clean tea production is 9.8% while it is 0% for organic tea production. Since the premium price for the clean tea product is usually lower than for the organic tea product (i.e., 10% higher than the regular tea price for clean tea as compared to 30% for organic tea), removing the premium price has a significant effect on the adoption rate of clean tea production. Survey results showed that some clean tea farmers did not receive the premium price but continued their clean tea production.

7.1.2 Changes in the Adoption Rate when Removing Outside Support

Results illustrated in Figure 7 were simulated by using adoption equations 7.1 and 7.2 in the previous section. For these simulations, variables are valued at their mean values for the sample. The outside support variable is varied according to current levels of outside support received by conventional tea growers. Again, the graphs depicted in Figure 7 are the cumulative probability density functions for response probabilities to adopt organic and clean tea production (i.e., ___ for clean production and ---- for organic tea production). The simulations were done using the @RISK 4.5 program to run 100 trials. As shown in equation 3.7 from section 3.3.2, if the response probability is less than or equal to 0.5 (the 0.5 delimiter), the adoption rate for organic or clean tea production will equal to zero. The portions of the graphs falling on the right hand side of the 0.5 delimiter show the adoption rate for organic or clean tea production. Graphs used in Figure 7 show changes in response probabilities for adopting organic and clean tea production while holding other socio-economic conditions for organic or clean tea production as they are now including premium prices but removing only outside support. Without outside support, the response probability for adopting organic tea production is 0.7% while it is 5.5% for clean tea production. After removing outside support, there are almost no tea farmers adopting organic tea production. However, there are some who do adopt clean tea production although the adoption rate is very low. These simulated results reflect the fact that both cases are heavily subsidized by government agencies or NGOs. It is an important consideration for policy makers in forming strategies involving government intervention for sustainable development.

Results illustrated in Figures 6 and 7 show the effects from two important factors affecting the adoption of organic and clean tea production in the Thai Nguyen province. The results from a follow-up survey found that three out of four organic tea farmers in the Minh Lap commune had returned to conventional tea production after one year when outside support was removed or the guaranteed premium price was reduced.

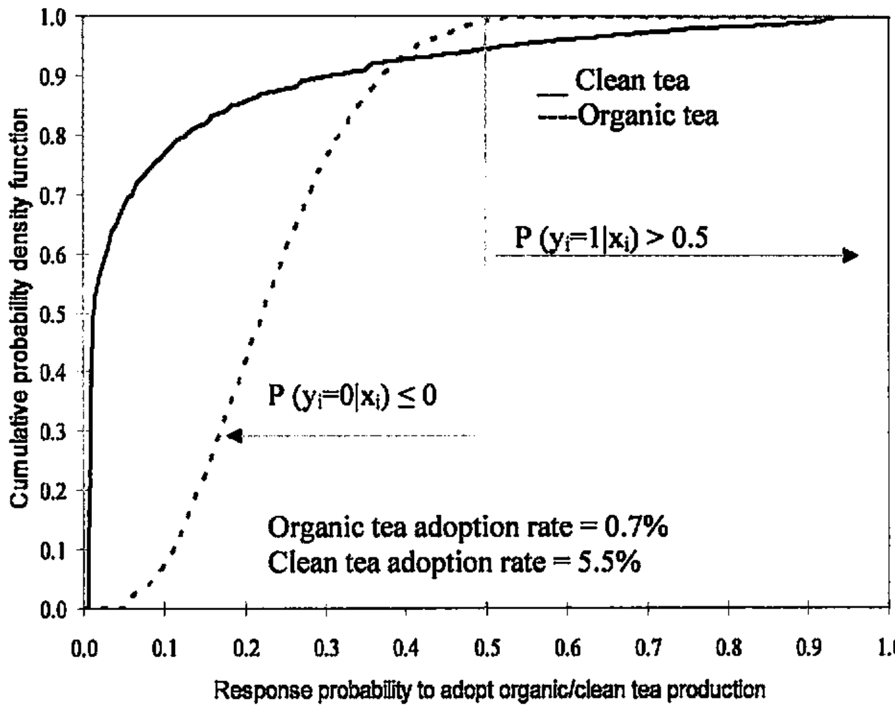


Figure 7. Adoption Rates for Organic and Clean Tea Production without Outside Support

7.2 Possible Intervention to Increase Adoption Rate for Organic Tea Production

7.2.1 Market Incentive

As discussed earlier in section 7.1.1, the premium price for organic tea plays an important role in promoting the adoption of organic production in the Thai Nguyen province. The market mechanism simulated in Figure 8 was based on the hypothesis that conventional tea growers would switch to organic tea production if there is a premium price that satisfies their income security and is high enough to offset losses in tea yields. In this scenario, socio-economic conditions are held constant but the premium price is varied proportionally to the regular market price (for conventional tea). The graph shown in Figure 8 illustrates changes in the adoption rate for organic tea production as the premium price increases (i.e., being proportionally higher (in % terms) than the regular market price for conventional tea). Given current socio-economic conditions for tea farmers in the Thai Nguyen province, conventional tea farmers are not willing to switch to organic tea production if an increase in the premium price is less than 20% of the regular market tea price. The adoption rate increases dramatically when the premium price is in the range of 40 – 90% higher than the regular market price. Figure 8 also shows that if the premium price for organic tea doubles as compared to the regular market price, a portion of conventional tea farmers will not switch to organic tea production (adoption rate is 87% when price doubles). This occurrence is similar to what Pimentel et al. (2005) reported in their studies on U.S. organic corn production. They found that the organic premium price required to equalize the organic and conventional returns was only 10% above the conventional product. However, they also found that premium prices range was 65% to 140% higher than the regular market price.

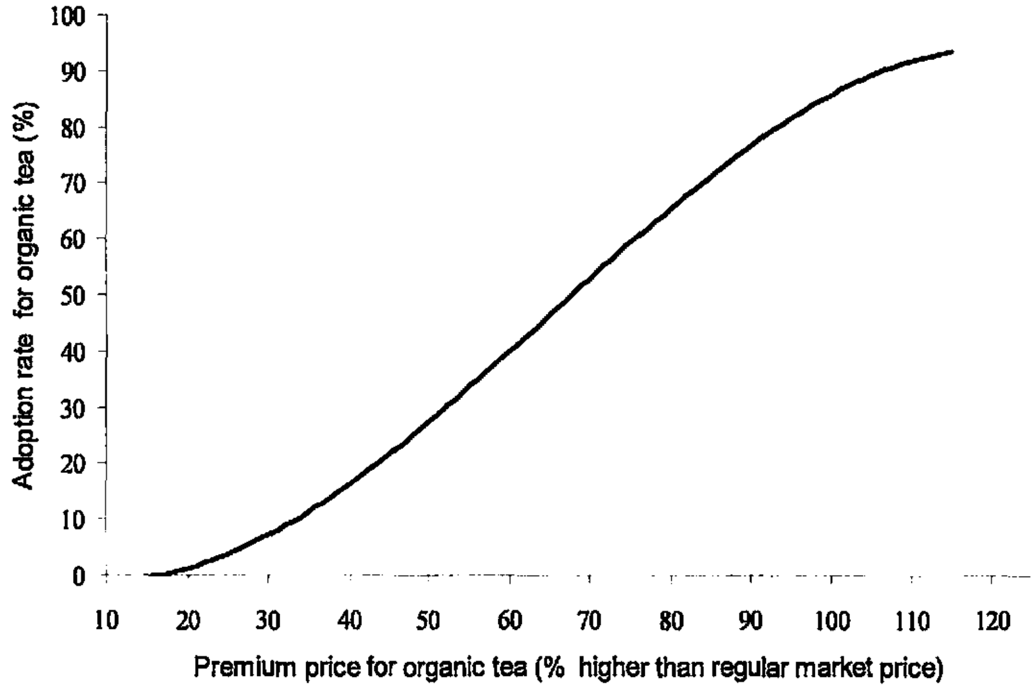


Figure 8. Adoption Rates for Organic by Varying the Premium Price

7.2.2 Tax on Conventional Tea Mechanism Intervention

A traditional policy instrument that a government can use to control environmental hazard is to levy a Pigovian tax on output value of production that causes the environmental hazard. It is assumed that the government knows there is a certain amount of pollution associated with the production output (Ballard, 1985). Figure 9 illustrates the relationship between levying a Pigovian tax on output values for conventional tea production and increasing the rate of adopting organic tea production. It is hypothesized that if the government imposes an environmental tax on output values for conventional tea production, this would lead to increased production costs. Therefore, a tax will reduce profits for conventional tea production as compared to organic tea production. Hence, adoption rates for organic tea production will increase. In this scenario, all socio-economic conditions are held constant but a lump sum tax is proportionally levied on output values for conventional tea production. The tax revenues compensate for environmental costs from conventional tea production. Simulated results from the @RISK program are illustrated in Figure 9. The graph shows how changes in the tax rate on output values for conventional tea affect the adoption rate of organic tea. It is observed that the tax increases the adoption rate for organic tea when the tax rate is less than 25%. For higher tax rates on conventional tea production, more conventional tea producers will be enticed to switch to organic tea production. However, the maximum effect of the tax on adoption rates for organic tea production is an adoption rate of about 9%.

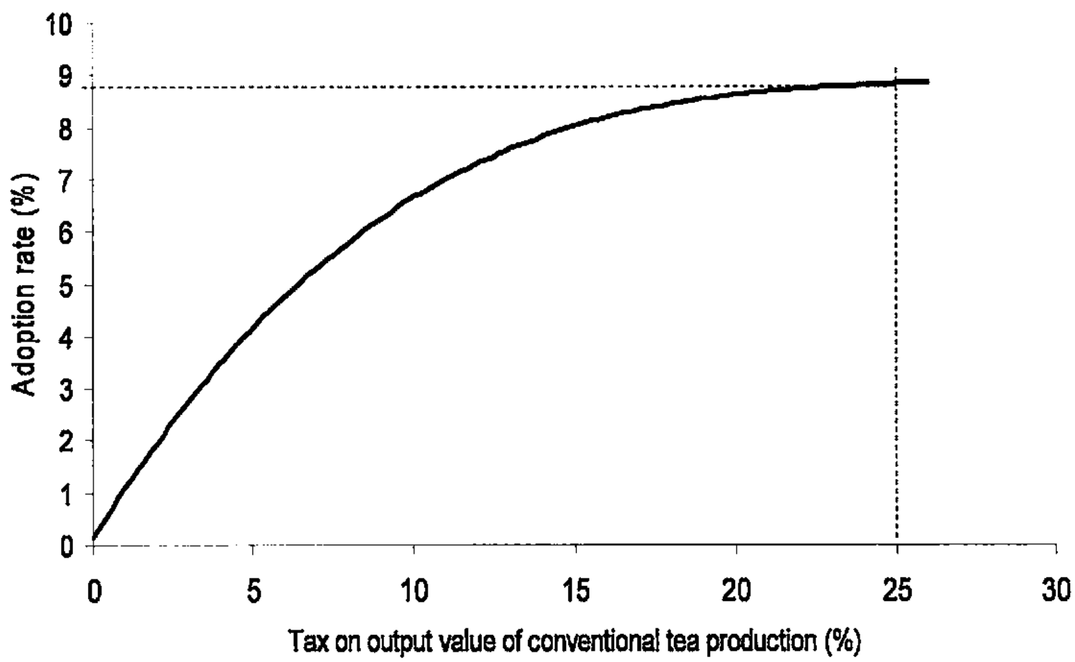


Figure 9. Tax on Output Value of Conventional Tea and the Increased Adoption Rate for Organic Tea Production

Observing these two simulations, it can be inferred that given the socio-economic conditions of tea growers in the Thai Nguyen province, the price premium scenario for organic tea appears to have a larger effect on increasing the adoption rate than a tax policy of levying a tax on the output value for conventional tea production.

7.3 Risk and Expected Profits

7.3.1 Risk and Profit for Organic Tea Production

The basic profit equation used in the profit efficiency analysis for tea production (see equation 3.4) is:

$$\pi = py - w^T x$$

The profit equation for organic tea production per hectare can be re-written as:

$$v\pi = py - labcost - fercost - pecost - hercost - hcost - ocost \quad (7.1)$$

where $v\pi$ is profit for tea production (th.VND/ha), p is fresh organic tea price (th.VND/kg), y is fresh tea yield (kg/ha), labcost is labor expenditures[19] (th.VND/ha), fercost is fertilizer expenditures (th.VND/ha), pecost is expenditures for pest and disease control[20] (th.VND), hcost is expenditures for health care and hospitalization (th.VND) as an indirect measurement of environmental cost, and ocost is other costs in th.VND (fuel, irrigation fee etc.,).

This profit equation was used as the objective function in risk analysis for organic tea production. The cumulative distribution function (CDF) depicted in Figure 10 is the result of a simulation conducted with 100 trials using a Monte Carlo risk analytical model discussed in section 3.4.3. The primary influence on profit is output price. From the results in section 7.1.3, it was observed that the premium price plays a crucial role in the

[19] Labor in this research was treated as aggregated labor consisting of family labor and hired labor for tea production per hectare (Lau and Yotopoulos, 1971; Sharma et al., 1999).
[20] Since pesticides are not allowed in organic tea production, for convenience in calculations and analyses, total expenditures for pest and disease control were used to replace pesticide price.

adoption of organic tea. In this simulation, the effect of how the premium price affects profit for organic tea production is examined again.

In this simulation, other variables are held constant and organic tea price is allowed to change. Figure 10 plots the simulations for tea price changes (with premium price and without premium price). This figure shows that given currently observed socio-economic conditions for organic tea farms in the Thai Nguyen province, if the premium price is removed, the cumulative probability density function for profit shifts to the left in parallel fashion and the probability of profit being less than 10 million VND/ha (about $600/ha) increases from zero to 60% (by 60%). By removing the premium price for organic tea product, the probability that organic tea farmers will have negative profits is about 30%. This result is consistent with the observations in sections 6.2.1 and 7.1.1 that the premium price plays an important role in creating economic incentives for farmers to switch to organic tea production.

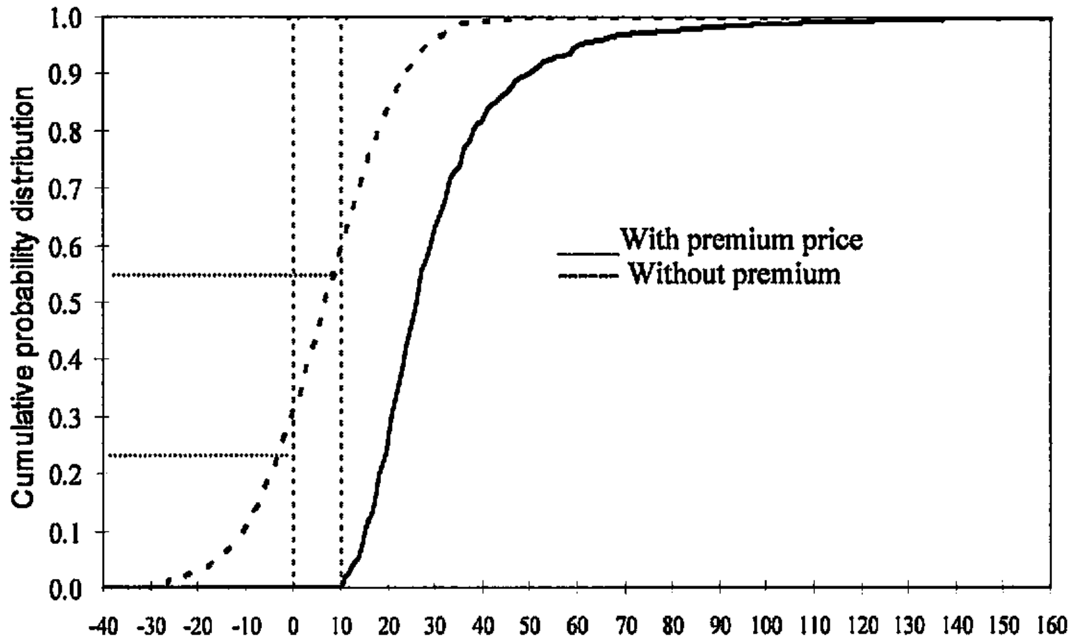


Figure 10: Profit for Organic Tea and the Premium Price

7.3.2 Risk and Profit for Clean Tea Production

As in risk analysis for organic tea production, the profit equation for clean tea production per hectare can be re-written as:

$v\pi$ = py- labcost-fercost-pecost-hercost-hcost-ocost (7.1)

where $v\pi$ is profit for tea production (th.VND/ha), p is fresh clean tea price (th.VND/kg), y is fresh tea yield (kg/ha), labcost is labor expenditures (th.VND/ha), fercost is fertilizer expenditures (th.VND/ha), pecost is expenditures for pest and disease control (th.VND), hcost is expenditures for health care and hospitalization (th.VND) as an indirect measurement of environmental cost, and ocost is other costs in th.VND (fuel, irrigation fee etc.,).

This profit equation for clean tea was used as the objective in the risk analytical model for clean tea production. As discussed in chapter 5 and in section 7.1.1, the premium price for clean tea also plays an important role in clean tea production. The influence of output price on profit for clean tea production was simulated and once again, the effect of the premium price for clean tea is examined. Similar to results from analysis in section 7.1.1, it was observed that the premium price for clean tea does not play an important role in the adoption of clean tea production as it does for organic tea production. Figure 11 shows that given currently observed socio-economic conditions for clean tea farms, if there is no premium for clean tea product, then, the probability of having profit less than zero about 30%. The effect of removing the premium price on the probability of facing losses is similar between organic production and clean tea production. However, the probability of profits being less than 10 million VND increases by 40% (from 17% to 57%). This effect is less severe in comparison to the effect of removing the premium price on organic tea production (i.e., the probability of profit being less than 10 million VND increased by 60% for organic tea). This result implies that removing the premium price will produce higher risks for organic tea producers than it does for clean tea producers.

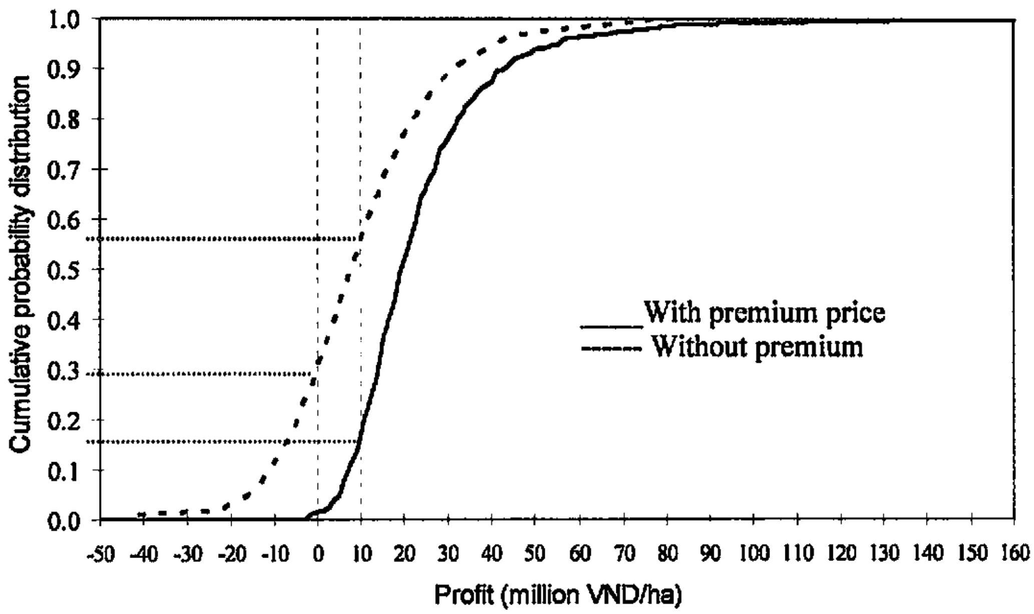


Figure 11: Profit for Clean Tea and the Premium Price

CHAPTER VIII

ENVIRONMENTAL IMPACTS AND BENEFITS

8.1 CBA Model to Evaluate Environmental Impacts

As discussed in section 2.8, there is an important distinction to be made between private and social costs (benefits). Coase (1960) argues "the private product is the value of the additional product resulting from a particular activity of a business. The social product equals the private product minus the fall in the value of production elsewhere for which no compensation is paid". Arrow & Lind (1970) show that the social cost of risk-bearing will depend both upon which individual receives the benefits and pays the costs and how large each individual's share of these benefits and costs are. In calculating present value of net returns (NPV) for switching from conventional tea production to organic or clean tea production, a distinction must be made between private and public benefits and costs. This distinction will provide information on how different tea production methods determine benefits or costs under both private and social perspectives. As a profit maximizer, the individual tea producer is primarily interested in private NPV whereas social planners might be more interested in social NPV. The following section will provide further insights into this analysis.

Helfert (2003) and Pearce et al. (2006) discuss the time-horizon (i.e., how far in the future impacts would be estimated) and the importance of this concept when applying CBA to assess a project or an investment. In this research, two time periods (i.e., 5 year and 30 year periods) were used to estimate both private and social NPV for three tea production methods. A short-run analysis (5 year period) is used to compare private and social NPVs of three different tea production methods during the transition period from conventional tea to organic tea production (note that at the time of the follow-up survey in October, 2007, the oldest organic tea farm was 5 years old).

According to Helfert (2003) and Pearce et al. (2006), the time-horizon was determined as the physical or economic life of the investment. Although tea has an economic life of 100 years, it has a sub-economic cycle of 30 years (Do and Le, 2000). Therefore, for the long-run analysis in this research, the time-horizon was set for a 30 year period.

As discussed in section 3.3.4, NPV comparisons involve streams of benefits and costs from different tea production methods (with and without organic and clean tea production methods). In equation form, can be written as:

$$\text{NPV} = \sum_{j=0}^{\infty} (B_j - C_j)/(1+i)^j$$

where B_j is the benefits at the j th period, C_j is the costs at the j th period, and i is the discount rate[21]. Based on data collected for the 2007 crop year and three previous crop years (2004, 2005 and 2006), CBA will be calculated for the three different tea production methods on a hectare basis. The data were collected based on farmer recall of what were inflows and outflows for the year just before farms were converted to a "new" production method (i.e., from conventional tea production to either organic tea production or clean tea production). Based on the data reported after conversion, the NPV was calculated for a 5 year span after the conversion year. According to Dinwiddy and Teal (1996), individuals do discount future utility. In this research the discount rate applied in the model is the current interest rate prevailing in the market for commercial lending (interest rate for Agricultural Bank is 10.8% APR). Helfert (2001) also states that

[21] Discount rate is 10.8% for Agricultural Bank and 7.2% for the Bank for the Poor (source: Agriculture Bank website, 2007)

"in calculating the NPV for a project, a rate of discount representing a normal expected rate of return first must be specified as the standard to be met." For normal tea production, the minimum expected return is the interest rate of borrowing money from a commercial bank. For the NPV model, present values of all inflows and outflows over the transition period and project life under alternative tea production methods are determined.

Dinwiddy and Teal (1996) discuss the essential differences between the CBA procedures applied for private firms and for public sector projects where social planners use prices which reflect social objectives to capture social profitability. Also, Dinwiddy and Teal (1996) state that "private rates of individual time preference may not be an interest rate measure of a discount rate intended to measure the value of the consumption at different points in time for all members of society." Therefore, the discount rate used to measure social NPV for the three different tea production methods in this study is the rate of The Bank for the Poor (a social bank) that reflects a perceived rate of social time preference currently used in Vietnam. The following equation was used to calculate environmental costs based on expressed WTA for social NPV.

$$EC_j = TIN_j \frac{WTA_{in} - R_j}{100} \qquad (8.1)^{22}$$

where EC_j is the estimated environmental cost (th.VND) paid by the j^{th} farm, TIN_j is the income from tea production from the j^{th} farm, WTA_{in}[23] is the average willingness to accept a reduction in income to have a "safe" environment in (%), and R_j is the actual stated reduction in income (in %) when switching to the new production method (see Appendix D for detail calculation). Note that health care related cost was calculated as a

[22] Modifying equation introduced by Haab & McConnell (2002) and Haefeli et al. (2007).
[23] Average WTA is considered as socially accepted WTA (environmental cost) from the surveyed area (see Haab & McConnel, 2002).

cost component for both private and social NPVs although it might be implicitly reflected in the WTA calculation since tea farmers would pay more for a "better" environment with the expectation of reducing health care problems.

8.1.1 Private Net Present Value (NPV)

- Short-run Analysis for Private NPV

For short-run analysis, the NPVs for different tea production methods are calculated over a 5 year period since it requires at least a 2 year transition period from conventional tea production to organic tea production and the oldest organic farm in the sample is 5 years. Interest in this analysis stems primarily from what happened to tea producers during the transition period to organic tea production.

Table 25. Private Net Present Value Analysis for Tea Production (5 year span)

A. General statistics Production method	Mean of NPV in (th.VND)	Standard deviation	Coefficient of Variation
Organic tea	141,994	90,947	0.6404
Clean tea	169,811	88,255	0.5197
Conventional tea	129,243	79,827	0.6176

B. T-test for difference between means

Group comparisons	Prob. $\lvert t \rvert > t$
Organic tea vs. conventional tea	0.545
Organic tea vs. clean tea	0.210
Clean tea vs. conventional tea	0.004 ***

H_0: no difference in means; * = statistically significant at the 10% level, ** = significant at the 5% level, *** = significant at the 1% level.

Results for the private NPV analysis in Table 25 show that there is no statistically significant difference between the average private net benefits for organic tea and for conventional tea production. Also, there is no statistically significant difference between the average private net benefits for organic tea and for clean tea production. Considering that net revenues were reduced significantly in the first three years of organic tea production (by about 30%), the average private net benefit from organic tea production was not statistically different as compared to the average private net benefit for clean tea and for conventional tea production. From the production and profit efficiency results discussed in chapters 4 and 5, organic tea production has shown to be more efficient for both types of analyses. In the short run during the transition period to organic tea production, private net benefit for organic tea production may be less than that for clean tea and conventional tea production. This stems from yield reductions as farmers adjust to a new production method and the fact that these farms are not certified as organic and can not receive the premium price for organic tea.

Average private net benefit for clean tea production is significantly higher than that for conventional tea production. The higher net private benefits result from reducing/eliminating the costs of buying synthetic inputs (Charles, 1998). Also, a higher NPV is the result from receiving the premium prices for safe or pesticide free products. This is similar to the situation found in alternative agricultural production studies done in the U.S. (see Fox et al. (1991), Klepper et al. (1977), Lockeretz et al. (1978)). These studies show that "the most profitable pest control strategies were generally flexible management strategies that involved a combination of control measures." Table 25 also shows that clean tea production has the lowest coefficient of variation (0.5197). Ryan and

Garder (1965) suggest that the coefficient of variation is a measure of risk. It follows that clean tea production is the lowest risky production method in terms of private NPV.

- Long-run Analysis for Private NPV

Dinwiddy and Teal (1996) suggest that "almost by definition, the costs and benefits from an investment project will extend present to the future and over its projected lifetime." Results of the long-run analysis for private NPV are presented in Table 26. The results in Table 26 show, in the long-run, there is significant difference between the average private net benefits for organic tea and conventional tea production and between the average private net benefits for organic tea and for clean tea production. However, in the long-run, there is insignificant difference between the average private net benefits for clean tea and conventional tea production. These results together with the results in Table 25 suggest that after a period of time, organic tea farmers have adjusted to the new production method and receive the premium price for certified organic products. Therefore, overtime, organic tea farmers will cumulate a higher private NPV than clean tea and conventional tea farmers. Whereas, overtime, the difference between clean tea and conventional tea NPVs will disappear.

Table 26. Private Net Present Value Analysis for Tea Production (30 year span)

A. General statistics Production method	Mean of NPV in (th.VND)	Standard deviation	Coefficient of Variation
Organic tea	5110937	2606075	0.5099
Clean tea	4409645	2325702	0.5274
Conventional tea	3775475	2253008	0.5967

B. T-test for difference between means

Group comparisons	Prob. |t| > t
Organic tea vs. conventional tea	0.032**
Organic tea vs. clean tea	0.092*
Clean tea vs. conventional tea	0.154

H_o: no difference in means; * = statistically significant at the 10% level,

** = significant at the 5% level.

Table 26 also shows that organic tea production has the lowest coefficient of variation (0.5099) and would suggest that this production method may be least risky in terms of private NPV for the long-run analysis.

8.1.2 Social Net Present Value Analysis

- Short-run Analysis for Social NPV

Results from Table 27 illustrate that organic and clean tea production have significantly higher average net social benefits than conventional tea production (in the short-run of 5 years). There is no significant difference between social NPV for organic tea and for clean tea production. One explanation is that by reducing the use of pesticides and chemical inputs, clean tea production produces less negative externality to the environment in the short run. Therefore, clean tea producers pay lower environmental costs while tea yield for clean tea is not affected by the reduction in pesticide uses. Also, the results suggest that clean tea production is a viable intermediate tea production method as farmers switch from conventional tea to organic tea production.

Similar to Fox et al. (1991) which determined that a ban on pesticides could reduce income, this study showed that the reduction in farm income is small in comparison to the improvement in environmental quality (reducing the cost of environmental externalities). Therefore, the social NPV of organic tea production is the highest for the three tea production methods.

Table 27. Social Net Present Value Analysis for Tea Production (5 year span)

A. General statistics Production method	Mean of NPV (th.VND)	Standard deviation	Coefficient of Variation
Organic tea	141520	89920	0.63538
Clean tea	110561	77650	0.7023
Conventional tea	44730	64042	1.4317

B. T-test for difference between means

Group comparisons	Prob. |t| > t
Organic tea vs. conventional tea	0.000***
Organic tea vs. clean tea	0.149
Clean tea vs. conventional tea	0.000***

H_0: no difference in means and * = statistically significant at the 10% level,

significant at the 5% level, * = significant at the 1% level.

- Long-run Analysis for Social NPV

Results from long-run analysis for social NPV are shown in Table 28. These results illustrate that organic tea production has statistically the highest social NPV, whereas, conventional tea production has the lowest social NPV. Not surprisingly, in the long-run, organic tea production has significantly higher social NPV than clean tea production. Although clean tea producers pay less environmental cost as compared to conventional tea producers, accrued environmental costs overtime will be significant. This explains why in the long-run, clean tea production has a significantly lower social NPV than organic tea production. Similar to the short-run analysis, clean tea production has significantly higher average net social benefits as compared to conventional tea production.

Table 28. Social Net Present Value Analysis for Tea Production (30 year span)

A. General statistics Production method	Mean of NPV (th.VND)	Standard deviation	Coefficient of Variation
Organic tea	2964536	1510760	0.5096
Clean tea	1813151	1515951	0.8361
Conventional tea	958042	1066629	1.1133

B. T-test for difference between means

Group comparisons	Prob. |t| > t
Organic tea vs. conventional tea	0.000***
Organic tea vs. clean tea	0.003***
Clean tea vs. conventional tea	0.000***

H_o: no difference in means and *** = significant at the 1% level.

There are two major reasons contributing to this high social NPV for organic tea production in both the short-run and long-run analyses: i) organic tea products receive higher prices (premium price) and ii) organic tea farmers do not pay the imputed environmental costs (as imposed in this scenario). Fox et al. (1991) also suggested that input-use restrictions which reduce output can lead to higher farm prices and increases in farm income.

In terms of the coefficient of variation for the social NPV, organic tea production has the lowest coefficient of variation suggesting that organic tea production is the least risky production method (Ryan & Garder, 1965) to society as a whole, while conventional tea production is the most risky tea production method to society in both short-run and long-run analyses.

8.1.3 Private NPV versus Social NPV

- Short-run Analysis

Computed results shown in Tables 32 represent the gaps between private and social NPVs for different tea production methods (i.e., conventional, clean and organic tea production) for short-run analysis. As Williams & Hammitt (2001) reported, the greatest social benefit for switching from conventionally grown to organically grown produce is a risk reduction in pesticide-related hazards. In other words, organic production systems produce the least environmental hazards. There is no statistically significant difference between the average private NPV and average social NPV for organic tea production in the short-run while there are 53.5% and 88.9% differences for clean tea production and conventional tea production respectively. An explanation for this large gap between private and social NPVs for conventional tea production is this production method produces higher environmental externalities than either clean tea or organic tea production and hence, pays higher environmental costs. Although clean tea production (reduced pesticide-use alternative) produces less pollution to the environment as compared to conventional tea production, it still produces a significant amount of externalities to the environment. Therefore, clean tea farmers pay certain environmental costs, whereas, organic tea farmers do not explicitly pay environmental costs.

Table 29. Social NPV and Private NPV Comparison (5 year period)

Production Method	Social NPV (th.VND)	Private NPV (th.VND)	% Different
Organic tea production	141520	141994	3.3
Clean tea production	110561	169811	53.5***
Conventional tea production	44730	129243	88.9***

H_0: No difference in means; * = statistically significant at the 10% level, , ** = significant at the 5% level, *** = significant at the 1% level.

- *Long-run Analysis*

Results in Table 30 show the gap between private NPV and social NPV for the long-run analysis. These results illustrate that the private NPV for all three tea production methods are significantly higher than their corresponding social NPV. The gaps between the private NPV and social NPV becomes wider for the long-run analysis as compared to the short-run analysis. The primary difference between social NPV and private NPV is the environmental cost component for the social NPV calculation. The results in Table 30 show the largest gap between social NPV and private NPV is for conventional tea production which suggests that conventional tea producers pay the highest environmental costs while organic tea producers pay the least.

Table 30. Social NPV and Private NPV Comparison (30 year period)

Production Method	Social NPV (th.VND)	Private NPV (th.VND)	% Different
Organic tea production	2964536	5110937	72.4***
Clean tea production	1813151	4409645	143.2***
Conventional tea production	958042	3775475	294.1***

H_o: No difference in means; * = statistically significant at the 10% level,
** = significant at the 5% level, *** = significant at the 1% level.

8.2 Residues of Agrochemicals in Soils, Water Body and Tea Product

As discussed in section 2.8, one of the obviously positive impacts of organic tea production is the reduction of pesticide and chemical residues from tea production. In this study, soil and water samples were taken on a monthly basis. The soil samples were obtained from two separate tea farms, one farm under the first year conversion to organic tea production and the other under conventional tea production. Water samples were taken from water catchments (water body) which captured surface runoff from the tea farms where the soil samples were obtained. The soil and water samples were sent directly to the laboratory center at Thai Nguyen University of Agriculture and Forestry (TUAF) for analysis soon after they were taken from the fields. As planned, tea samples were taken three times in the months of March, June and October 2007 which correspond to the beginning, middle and end of the tea production period in a typical year. All tea samples were analyzed in the laboratory center at TUAF. Procedures for laboratory analysis of agrochemical residues in soil, water and tea samples followed the protocol suggested in the GC/MS Practical Guide (McMaster & McMaster, 2007). Residues of agricultural chemical inputs were identified by using a GCMS- Gas Chromatograph/Mass Spectrometer.

8.2.1 Agrochemical Residues in the Soils

One reason for converting to organic tea production is to improve environmental quality by eliminating synthetic chemical residues in the environment. Soil samples from an organic tea farm near the end of its transition period (at least two years as required by VTA, 2005) are expected to have lower level of pesticide and other synthetic agrochemical residues. Results of laboratory analysis for soil samples represented in Table 31 show changes in pesticide residues in the soils for two different farming practices, organic tea production and conventional tea production over an eight month period (from March to October 2007) in Tan Cuong commune of the Thai Nguyen province.

Table 31. Pesticide Residues in Tea Cultivated Soils from Tan Cuong Commune

Common name	Health hazard rating[a]	Residue concentration level (ppb)			
		March		October	
		Conv'l[b]	Organic	Conv'l	Organic
2,5 Dichloraniline	Toxic, 3	6.8	7.8	4.3	2.0
2,3 Dichloraniline	Toxic, 3	6.2	6.0	5.7	2.0
Propanil	Moderate	0.0	2.3	0.0	0.0
Fenobucarb	moderate	2.0	0.0	0.0	0.0

[a]: Health hazard rating by European Union Commission Directive 2001/59/EC.

[b] Conv'l: samples taken from conventional tea production.

Results of the soil sample analysis in Table 31 indicate possible reductions in pesticide residues during the first year for the organic tea farm. However, some trace levels of toxic chemicals still remain in the soil (see the trends plotted in appendix 5) . The concentration levels of different chemicals in the samples drawn from the organic tea farm were high in March because this farm was recently converted to organic tea production in February, 2007 (new tea production season) and pesticides and growth regulators were applied until the end of February for the late harvest before conversion to organic tea production. It takes time for chemical elements that are strongly tied to soil structure to be removed or leached into deeper soil layers. However, this preliminary analysis did show a reduction in pesticide residues and further testing should be continued with more extensive sampling and analysis.

8.2.2 Pesticide Residues in the Water Body

It is observed from results of the water sample analysis presented in Table 32 that there is obvious improvement in water quality for the water bodies close to organic tea farms. Almost all of the toxic pesticide residues found in the first month of the production season (March) were not found in October (end of production season). While there were different toxic pesticide residues present in water samples taken from the conventional tea farm at the end of the production period (October, 2007), only a trace of Carbetamide was found in the water samples taken from the organic farm. This observation would suggest that chemical residues will persist longer in the soil than in the water bodies. However, water dilutes chemicals and transports them elsewhere in the environment while the source of pollution from the organic tea farm was already eliminated.

Table 32. Agrochemical Residues in Water Samples

Common name	Health hazard rating[a]	Residue concentration level (ppb)			
		March		October	
		Conv'l[b]	Organic	Conv'l	Organic
Chloroneb	Slight	4.0	4.0	0.0	0.0
Fenobucarb	Moderate	1.0	9.0	0.0	0.0
2,5 Dichloranilin	Toxic, 3	0.0	7.0	2.1	0.0
2,3 Dichloranilin	Toxic, 3	0.0	7.0	3.0	0.0
Carbetamide	Moderate	0.0	9.0	4.2	1.0
Dimethipin	Very slight	2.0	0.0	1.0	0.0
Bifenox	Moderate acute	2.0	0.0	0.0	0.0

[a] Health hazard rating by European Union Commission Directive 2001/59/EC.

[b] Conv'l: samples taken from conventional tea production.

Unlike soils, where chemicals are absorbed tightly by soil structural components, chemicals in water can be easily diluted and transported with out of water bodies.

8.2.3 Chemical Residues in Tea Samples

We know from earlier discussion that chemical residues exist longer in soil samples than in water samples. Results from the tea sample analysis shown in Table 33 indicate that while the two toxic chemical residues in the tea samples taken from the conventional tea farm (2,5 Dichloranilin. 2,3 Dichloranilin) were found in both samples for March and October, 2007, their quantities were reduced dramatically in the October sample. In the case of organic tea samples, these two chemicals were not found in the October 2007 sample. These two chemical residues are on the list of chemical substances that are banned from use in organic tea production for the Tan Cuong commune certification requirement by Ecolink[24].

Table 33 also shows that there is still a presence of Carbetamide in the organic tea sample for October. Probably this chemical is still present in the deeper soil layers of the organic farm. In the case of the samples from the conventional farm, the quantity of Carbetamide residues present is reduced for the October sample (as compared to the March sample). This reflects the fact that by the end of production season, the advent of cooler weather in October reduces the presence of pests on tea farms and necessitates less use of pesticides (Do & Le, 2000).

The results of the analyses in this section illustrate that after one year of conversion to organic tea production pesticide residues in the soil were reduced. However, traces of pesticide residues were not completely eliminated from water bodies and from tea products for the first year organic tea farm. As explained earlier, residues from agro-chemicals tend to remain much longer in soils than in water.

Although preliminary analyses of soil, water and tea samples did find a possible reduction in pesticide and chemical residues, more samples over a longer period of time should be analyzed in order to determine costs of abatement (as an environmental cost component) in NPV calculations.

[24] Ecolink Co. is an organic promoting company that provides subsidies for organic tea certification costs for those in the Thai Nguyen province.

Table 33. Chemical Residues in Tea Products in Tan Cuong Commune

Common name	Health hazard rating[a]	Concentration in tea product (ppb)			
		March		October	
		Conv'l[b]	Organic	Conv'l	Organic
2,5 Dichloranilin	Toxic, 3	8.7	5.4	3.0	0.0
2,3 Dichloranilin	Toxic, 3	7.4	4.6	2.1	0.0
Carbetamide	Moderate	3.0	3.0	4.2	1.0
Propanil	Toxic, 3	5.0	0.0	0.0	0.0

[a] Health hazard rating by European Union Commission Directive 2001/59/EC.

[b] Conv'l: samples taken from conventional tea production.

CHAPTER IX

CONCLUSIONS AND POLICY IMPLICATIONS

This study utilizes the neo-classical theory of production, risk analysis and the theory of innovation and adoption as the primary theoretical and methodological bases. The major objectives of this study are to examine the efficiency of three different tea production methods (i.e., organic, clean and conventional tea production), to determine effects of risks in the decision making process of switching to organic farming, to assess the environmental impacts of organic and conventional farming methods, to determine the government's role in assisting farmers switching to organic tea production, and to develop policy recommendations for ensuring food security and income stability for tea growers in the transition from conventional to organic farming.

The empirical analysis is centered on:

- Production and profit efficiency of the three different tea production methods;
- Primary factors affecting tea farmers' decision to switch to organic and clean tea production;
- Market and production risks affecting the change in probability to adopt organic/clean tea production and its profitability;
- Policy scenarios (premium price, outside support and tax on conventional tea output value) affecting tea farmers' decision for adopting new tea production methods; and
- Private and social net present values calculated for the three different tea production methods over a 5 year period as criteria for selecting of production alternatives.

The integrated framework for this analytical process includes four different empirical models. First, a stochastic frontier model was used for analyzing production and profit efficiency of the three different tea production methods in the Thai Nguyen province. To gain insights into the level of inefficiency for different tea production methods, farm level data for each tea production method were used to compute production and profit efficiency. Second, a probit model was used to analyze the response probability for adopting the new tea farming practice (i.e., clean tea production or organic tea production). The data set consisted of 176 observations (four were eliminated due to outlier and incomplete information) for this adoption analysis. Third, a Monte Carlo model for risk analysis was developed to determine market factors (e.g., price) and the policy instrument affecting the change in the probability for adopting the new tea production method (e.g., organic tea production or clean tea production) and profitability of tea production. The last component of the analytical framework is the cost-benefit analysis (CBA) model to calculate net present values from the private and social perspectives for the three tea production methods over a 5 year period. This determines net benefits of each alternative.

9.1 Summary Conclusions

9.1.1 Efficiency Analysis

- Production Efficiency

Organic tea farmers are very production efficient farmers. For organic tea farms, labor and capital have significant and positive effects on tea production efficiency. There are only two inefficiency factors (i.e., distance to tea farm and family size) that have statistically significant effects on the production efficiency of organic tea farms.

For clean tea production, only pesticide use has a significant effect on the production efficiency of clean tea production. Similar to organic tea production, family size also has a statistically significant effect on production efficiency of clean tea farms.

The highest mean production efficiency is obtained from organic tea production while conventional tea production has the lowest mean production efficiency. There is no statistically significant difference in average production efficiency levels between clean tea production and conventional tea production.

- *Profit Efficiency*

Organic tea farmers were not only highly production efficient but also very profit efficient. Factors having significant effects on profit efficiency for organic tea farms include pest control costs and tea growing experience. Pest control costs (non-chemical alternatives for organic tea production) had a significant and negative effect on profit efficiency indicating that pest control is a major concern in organic tea production. Among inefficiency factors, tea growing experience had a significant and positive effect on profit efficiency for organic tea production suggesting more experienced farmers have higher profit efficiency.

The fertilizer price and health care related costs were significant and negatively related to profit efficiency for clean tea production while other input costs (labor, pesticide, and other costs) did not have significant effects on profit efficiency for clean tea production. Among inefficient factors, only family size had a significant and positive effect while the age of the household head had a negative and significant effect on profit efficiency for clean tea production.

The highest mean profit efficiency was obtained from organic tea production while conventional tea production had the lowest mean profit efficiency. Also, the mean profit efficiency for clean tea production was statistically higher than for conventional tea production.

9.1.2 Adoption Analysis

There are statistically significant and positive relationships between the probability of adopting organic tea production and the following variables: tea yield, the premium price for organic tea products, the value of capital investment in tea production, WTA and outside support. There is a significant and negative relationship between the probability of adopting organic tea production and health related costs.

For clean tea production, the premium price, outside support, and WTA are positive and statistically significant variables explaining the adoption rates for clean tea production. Unlike organic tea production, tea yield did not have a significant effect on the farmers' decision whether or not to adopt clean tea production

9.1.3 Risk Analysis

- Risk to Adoption Probability

Results from risk analysis illustrate that the probability of adopting organic tea production is very sensitive to the premium price for organic tea products and outside support for organic tea production. Without the premium price, the probability of adopting organic tea production would be zero and without outside support the probability of adopting organic tea production would be just about 0.7%.

The premium price should be at least 20% higher than the regular market price for conventional in order for adoption to occur. Also, it appears that the most effective range for the premium price is 40%-90% above the regular market price. It is estimated that doubling the price for organic tea would lead to an adoption rate for organic tea production of about 87%. A Pigovian tax on output value for conventional tea production would also increase the adoption rates for organic tea production. However, the magnitude of the effect is limited, with a maximum of a 9% increase in the adoption rate for organic tea production. The Pigovian tax illustrate the effect of increasing organic tea adoption rates only for a tax rate less than 25% of output value for conventional tea production.

The probability of adopting clean tea production is also sensitive to the premium price and outside support. Without the premium price, the probability of adopting clean tea production would be 10%, whereas, without outside support the probability of adopting clean tea production is 5.4%.

- Risk and Profit of Tea Production:

Given current and observed socio-economic conditions for organic tea farms in the Thai Nguyen province, if the premium price is removed for the organic tea product, the probability of profit being less than 10 million VND/ha (about $600/ha) increases by 60%. By removing the premium price for the organic tea product, the probability that organic tea farmers would incur a negative profit or economic loss is about 30%.

Given current and observed socio-economic conditions for clean tea farms, if there is no premium price for the clean tea product, then, the probability of having negative profits or losses is about 30%. However, the probability of profit being less than 10 million VND increases by 40% (from 17% to 57% see Figure 11). The effect of removing the premium price on profit reduction is less severe for clean tea production than for organic tea production because clean tea receives a lower premium price than organic tea production (currently the premium prices are about 10% and 30% higher than the regular market price for clean tea and organic tea products respectively).

9.1.4 Agrochemical Residue

There is significant reduction in pesticide residues in the soil after eight months of organic tea production. However, some traces of toxic chemicals still remained in the soil samples. While there were significant findings of toxic pesticide residues in the water samples taken from the conventional tea farm, none of these toxic chemicals were found in the water samples from the organic farm in October, 2007. No toxic chemical residues were found in tea product samples from the organic farm although a trace of Carbetamide was found in the October sample. Whereas, traces of toxic chemicals were found in the tea product samples taken from the conventional farm in October, 2007.

9.1.5 Net Present Value Analysis (NPV)

- Private NPV

In the analysis over a 5 year period (see Table 25), there is no statistically significant difference between private net benefits for organic tea production and clean tea production, and between organic tea production and conventional tea production. However, private NPV for clean tea production is significantly higher than that for conventional tea production. The private NPV is statistically significant higher than the net social benefits for clean tea and conventional tea production methods but not for organic tea production for the 5 year period analysis.

For the 30 year period (see Table 27), private NPV for organic tea production is significantly higher than clean tea and conventional tea production. However, the private

NPV for clean tea production is not significantly different from conventional tea production in the long-run.

- Social NPV

Both organic and clean tea production have significantly higher social NPV as compared to conventional tea production (Table 27). However, there is insignificant difference between the social NPV for organic tea production and clean tea production for the short-run analysis.

For long-run analysis (Table 28), organic tea production has the statistically highest social NPV among the three production methods tested. Also, clean tea production has significantly higher social NPV than conventional tea production.

9.1.6 Overall Results

Novick and Marr (2001) suggest using the ranking technique as a prioritization method to rank interventions. For this technique, each intervention is ranked based on a set of criteria and the overall score for each intervention is calculated by summing the score (rank) received for each criterion. The lowest summed score is judged to be the best (i.e., a "1" is assigned if ranked first, a "2" is assigned if ranked second, etc.)

Overall results for this analytical framework are shown in Table 34 which applies Novick and Marr's ranking technique. For the production efficiency criterion, organic tea production is ranked as being first (and received one point) for having the highest mean production efficiency (see section 4.2.5). Since there is no significant difference between production efficiencies for clean tea and conventional tea production, each production method receive 2.5 points for a total of six points assigned for each criterion. Likewise, one, two and three points were assigned to organic tea, clean tea and conventional tea production respectively, according to their mean profit efficiency ranking (see section 5.2.4). Here, like the production efficiency criterion, the production method with the highest profit efficiency is ranked as being first (one point).

For the market risk criterion, three points (ranked third) were given to organic tea production because it had the highest change in probability for having profit less than 10 million VND/ha when removing the premium price. Two points were given to clean tea production and one point was assigned to conventional tea production (see section 7.3). For institutional risk, three points were given to organic tea production for having the lowest probability for adopting this production method when outside support was removed (see section 7.2.2). Likewise, two points were given to clean tea production and one point to conventional tea production.

For the two NPV criteria (private and social – see section 8.2.1 and 8.2.2 respectively), conventional tea production had the lowest private and social NPV and received three points apiece. Clean tea production had the second highest private NPV and its social NPV was not significant different from organic tea production.

Lastly, for the environmental impact criterion (see discussion in section 8.2.3), organic tea production had the lowest mean environmental cost (smallest gap between private NPV and social NPV) was assigned one point. Clean tea production and conventional tea production had significantly higher environmental costs with the latter having the highest environmental cost.

Table 34. Overall Analytical Ranking Score and Comparison

Determinant	Tea production method (ranking score)[a]		
	Organic tea	Clean tea	Convent'l tea
Production efficiency	1[b]	2.5	2.5
Profit efficiency	1	2	3
Market risk (premium price)	3	2	1
Institutional risk (outside support)	3	2	1
Private NPV	2 (1)[c]	1(2)	3
Social NPV	1.5 (1)	1.5 (2)	3
Environmental impact	1	2	3
Total score	12.5 (11)	13 (14.5)	16.5

[a] Lower score implies higher rank. It follows that a lower score suggests a higher prioritized method.

[b] Figures represent rankings from the short-run analysis (5 year period).

[c] Figures in parentheses represent rankings from the long-run analysis (30 year period).

Given current socio-economic conditions in the Thai Nguyen province for the short-run, the overall ranking of results from all four analytical models finds that organic tea has the lowest overall score. This suggests that organic tea production is the highest prioritized production alternative. However, the difference in overall scores for organic and clean tea production is small (0.5 points) suggesting that both organic tea and clean production are higher prioritized production alternatives than conventional tea production in the short-run.

For the long-run, organic tea production has the lowest overall score. Although in the short-run, overall score for organic tea production and clean tea production were close, it is more apparent in the long-run that organic tea is the highest prioritized production method.

Caution should be used in interpreting the results of this research since the study involved only 23 organic tea producers (this represents the total number of organic tea producers in the Thai Nguyen province when the research was implemented). Also, organic tea production is relatively new to the Thai Nguyen province having started five years ago and has been heavily supported by NGOs and by the government (i.e., certification payment, extension services, technical training etc.). Consequently, the economic data collected from organic tea production may not reflect actual realizations from long term production. In addition, NPV analyses in this research were calculated by assuming static conditions. Thus, verification of research conclusions by utilizing a larger sample size with a longer time period of analysis is recommended.

9.2 Policy Implication

Together with other exporting crops, tea production in Vietnam in general and in the Thai Nguyen province in particular, has faced numerous opportunities and challenges globally and domestically ever since becoming the 150^{th} member of the WTO in December, 2006. Domestically, there are new environmental standards, such as the requirement of submitting a certificate of product quality when registering for a new business in the tea industry (VTA, 2005). The government of Vietnam in its 10 year strategic plan affirmed that "Vietnam's tea production should shift to organic production by creating organic substance, irrigation, intensive cultivation, ecology and sustainable development for tea" (VN Economy, 2003). According to the Vietnam Tea Association, the conversion period for organic tea production in Vietnam is at least 2 years. During the transition period, tea farmers have faced several problems which were discussed in previous chapters, such as not being allowed to use pesticides or chemical inputs, not being certified as organic and therefore not qualified to receive the premium price, higher production costs due to using labor intensive pest and weed control method and reduced crop yields. Understanding these problems and finding solutions to ease tea farmers' difficulties in the transition period was a major concern for this study and should be dealt with by policy makers in the future.

In the global tea market, demand for tea has increased significantly over the past decade. Tea production has also expanded while Vietnamese tea is still being sold primarily in traditional markets, e.g., China, Taiwan and Russia. The potential for exporting tea is expanding due to recent publicity about the usefulness of green tea in preventing ulcers and stomach cancer. However, the world market for tea has also demanded higher quality products. In order to compete in the world market, tea from Vietnam should be more competitive not only in terms of price but more importantly in terms of product quality. This challenge has sparked a movement towards organic tea production.

- *Support for Organic Tea Production*

The findings discussed in sections from chapters 4 through 8 suggest that there are ways that the government can play an important role in promoting organic tea production. Given the current situation, government support (through governmental agencies or NGOs) still play an important role in increasing the probability of adopting organic tea production (section 7.1). Also, outside support (i.e., government agencies and NGOs) plays a significant role by enabling tea farmers to participate in intermediate tea production methods, e.g., clean tea production. The most common form of outside support observed from this study's field survey was technical and extension services (i.e., technical training, on farm monitoring, non pesticide pest control training, etc.). Support also includes providing ways for marketing organic tea products, subsidizing certification costs and providing organic farm inputs that satisfy certification requirements for organic tea farmers. However, these support programs may not be enough and sustainable for promoting organic tea production in the long run.

- *Price Support (maintaining the premium price for organic tea)*

The other form of government intervention is the creation of a market mechanism that guarantees a premium price for the organic tea product. As illustrated in section 7.1.2, the premium price level that begins to increase the adoption rate for organic tea production is about 20% higher than the regular market price. Removal of the premium price is expected to reduce the probability of adopting organic tea production to zero. The premium price mechanism has been a sustainable way to promote organic production. Pimentel et al. (2005) reported that the premium price for organic corn in the U.S. requires the equalization of organic and conventional returns which is estimated to be 10% above the price of the conventional product. However, premium prices now range from 65% to 140% (Pimentel et al., 2005). At present, the premium price for organic tea in the Thai Nguyen province is set by sponsoring companies (i.e., Ecolink Co.) who purchase the organic products from organic tea farmers through contracts signed at the beginning of the tea production year.

Note that there are market niches for organic tea products in the domestic market. Raising awareness of health and environmental benefits from organic tea production or requiring product labeling with product quality control certification would competitively create a higher price for organic tea products domestically in the long run without the use of governmental administrative intervention.

- Tax on Conventional Tea

One of the choices for government intervention aimed at reducing environmental externalities is to internalize the externality by imposing a Pigovian tax on polluters (conventional tea producers in this case). The discussion in section 7.1.2 suggests that the tax on conventional tea output may shift some conventional tea producers to organic tea production (from Figure 9, the tax can increase the adoption probability by at most 9%). As shown, the effect of imposing a tax on conventional output is small in terms of prompting conventional tea farmers to switch to organic production given current socio-economic conditions.

-Applying an Alternative System

As discussed in chapter 1, organic tea production is a way to improve tea quality standards by satisfying demands for higher quality products and improving health conditions in a highly competitive market. However, not all conventional tea farmers can immediately switch to organic tea production because of factors affecting this decision. As an intermediate solution between two production extremes, organic production on one hand, without using chemical and synthetic inputs, and conventional production on the other hand, with intensive use of off farm inputs, clean tea production is a compromising alternative. As shown from earlier analyses, clean tea production has significantly higher production and profit efficiencies and social net present value than conventional tea production. Clean tea production also has a higher probability of adoption, even without outside support or without the premium price as compared to organic tea production.

However, clean tea production is less efficient and has lower social net benefit than organic tea production. Introducing clean tea production as an intermediate alternative, by relaxing restrictions on pesticide and other chemical input usage, will help prepare tea farmer readiness in terms of production adjustments and attitude changes as they move toward organic tea production later.

Results from a combination of results using all four analytical models shown in Table 28 (see section 9.1.6) imply that clean tea production can be a viable alternative tea production method in the short run (5 year period) in terms of satisfying higher quality standards and profitability of tea growers in the Thai Nguyen province. However, in the long run (30 year period), organic tea production is the best tea production method in terms of satisfying both individual tea producer's food and income security objectives and society's safer environment objective.

9.3 Research Contributions

9.3.1 Theoretical and Methodological Contribution

Efficiency analysis for both production efficiency and profit efficiency is based on the assumption that the tea production function is of the Cobb-Douglas form. However, the translog form for variable is used as a correction procedure due to skewness and kurtosis problems.

For CBA, obtaining appropriate information on inflows and outflows is very important because this information ensures the accuracy of analytical results and, hence, the selection of alternatives. This becomes even more critical when evaluating environmental costs and benefits for a project since a market mechanism to evaluate these benefits and costs is often not available. During the data gathering (surveying) portion of this study, it was difficult for farmers to recall information about previous production years since bookkeeping in rural Vietnam is not practiced. Therefore, data based on recall should be cross-checked and re-calculated before being utilized in the analyses. To overcome problems involved with recall information, a penal survey was implemented for one production year to compare the accuracy of the information and data provided by interviewees. During the research period, recording notebooks were provided to all interviewees at the first survey meeting and were collected at the follow-up survey meeting as a source for cross-checking and re-calculating survey data.

For the analytical framework, several different models were integrated to capture the decision making process of typical tea growers. The SFA evaluates the production and profit efficiency for the three different tea production processes. It is critical to highlight these variables which are used in the adoption model. The output from the adoption analysis and the profit equation (via profit efficiency analysis) are utilized in the risk model to determine risk factors involved in selecting different tea production methods.

The policy scenario simulations provide additional information about possible exogenous market and institutional changes which could affect the farmers' adoption decision. For tea growers, in the Thai Nguyen province in particular and in Vietnam in general, information about production efficiency, profit efficiency, potential risks, and NPVs of different tea production methods alone are important but perhaps a greater contribution is illustrating the linkages which determine how the final decision is made. The results represented in Table 28 show that the overall conclusion could change as results from individual analytical models change.

As discussed in section 1.3, there were four research questions which initiated this research: i) What factors affect tea farmers' decision to convert their production from conventional to organic tea? ii) If a tea grower switches to organic farming, what challenges and risks would he/she face? iii) What are the costs and benefits of converting from conventional production to organic tea production for tea growers and for society as a whole in the Thai Nguyen province? and iv) What is the government's role in assisting farmer adoption of organic farming? Figure 12 illustrates linkages of the four analytical models that lead to answers for these research questions. The adoption model provides information to answer the first question. The risk model answers the second question and the CBA model provides information for the third question. However, objective functions and decision variables in the risk model are outputs of the profit efficiency and adoption models. Consequently, answering the fourth question requires a combination of results from efficiency, adoption and risk analyses.

The linkages illustrated in Figure 12 show that improving tea yield is one way to increase the adoption rate for organic tea production (adoption model result). The answer for how organic tea farmers can improve their tea yield is obtained from the production efficiency model analysis (more labor or capital to substitute for chemical inputs). Likewise, improving net benefits from organic tea production requires organic tea growers gaining more experience (overtime) and reducing pest and disease control costs (profit efficiency model). The combination of these four analytical models provides a tool to assist policy makers in designing appropriate policies to encourage organic tea production.

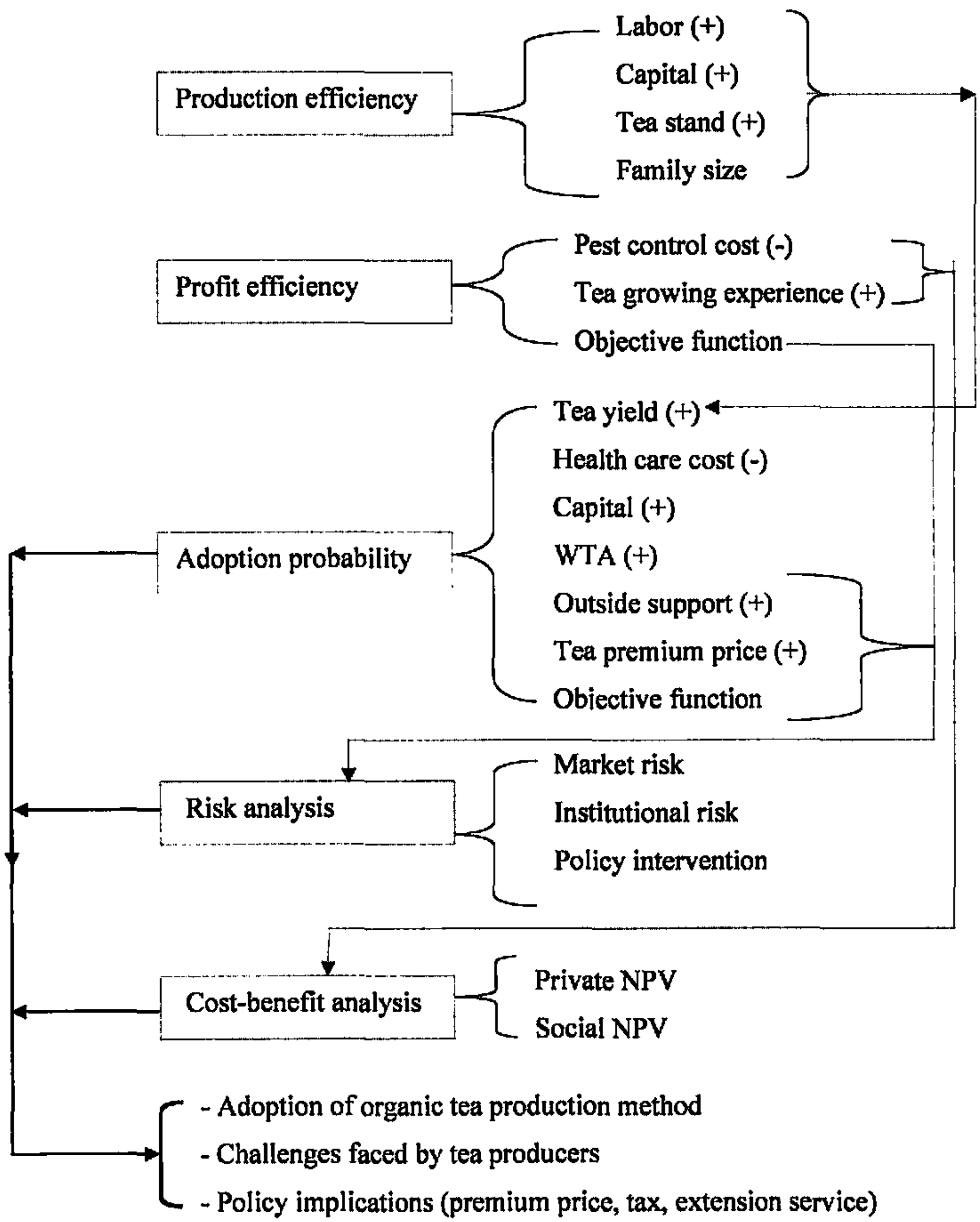


Figure 12. Overall Outcomes for Entire Analytical Framework for Organic Tea Production in the Thai Nguyen Province

Note: (+): positive relationship; (-): negative relationship

9.3.2 Empirical Contribution to Tea Research

Use of production and profit efficiencies to analyze tea production in Vietnam is new. Although there have been many studies done for different annual crops such as rice (Ali and Flinn, 1989; Kolawole, 2006), pasture (Battese and Corra, 1977) and corn (Lui, 2006), no studies were found for tea production. This research also integrates four different analytical models (stochastic frontier analysis, adoption analysis, risk and uncertainty analysis and cost-benefit analysis). This combination provides comprehensive information for tea producers in making their decision of whether or not to switch to organic tea or clean tea production. Although tea farmers may not be interested in production and profit efficiency levels, they are interested in finding answers to questions such as: i) If a tea grower switches to organic farming, what challenges and risks would he/she face? ii) What are the costs and benefits of converting from conventional production to organic tea production for tea growers? iii) What is the government's role in assisting them to adopt organic farming? The answers resulting from this integrated analytical research framework are: i) Organic tea production is the highest prioritized production alternative in the short-run and it is more apparent in the long-run that organic tea is the highest prioritized production method (see Table 34). ii) If tea farmers switch to organic tea production, they will face higher market risks and institutional risks. iii) They should be able to sell their organic products at a premium price and improve the environmental conditions in the area, and iv) The government can assist organic tea farmers by maintaining and increasing the premium price, providing technical and extension service so that tea farmers can reduce costs for pest and disease control, and by levying a tax on conventional tea products. Also, these answers provide appropriate information for policy makers in designing policies to help organic tea growers in Vietnam.

9.4 Recommendations for Further Research

This study combines four different analytical models in an integrated analytical framework to provide insights of the situation(s) and consequences of switching to organic tea production in the Thai Nguyen province. Although findings of this research provide useful information on the economic and environmental impacts for the transitioning to organic tea production from conventional tea production in the Thai Nguyen province, it is still limited in geographical areas to two districts of the Thai Nguyen Province. Expanding this study to other tea growing areas of Vietnam to test the findings before applying them at the national level is necessary.

As discussed in section 6.2.1, if organic tea yields increase then the adoption of organic tea production will also increase. This finding suggests a research opportunity in the area of selecting tea varieties or cropping technologies that produce higher organic tea yields and higher product quality. Also, the discussion in section 5.2.1 shows that one of the effective ways to increase profit efficiency and hence, the profitability for organic tea production is to reduce pest and disease control expenditures for organic tea. Tea varieties that resist pests and diseases while producing higher yields and a higher quality product, can contribute to cost reductions for pest and disease control. This potential research is an encouraging way to promote organic tea production in Vietnam.

With time and resource constraints, this research focused primarily on the supply side of organic tea production, another area for further research is the demand side. Research on the demand side should include, but not be limited to: How much consumers would be willing to pay for organic tea products in domestic markets? What marketing schemes could organic tea producers utilize in order to expand their market share domestically and globally?

Although this research did provide information about how organic tea production could contribute to a reduction of pesticide and agro-chemical residues in the soil, water and tea product, the data were limited to one organic tea farm and one conventional tea farm and over a short period of time (8 months). It would be more useful and persuasive if other research were conducted involving more tea producing farms (at least three replicates for each type of tea production including clean tea producing farms) and for a longer period (2 year transition period). Also, results of such research would be more useful for calculating an environmental abatement payment or an environmental cost in the net present value (NPV) analysis.

The results from the policy analysis scenario in section 7.2 have shown the important role that the government can play in promoting organic tea production in Vietnam, i.e., price support for organic products, levying a tax on conventional tea output. These results open up another research area to determine the appropriate payment vehicle for environmental benefits in the case of organic tea production in particular and organic production in general.

Last but not least, search for an improved data collection procedure based on information recall by interviewees is needed. Often, it is quite difficult for farmers to recall inflows and outflows of their production in years prior to the current production year. Therefore, to cross-check collected data from a survey with data from a bookkeeping system or data from an artificial market experiment is highly recommended.

APPENDIX A

STATA.9 OUTPUT OF PRODUCTION EFFICIENCY ANALYSIS

A1. Production Efficiency of Organic Tea Production

```
frontier lnyldaf lnlabora lnfera lnpesta lntare lnstand distf ir lncapt lnage
fsiz eth edu lntexp
Stoc. frontier normal/half-normal model           Number of obs   =        23
                                                  Wald chi2(13)   =     40.50
Log likelihood =  19.011888                       Prob > chi2     =    0.0001
------------------------------------------------------------------------------
     lnyldaf |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lnlabora |   .2434184   .1322693     1.84   0.066    -.0158247    .5026615
      lnfera |   .0821333   .0661902     1.24   0.215     -.047597    .2118637
     lnpesta |   .0005789   .0048919     0.12   0.906     -.009009    .0101668
      lntare |  -.0642987   .0910197    -0.71   0.480     -.242694    .1140965
     lnstand |   .2040206   .0639309     3.19   0.001     .0787183    .3293229
       distf |  -.0890211   .0738505    -1.21   0.228    -.2337654    .0557233
          ir |   .0005411   .1263577     0.00   0.997    -.2471155    .2481977
      lncapt |   .0088508   .0043725     2.02   0.043     .0002808    .0174208
       lnage |  -.1585291   .1459575    -1.09   0.277    -.4446006    .1275424
        fsiz |    .095086    .028691     3.31   0.001     .0388526    .1513193
         eth |  -.0008166   .0590129    -0.01   0.989    -.1164798    .1148466
         edu |  -.0592556   .0803186    -0.74   0.461    -.2166771     .098166
      lntexp |   -.124306   .0858459    -1.45   0.148    -.2925609    .0439489
       _cons |   2.782541   1.498249     1.86   0.063    -.1539736    5.719056
-------------+----------------------------------------------------------------
    /lnsig2v |  -4.491248   .2988524   -15.03   0.000    -5.076987   -3.905508
    /lnsig2u |  -12.13205   277.4457    -0.04   0.965    -555.9156    531.6515
-------------+----------------------------------------------------------------
     sigma_v |   .1058615   .0158185                      .0789853    .1418828
     sigma_u |   .0023204   .3218889                     1.9e-121    2.8e+115
      sigma2 |    .011212     .00344                      .0044697    .0179544
      lambda |    .021919   .3248165                     -.6147096    .6585475
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 0.00    Prob>=chibar2 = 1.000
```

A2. Production Efficiency of Clean Tea Production

```
frontier lnsyldaf lnsage lnstare lnstands lnslabora lnsfera lnspesta lnsmcr
fsiz eth edu lnstexp ir distf
Iteration 31:  log likelihood =  58.012786
Stoc. frontier normal/half-normal model            Number of obs    =        67
                                                   Wald chi2(13)    =  3.797e+08
Log likelihood =  58.012786                        Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lnsyldaf |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lnsage |   -.039021   .0160529    -2.43   0.015    -.0704842   -.0075579
     lnstare |  -.0979319   .0171719    -5.70   0.000    -.1315881   -.0642756
    lnstands |   .0290684   .0006142    47.33   0.000     .0278647    .0302722
   lnslabora |   .0370885   .0332656     1.11   0.265    -.0281108    .1022879
     lnsfera |   .0142346   .0180087     0.79   0.429    -.0210618    .0495309
    lnspesta |  -.0172238    .019167    -0.90   0.369    -.0547904    .0203428
      lnsmcr |  -.0464723   .0080205    -5.79   0.000    -.0621922   -.0307523
        fsiz |  -.0286483   .0160956    -1.78   0.081    -.0609319    .0036353
         eth |  -.1333699   .0832582    -1.60   0.115    -.3003647    .0336249
         edu |  -.0240838   .0563094    -0.43   0.671    -.1370262    .0888586
     lnstexp |    .020476   .0358072     0.57   0.567    -.0497049    .0906569
          ir |   -.009397   .0010423    -9.02   0.000    -.0114399    -.007354
       distf |  -.0035821   .0336553    -0.11   0.916    -.0710861     .063922
       _cons |   2.184917   .0285125    76.63   0.000     2.129033      2.2408
-------------+----------------------------------------------------------------
    /lnsig2v |  -37.49426   728.1711    -0.05   0.959    -1464.683    1389.695
    /lnsig2u |  -3.183308   .1727737   -18.42   0.000    -3.521938   -2.844677
-------------+----------------------------------------------------------------
     sigma_v |   7.21e-09   2.63e-06                             0    5.9e+301
     sigma_u |   .2035886   .0175874                      .1718782    .2411494
      sigma2 |   .0414483   .0071612                      .0274127     .055484
      lambda |   2.82e+07   .0175874                      2.82e+07    2.82e+07
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 43.05  Prob>=chibar2 = 0.000
```

A3. Production Efficiency of Conventional Tea Production

```
frontier  lnyldaf lnlabora lnfera lnpesta lnstare lnstand distf ir lncapt edu
fsiz eth lntexp lnage

Iteration 5:   log likelihood =  54.711866

Stoc. frontier normal/half-normal model           Number of obs   =        86
                                                  Wald chi2(13)   =     40.51
Log likelihood =  54.711866                       Prob > chi2     =    0.0001

------------------------------------------------------------------------------
     lnyldaf |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lnlabora |   .1040801   .0618036     1.68   0.092    -.0170527     .225213
      lnfera |  -.0021808   .0046945    -0.46   0.642    -.0113819    .0070203
     lnpesta |   .0072746    .004917     1.48   0.139    -.0023625    .0169116
     lnstare |  -.0759543   .0305452    -2.49   0.013    -.1358219   -.0160868
     lnstand |  -.0033047   .0306888    -0.11   0.914    -.0634536    .0568442
       distf |   .0609124   .0255721     2.38   0.017     .0107919    .1110329
          ir |  -.0974455    .049191    -1.98   0.048     -.193858    -.001033
      lncapt |    .001943    .002178     0.89   0.372    -.0023257    .0062118
        fsiz |   .0275527     .01362     2.02   0.043     .0008579    .0542474
         eth |   .0078264   .0228521     0.34   0.732     -.036963    .0526158
         edu |  -.0039294   .0030240    -1.30   0.413    -.0110572    .0011983
     lnstexp |  -.0133926   .0332756    -0.40   0.687    -.0786115    .0518263
      lnsage |  -.0192482   .0861565    -0.22   0.823    -.1881117    .1496154
       _cons |   3.862967   .4936047     7.83   0.000     2.895519    4.830414
-------------+----------------------------------------------------------------
    /lnsig2v |  -5.610219   .9952504    -5.64   0.000    -7.560874   -3.659564
    /lnsig2u |  -3.219273   .4090301    -7.87   0.000    -4.020958   -2.417589
-------------+----------------------------------------------------------------
     sigma_v |   .0605001   .0301064                      .0228127    .1604485
     sigma_u |   .1999602   .0408949                      .1339245    .2985569
      sigma2 |   .0436444   .0133852                      .0174098    .0698789
      lambda |    3.30512   .0683961                      3.171066    3.439174
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 6.09   Prob>=chibar2 = 0.007
```

APPENDIX B

STATA.9 OUTPUT OF PROFIT EFFICIENCY ANALYSIS

B1. Profit Efficiency of Organic Tea Production

```
frontier lnprofan lnlapan lnpevna lnheafn lnothan lnage  edu lnstare distm
lntexp lnferan
Stoc. frontier normal/half-normal model            Number of obs    =        23
                                                   Wald chi2(10)    =  2.603e+07
Log likelihood = -9.0260557                        Prob > chi2      =     0.0000

------------------------------------------------------------------------------
    lnprofan |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     lnlapan |  -.4965223   2.772597    -0.18   0.858    -5.930712    4.937667
     lnpevna |  -.0234022   .0117579    -1.91   0.057    -.0454473    .0006429
     lnheafn |   -.004586   .0034688    -1.32   0.186    -.0113847    .0022128
     lnothan |  -.0072722   .0132351    -0.55   0.583    -.0332125     .018668
       lnage |  -.3922559   .2661869    -1.47   0.141    -.9139727    .1294608
         edu |   .0320463   .0402118     0.80   0.425    -.0467674    .1108601
     lnstare |  -.1642428   .2690434    -0.61   0.542    -.6915582    .3630727
       distm |  -.0488977    .151421    -0.32   0.747    -.3456773     .247882
      lntexp |   .7958037   .3150738     2.53   0.012     .1782703    1.413337
     lnferan |   .4031859   2.295279     0.18   0.861    -4.095479     4.90185
       _cons |    7.51103   1.891979     3.97   0.000     3.802819    11.21924
-------------+----------------------------------------------------------------
    /lnsig2v |    -32.797   795.4222    -0.04   0.967    -1591.796    1526.202
    /lnsig2u |  -.6667087    .294884    -2.26   0.024    -1.244671   -.0887468
-------------+----------------------------------------------------------------
     sigma_v |   7.55e-08     .00003                             0           .
     sigma_u |   .7165162   .1056446                      .5366896    .9565967
      sigma2 |   .5133955   .1513921                      .2166725    .8101186
      lambda |    9484284   .1056446                       9484284     9484284
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01) = 13.48  Prob>=chibar2 = 0.000
```

B2. Profit Efficiency of Clean Tea

```
frontier lnprofan lnlapan lnpevna lnheafn lnothan lnfervna distm lnstare lnage
edu lntexp
Final   normal/half-normal model                    Number of obs    =        67
                                                     Wald chi2(10)   =  3.208e+08
Log likelihood = -24.004103                          Prob > chi2     =    0.0000
```

lnprofan	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnlapan	.09897	.2979028	0.33	0.740	-.4849087	.6828487
lnpevna	-.048126	.0524173	-0.92	0.359	-.150862	.05461
lnheafn	-.0055053	.0010838	-5.08	0.000	-.0076296	-.003381
lnothan	.0098114	.0244098	0.40	0.688	-.0380309	.0576538
lnfervna	-.3979353	.026114	-15.24	0.000	-.4491178	-.3467529
distm	-.1210896	.042704	-2.84	0.005	-.2047879	-.0373912
lnstare	.1642749	.0763152	2.15	0.031	.0146998	.31385
lnsage	-.062471	.1927231	-0.32	0.747	-.4493788	.3244368
edu	.0846781	.039905	2.12	0.034	.0064656	.1628905
lntexp	-.0645777	.0112714	-5.73	0.000	-.0866693	-.0424861
_cons	11.90978	.2039454	58.40	0.000	11.51005	12.3095
/lnsig2v	-34.88479	765.6164	-0.05	0.964	-1535.465	1465.696
/lnsig2u	-.7350424	.1727737	-4.25	0.000	-1.073673	-.3964122
sigma_v	2.66e-08	.0000102			0	.
sigma_u	.6924486	.0598185			.5845948	.8202008
sigma2	.4794851	.0828424			.317117	.6418533
lambda	2.60e+07	.0598185			2.60e+07	2.60e+07

```
Likelihood-ratio test of sigma_u=0: chibar2(01) = 54.42  Prob>=chibar2 = 0.000
```

B3. Profit Efficiency of Conventional Tea Production

```
frontier lnprofan lnlapan lnpevna lnheafn lnothan  edu lnferan lnsage  distm

lnstare lnstexp

Stoc. frontier normal/half-normal model          Number of obs    =          86
                                                 Wald chi2(10)    =  4834802.1
Log likelihood = -230.12825                      Prob > chi2      =     0.0000
```

lnprofan	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnlapan	2.684799	4.794284	0.56	0.576	1.519473	3.850124
lnpevna	-.0524917	.0121508	-4.32	0.000	-.2363287	.1313453
lnheafn	.0071847	.005359	1.34	0.180	-.0033188	.0176881
lnothan	-.0063716	.0164634	-0.39	0.699	-.0386393	.0258962
edu	-.0474386	.0410824	-1.15	0.248	-.1279585	.0330814
lnferan	-4.196863	1.44568	-2.90	0.004	-7.030343	-1.363383
lnsage	.3880127	1.046225	0.37	0.711	-1.662551	2.438576
distm	.03104418	.0818291	0.038	0.706	-0.320792	0.941676
lnstare	.5163148	.4470648	1.15	0.248	-.3599162	1.392546
lnstexp	-.4567328	.6143202	-0.74	0.457	-1.660778	.7473126
_cons	8.298414	1.264674	6.56	0.000	5.819698	10.77713
/lnsig2v	-28.23053	233.7805	-0.12	0.904	-486.4319	429.9708
/lnsig2u	3.900239	.1524988	25.58	0.000	3.601347	4.199131
sigma_v	7.41e-07	.0000866			2.4e-106	2.33e+93
sigma_u	7.029529	.5359972			6.053724	8.162624
sigma2	49.41427	7.535615			34.64474	64.18381
lambda	9486527	.5359972			9486526	9486528

Likelihood-ratio test of sigma_u=0: chibar2(01) = 88.55 Prob>=chibar2 = 0.000

APPENDIX C

STATA.9 OUTPUT OF ADOPTION ANALYSIS

C1. Organic Tea Adoption Probability

```
Probit model with endogenous regressors           Number of obs   =        176
                                                  Wald chi2(12)   =     188.22
Log pseudolikelihood = -710.75568                 Prob > chi2     =     0.0000

------------------------------------------------------------------------------
             |               Robust
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
org          |
       yldaf |   .0642549   .0069864     9.20   0.000     .0505618    .0779481
        heaf |  -.0000342   .0000134    -2.56   0.011    -.0000004   -5.30e-08
     capital |   .0000056    2.69e-6     2.11   0.034     .0006228    .0164473
        flab |  -.1066383    .108328    -0.98   0.325    -.3189573    .1056806
       sport |     .36672   .1302709     2.82   0.005     .1113938    .6220462
        prob |  -.0581769   .0822788    -0.71   0.480    -.2194403    .1030865
     avpriaf |   .1398102   .0868937     1.61   0.108    -.0304984    .3101189
         wtp |    .015553   .0073835     2.11   0.035     .0010817    .0300244
          ir |   .9385068   .2860259     3.28   0.001     .3779063    1.499107
         edu |  -.0102423   .0137241     0.75   0.652     -.037691     .017205
        fsiz |  -.0123297   .0810151    -0.15   0.879    -.1711164     .146457
       distf |  -.1890686     .18036    -1.05   0.295    -.5425678    .1644306
         age |  -.0161359   .0101418    -1.59   0.112    -.0360136    .0037417
       _cons |  -7.978774   1.092039    -7.31   0.000    -10.11913   -5.838417
-------------+----------------------------------------------------------------
    /lnsigma |   2.563306   .0676792    37.87   0.000     2.430657    2.695955
     /athrho |  -3.303569   .7037456    -4.69   0.000    -4.682885   -1.924253
-------------+----------------------------------------------------------------
       sigma |   12.97865   .8783851                      11.36635    14.81966
         rho |  -.9973023   .0037919                     -.9998288   -.9582663
------------------------------------------------------------------------------
Instrumented:  yldaf
Instruments:   heaf mcr flab sport prob avpriaf wtp ir fsiz distf age texp edu
tare stand
------------------------------------------------------------------------------
Wald test of exogeneity (/athrho = 0): chi2(1) =    22.04 Prob > chi2 = 0.0000
```

C2. Clean Tea Adoption Probability

```
Probit model with endogenous regressors           Number of obs   =        153
                                                  Wald chi2(13)   =      71.55
Log pseudolikelihood =  -640.5986                 Prob > chi2     =     0.0000

------------------------------------------------------------------------------
             |               Robust
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
clean        |
       yldaf |  -.0089971    .0307861    -0.29   0.770    -.0693367    .0513424
        heaf |   .0000288    .0000203     1.41   0.157    -.0000111    .0000686
     capital |  -.0000124    9.50e-06    -1.31   0.190    -.0000311    6.17e-06
        flab |  -.4607197    .2494888    -1.85   0.065    -.9497087    .0282694
       sport |   1.354438    .4355919     3.11   0.002     .5006936    2.208182
        prob |   .2936759    .2163283     1.36   0.175    -.1303198    .7176717
     avpriaf |   .4328601    .1063402     4.07   0.000     .2244371    .6412831
         wtp |   .0334165    .0143531     2.33   0.020      .005285     .061548
         edu |  -.2087034    .3586315    -0.58   0.561    -.9116082    .4942014
        fsiz |  -.0251549     .148114    -0.17   0.865     -.315453    .2651431
         age |  -.0007334    .0143477    -0.05   0.959    -.0288544    .0273875
          ir |  -.1219258     .498471    -0.24   0.807    -1.098911    .8550593
       distf |   .9483441    1.047891     3.07   0.002     .3434354    1.553253
       _cons |  -5.764977    4.885468    -1.18   0.238    -15.34032    3.810365
-------------+----------------------------------------------------------------
    /lnsigma |   2.467542    .0852784    28.94   0.000     2.300399    2.634684
     /athrho |   .2439538    .3829092     0.64   0.524    -.5065344     .994442
-------------+----------------------------------------------------------------
       sigma |   11.79342    1.005724                      9.978166    13.93891
         rho |   .2392268    .3609955                     -.4672406    .7592501
------------------------------------------------------------------------------
Instrumented:  yldaf
Instruments:   heaf mcha flab sport prob avpriaf wtp edu fsiz age ir distf tare
               texp stand
------------------------------------------------------------------------------
Wald test of exogeneity (/athrho = 0): chi2(1) =     0.41 Prob > chi2 = 0.5241
```

APPENDIX D

Environmental Cost Estimation for Three Tea Production Methods (using equation 8.1)

Tea producer group	WTA_{ai} (%)	R_{ai} (%)	WTA-R_{ai} (%)
Organic tea	32	34	-10
Clean tea	22	7.4	16.6
Conventional tea	23	0	24
Overall	WTA = 24 (%)		

Note:

- WTA is the average WTA for 176 tea producers in the sample = 24% reduction in tea income.

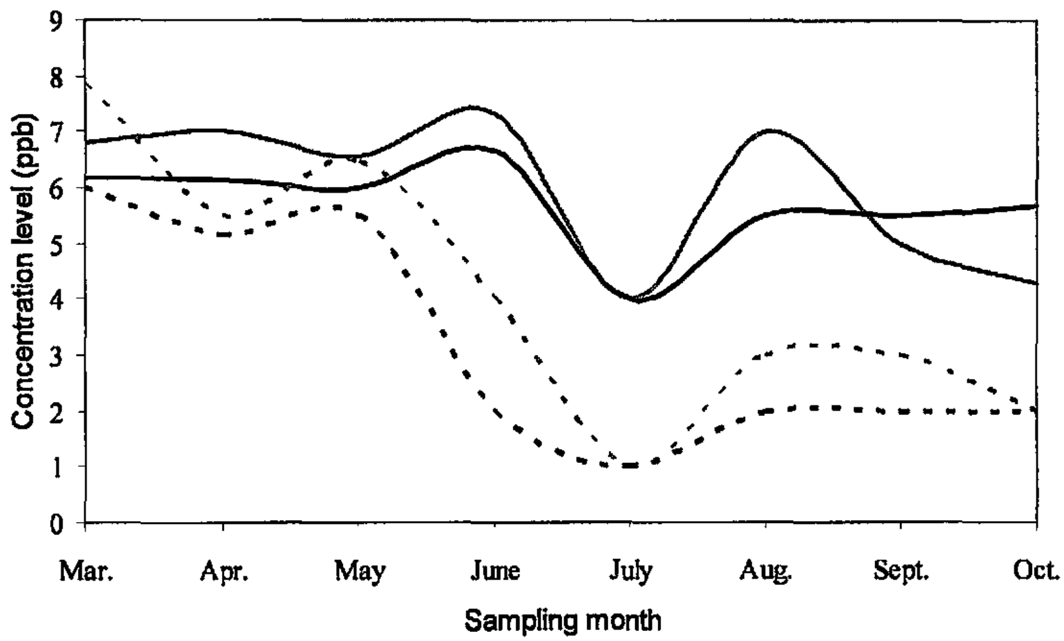
- WTA_{ai} is the average WTA by tea producer groups (i.e., organic, clean and conventional tea producers).

- R_{ai} is the average percentage of actual reduction in tea income by tea producer groups. In NPV calculation, R_{ai} is replaced by R_i (percentage of actual reduction in tea income for each producer).

APPENDIX E

PESTICIDE RESIDUES IN THE SOIL AND WATER

E1. Pesticide Residues in Organic and Conventional Farm Soils



______ 2,5 Dichloraniline residues in the conventional farm soil

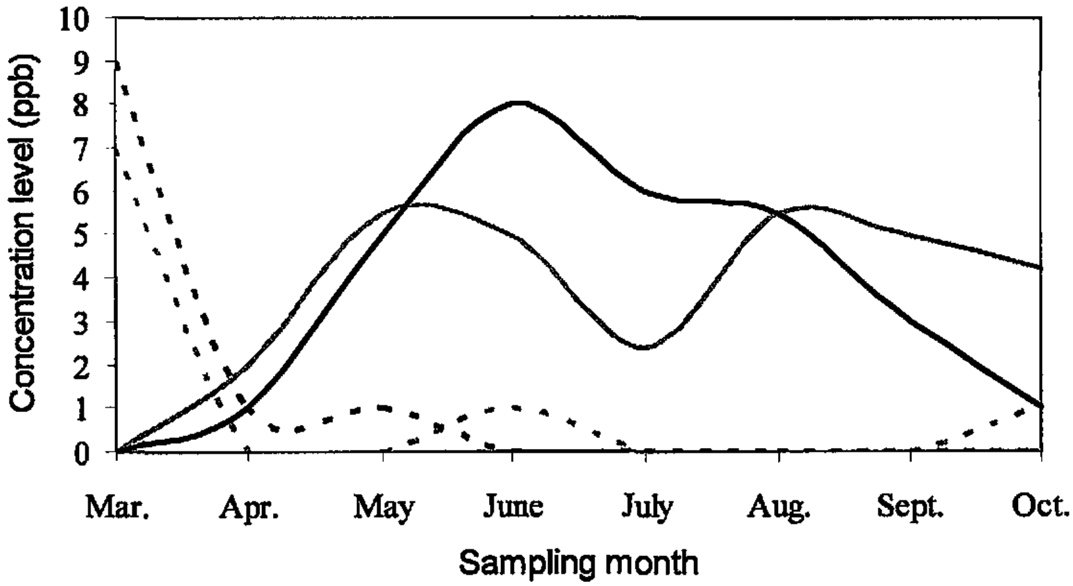
-------- 2,5 Dichloraniline residue in the organic farm soil

______ 2,3 Dichloraniline residues in the conventional farm soil

-------- 2,3 Dichloraniline residue in the organic farm soil

Figure 13. Pesticide Residue Concentration in the Soils Taken from the Organic and Conventional Tea Farms in Tan Cuong Commune in 2007.

E2. Pesticide Residues in the Water Samples Taken from Organic and Conventional Farms



_____Carbetamide residues in water samples taken from the conventional farm

------ Carbetamide residue in water samples taken from organic farm soil

_____2,3 Dichloraniline residues in water samples taken from the conventional farm

--------2,3 Dichloraniline residue in water samples taken from the organic farm

Figure 14. Pesticide Residue Concentration in Water Samples Taken from the Organic and Conventional Tea Farms in Tan Cuong Commune in 2007.

APPENDIX F

RESULTS OF T-TESTS FOR NPV ANALYSES

F1.T-test for Social Net Present Value (5 year period)

.ttest spv1 if pmet~=1, by(pmet) unequal (clean vs conventional tea)

Two-sample t test with unequal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
2	67	110561.6	9486.459	77650.02	91621.25	129501.9
3	86	44730.56	6905.83	64042.03	30999.92	58461.2
combined	153	73558.52	6254.598	77365.11	61201.35	85915.69
diff		65831.02	11733.86		42611.54	89050.51

```
    diff = mean(2) - mean(3)                                      t =   5.6103
Ho: diff = 0                     Satterthwaite's degrees of freedom =   126.83

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

. ttest spv1 if pmet~=2, by(pmet) unequal (organic vs conventional tea)

Two-sample t test with unequal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
1	23	141520.9	18749.66	89920.2	102636.5	180405.3
3	86	44730.56	6905.83	64042.03	30999.92	58461.2
combined	109	65154.2	7691.972	80306.55	49907.38	80401.03
diff		96790.31	19980.99		55876.72	137703.9

```
    diff = mean(1) - mean(3)                                      t =   4.8441
Ho: diff = 0                     Satterthwaite's degrees of freedom =  28.2393

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

. ttest spv1 if pmet~=3, by(pmet) unequal (Organic vs clean tea)

Two-sample t test with unequal variances

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
1	23	141520.9	18749.66	89920.2	102636.5	180405.3
2	67	110561.6	9486.459	77650.02	91621.25	129501.9
combined	90	118473.4	8598.726	81574.67	101387.9	135558.9
diff		30959.29	21012.91		-11745.79	73664.37

```
    diff = mean(1) - mean(2)                                      t =   1.4733
Ho: diff = 0                     Satterthwaite's degrees of freedom =  33.9633

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9251         Pr(|T| > |t|) = 0.1499          Pr(T > t) = 0.0749
```

F2. T-test for Private Net Present Value (5 year period)

```
. ttest ppvl if pmet~=3, by(pmet) unequal (organic vs. clean)

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      23      141994    18963.76    90947.01    102665.5    181322.4
       2 |      67    169811.7    10782.13    88255.54    148284.5      191339
---------+--------------------------------------------------------------------
combined |      90    162702.8    9410.173    89272.74    144004.9    181400.6
---------+--------------------------------------------------------------------
    diff |           -27817.79    21814.64               -72009.4    16373.82
------------------------------------------------------------------------------
    diff = mean(1) - mean(2)                                      t =  -1.2752
Ho: diff = 0                     Satterthwaite's degrees of freedom =   37.226

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.1051         Pr(|T| > |t|) = 0.2101          Pr(T > t) = 0.8949

. ttest ppvl if pmet~=2, by(pmet) unequal (organic vs. conventional tea)

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      23      141994    18963.76    90947.01    102665.5    181322.4
       3 |      86    129243.2    8608.062    79827.89    112128.1    146358.4
---------+--------------------------------------------------------------------
combined |     109    131933.8    7856.284    82022.02    116361.2    147506.3
---------+--------------------------------------------------------------------
    diff |            12750.71    20826.02               -29688.79    55190.21
------------------------------------------------------------------------------
    diff = mean(1) - mean(3)                                      t =   0.6122
Ho: diff = 0                     Satterthwaite's degrees of freedom =  31.6522

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.7276         Pr(|T| > |t|) = 0.5447          Pr(T > t) = 0.2724

. ttest ppvl if pmet~=1, by(pmet) unequal

Two-sample t test with unequal variances (clean vs. conventional tea)
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       2 |      67    169811.7    10782.13    88255.54    148284.5      191339
       3 |      86    129243.2    8608.062    79827.89    112128.1    146358.4
---------+--------------------------------------------------------------------
combined |     153    147008.5    6932.645    85752.08    133311.8    160705.3
---------+--------------------------------------------------------------------
    diff |             40568.5    13796.85                13281.69    67855.32
------------------------------------------------------------------------------
    diff = mean(2) - mean(3)                                      t =   2.9404
Ho: diff = 0                     Satterthwaite's degrees of freedom =  134.515

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9981         Pr(|T| > |t|) = 0.0039          Pr(T > t) = 0.0019

. tabstat spvl ppvl if pmet ==1, stats(mean sd cv)
```

F3. T-test as Compared Private and Social Net Present Value (5 year period)

. ttest ppvl =spvl if pmet==1 (Organic tea)

Paired t test

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
ppvl	23	141994	18963.76	90947.01	102665.5	181322.4
spvl	23	141520.9	18749.66	89920.2	102636.5	180405.3
diff	23	473.087	311.6546	1494.643	-173.2451	1119.419

```
    mean(diff) = mean(ppvl - spvl)                              t =   1.5180
 Ho: mean(diff) = 0                          degrees of freedom =       22

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.9284       Pr(|T| > |t|) = 0.1433          Pr(T > t) = 0.0716
```

. ttest ppvl =spvl if pmet==2 (clean tea)

Paired t test

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
ppvl	67	169811.7	10782.13	88255.54	148284.5	191339
spvl	67	110561.6	9486.459	77650.02	91621.25	129501.9
diff	67	59250.16	2056.815	16835.76	55143.6	63356.73

```
    mean(diff) = mean(ppvl - spvl)                              t =  28.8068
 Ho: mean(diff) = 0                          degrees of freedom =       66

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000       Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

. ttest ppvl =spvl if pmet==3 (conventional tea)

Paired t test

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
ppvl	86	129243.2	8608.062	79827.89	112128.1	146358.4
spvl	86	44730.56	6905.83	64042.03	30999.92	58461.2
diff	86	84512.69	3395.259	31486.34	77762	91263.37

```
    mean(diff) = mean(ppvl - spvl)                              t =  24.8914
 Ho: mean(diff) = 0                          degrees of freedom =       85

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000       Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

F4. T-test for Social Net Present Value (30 year period)

```
. ttest spv30 if pmet~=2, by(pmet) unequal (organic tea vs. conventional tea)

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      23     2964536    315015.2     1510760     2311234     3617837
       3 |      86    958042.7    115017.6     1066629      729357     1186728
---------+--------------------------------------------------------------------
combined |     109     1381431    136698.2     1427171     1110472     1652391
---------+--------------------------------------------------------------------
    diff |             2006493    335355.9                 1319688     2693299
------------------------------------------------------------------------------
    diff = mean(1) - mean(3)                                      t =   5.9832
Ho: diff = 0                     Satterthwaite's degrees of freedom =  28.1273

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

. ttest spv30 if pmet~=1, by(pmet) unequal (clean tea vs. conventional tea)

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       2 |      67     1813151    185202.9     1515951     1443381     2182920
       3 |      86    958042.7    115017.6     1066629      729357     1186728
---------+--------------------------------------------------------------------
combined |     153     1332502    108923.5     1347309     1117302     1547701
---------+--------------------------------------------------------------------
    diff |            855107.8    218011.8                  423212     1287004
------------------------------------------------------------------------------
    diff = mean(2) - mean(3)                                      t =   3.9223
Ho: diff = 0                     Satterthwaite's degrees of freedom =  113.606

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9999         Pr(|T| > |t|) = 0.0002          Pr(T > t) = 0.0001

. ttest spv30 if pmet~=3, by(pmet) unequal (organic tea vs. clean tea)

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      23     2964536    315015.2     1510760     2311234     3617837
       2 |      67     1813151    185202.9     1515951     1443381     2182920
---------+--------------------------------------------------------------------
combined |      90     2107393    167446.3     1588535     1774681     2440106
---------+--------------------------------------------------------------------
    diff |             1151385      365424                411820.5     1890950
------------------------------------------------------------------------------
    diff = mean(1) - mean(2)                                      t =   3.1508
Ho: diff = 0                     Satterthwaite's degrees of freedom =  38.3111

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9984         Pr(|T| > |t|) = 0.0032          Pr(T > t) = 0.0016
```

F5. T-test Private Net Present Value (30 year period)

```
. ttest ppv30 if pmet~=3, by(pmet) unequal (organic tea vs. clean tea)

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      23     5110937    543404.3     2606075     3983986     6237888
       2 |      67     4409645    369648.3     2325702     3671618     5147672
---------+--------------------------------------------------------------------
combined |      90     4588864      308445     2926167     3975990     5201738
---------+--------------------------------------------------------------------
    diff |            701291.9    657212.3               -623287.8     2025872
------------------------------------------------------------------------------
    diff = mean(1) - mean(2)                                      t =   1.0671
Ho: diff = 0                         Satterthwaite's degrees of freedom =  43.9352

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.8541         Pr(|T| > |t|) = 0.0918          Pr(T > t) = 0.1459

. ttest ppv30 if pmet~=2, by(pmet) unequal (organic tea vs. conventional tea)

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       1 |      23     5110937    543404.3     2606075     3983986     6237888
       3 |      86     3775475    242948.1     2253008     3292429     4258521
---------+--------------------------------------------------------------------
combined |     109     4057269    228239.8     2382893     3604859     4509680
---------+--------------------------------------------------------------------
    diff |             1335462    595241.1                122008.8     2548916
------------------------------------------------------------------------------
    diff = mean(1) - mean(3)                                      t =   2.2436
Ho: diff = 0                         Satterthwaite's degrees of freedom =  31.3498

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9840         Pr(|T| > |t|) = 0.0321          Pr(T > t) = 0.0160

. ttest ppv30 if pmet~=1, by(pmet) unequal (clean tea vs. conventional tea)

Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
       2 |      67     4409645    369648.3     2325702     3671618     5147672
       3 |      86     3775475    242948.1     2253008     3292429     4258521
---------+--------------------------------------------------------------------
combined |     153     4053183    212568.5     2629327     3633213     4473154
---------+--------------------------------------------------------------------
    diff |            634170.4    442338.8               -241764.9     1510106
------------------------------------------------------------------------------
    diff = mean(2) - mean(3)                                      t =   1.4337
Ho: diff = 0                         Satterthwaite's degrees of freedom =  118.208

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9228         Pr(|T| > |t|) = 0.1543          Pr(T > t) = 0.0772

.
```

F6. T-test for Comparing between Private and Social Net Present Value (30 year period)

```
. ttest ppv30 =spv30 if pmet ==1 (organic tea production)

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   ppv30 |      23     5110937    543404.3     2606075     3983986     6237888
   spv30 |      23     2964536    315015.2     1510760     2311234     3617837
---------+--------------------------------------------------------------------
    diff |      23     2146401    605962.8     2906096    889711.2     3403091
------------------------------------------------------------------------------
     mean(diff) = mean(ppv30 - spv30)                             t =   3.5421
 Ho: mean(diff) = 0                              degrees of freedom =       22

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 0.9991         Pr(|T| > |t|) = 0.0018          Pr(T > t) = 0.0009

. ttest ppv30 =spv30 if pmet ==2 (clean tea production)

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   ppv30 |      67     4409645    369648.3     2325702     3671618     5147672
   spv30 |      67     1813151    185202.9     1515951     1443381     2182920
---------+--------------------------------------------------------------------
    diff |      67     2596495    394820.9     3231748     1808209     3384780
------------------------------------------------------------------------------
     mean(diff) = mean(ppv30 - spv30)                             t =   6.5764
 Ho: mean(diff) = 0                              degrees of freedom =       66

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000

. ttest ppv30 =spv30 if pmet ==3 (conventional tea production)

Paired t test
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   ppv30 |      86     3775475    242948.1     2253008     3292429     4258521
   spv30 |      86    958042.7    115017.6     1066629      729357     1186728
---------+--------------------------------------------------------------------
    diff |      86     2817432    268980.3     2494421     2282627     3352237
------------------------------------------------------------------------------
     mean(diff) = mean(ppv30 - spv30)                             t =  10.4745
 Ho: mean(diff) = 0                              degrees of freedom =       85

 Ha: mean(diff) < 0           Ha: mean(diff) != 0           Ha: mean(diff) > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

APPENDIX G

STANDARDS AND REQUIREMENTS FOR ORGANIC TEA PRODUCTS IN VIETNAM

A guide for farming practices, Vietnam Ecolink Co., Ltd., 2005

1. Prohibited to use synthetic fertilizers which are those were produced artificially and contain available nutrients such as nitrogen (N), phosphorus (P) and potassium (K). When applying those inorganic fertilizers, plants grow fast but soils soon become compacted, acid, and degraded.

2. Prohibited to use plant protective chemicals. Plant protective chemicals (pesticides, herbicides, and fungicides, etc.) are toxic substances that pollute the environment. Those chemicals not only kill insects, they also kill pest enemies such as lady bugs, birds and pest eating ants. They can also be toxic to domestic animals such as chicken, ducks, buffaloes, and cows and even to human health.

3. Prohibited to use growth regulators that cause harmful effects on human health.

4. Prohibited to use production tools and equipments, such as sprayers, that were previously used for inorganic production (vegetables, rice or conventional tea) for organic tea. Organic farming farmers must have separate tools and equipments used for organic productions.

5. Other production tools, such as hoes, shovels, baskets, knifes, and carrying tools, must be clean before being used in organic tea farms.

6. Farmers are required to record and keep track of all inputs used to produce organic tea including input sources, quantities, date of purchase, date of applying inputs and quantities applied each time.

7. Prohibits organic tea growers to produce both organic and inorganic teas simultaneously because it is easy to mix up both products.

8. A buffer zone is required to separate organic tea farms from other inorganic production. The buffer zone can be green fences or trenches and the organic farm must be at least 2 meters away from the buffer zones.

9. If there are potential effects from wind, the buffer zone must include tall trees that can protect the organic tea crop. The trees grown in the buffer zone must be different from the tea family. If there are potential effects from water sources, the buffer zone must include ditches to prevent water from getting into organic farms.

10. Prohibited to cut natural forest in order to farm organic tea.

11. Permanent crops (e.g., tea, litchi, and longan) are required to have at least a two year transition period in order to convert to organic production.

12. Prohibited to use GMO for organic tea production.

13. Seeds for propagation on organic tea farms and green manures applied on organic tea must also come from an organic farm.

14. Prohibited to use any chemicals for seed germination treatment.

15. Prohibited to burn crop residues on the fields.

16. Prohibited to use human waste as manure for organic farming.

17. If using poultry manure applied for organic tea production, the poultry raising practice must not be industrial concentration.

18. Prohibited to use treated urban waste as manure for organic farming.

19. Organic tea growers must combine different farming practices to control erosion (e.g., forest plantation, intercropping green manure trees and teas, etc.).

20. Prohibit use of artificial chemicals for storing organic tea and other organic products.

21. Allowed to use bio-pesticides that were produced from herbs such as bead tree leaves and hot chili roots.

APPENDIX H

DEGRADATION HALF-LIVES OF ALACHLOR AND METOLACHLO UNDER LABORATORY CONDITIONS

Soil Moisture (% field capacity)	Alachlor			Metolachlor		
	Temperate Clay loam[a]	Temperate Sandy Loam[a]	Tropical Sandy Loam[b]	Temperate Clay loam[a]	Temperate Sandy Loam[a]	Tropical Sandy Loam[b]
20	25	43	20	38	100	22
50	13	25	10	27	50	16
80	11	18	8	16	33	12

Source Racke, et al. (1997).

a: at 20°C and b : at 32°C

APPENDIX I

DEGRADATION OF ^{14}C FENAMIPHOS IN SOIL UNDER LABORATORY CONDITIONS

Soil Origin	Total Toxic Residues (TTR) % of applied at 90 days		Evolved $^{14}CO_2$ % of applied at 90 days	
	22°C	28°C	22°C	28°C
USA-Florida	43	33	5	9
Thailand	51	40	4	10
Philippines	25	14	24	40
Japan-Tsurug	47	30	4	10
Tropical / subtropical means	32	22	13	22

Source: Racke, et al. (1997).

APPENDIX K
SURVEY QUESTIONNAIRE
TRANSITIONING TO ORGANIC TEA PRODUCTION SURVEY IN THE THAI NGUYEN PROVINCE, JAN. 2007.
(First phase of a panel data survey)

Interviewer:
Date of the interview:
Questionnaire Number
Village
Commune
District
Size of household (hh)
Ethnic group
Respondent's gender
Head of household's gender
Head of household age

SECTION I. SOCIAL AND DEMOGRAPHIC CHARACTERISTICS OF THE HOUSEHOLD

	1	2	3	4	5	6	7	8
1. Respondent's relation to head of household; his/her own = 1 husband = 2, wife = 3, other adult members of household = 4, children (under age 18) = 5								
2. Age in years								
3. Gender (male = 1, female = 2)								
4. Ethnic group (Vietnamese = 1, Tay = 2, Other = 3)								
5. Education (elem. sch. = 1 Mid. school =2, high sch. = 3 and higher edu. = 4)								
6. Marital status (married = 1, single = 2, widowed = 3, divorced = 4)								
7. Occupation								
8. Place of primary employment: (farming = 1, off farm = 2, administrative center = 3, other = 4)								

SECTION 2: LABOR, INCOME, AND PRIVATE PLOT

9. What is the size of your land, in m^2, you obtain produce from? (private plot, rental, other allocated land, difficult to answer = 9).	

My own private plot rental other allocated land	
10. How do you pay for your land rental? (money = 1, exchange of produce = 2, provide a service = 3, do something else for landlord = 4, do not pay = 5, difficult to answer = 9). private plot other allocated land	
11. If you use money to rent your land, where do you obtain this money? (my private money = 1, selling of my produce = 2, bank credit = 3, personal loan = 4, something else = 5, difficult to answer =9)	
12. Does your household own these? (how many?) Cows (and calves) Buffaloes Pigs Other livestock (goats,) Poultry Motorcycle Tractor Tea dryer machine Tea crumpling machine Other mechanical equipment Telephone VCR TV /Radio	
13. If you do not have mechanical agricultural equipment, how do you cultivate your land? (by human power = 1, buffalo = 2, rental = 3, borrow from relatives = 4, difficult to answer = 9)	
14. If you do not have mechanical agricultural equipment, how do you process your tea after harvesting? (by human power= 1, sell to tea processors = 2, sell it as fresh tea in local markets = 3, difficult to answer = 9)	
15. Does your household use contemporary inputs for production on your plot? (yes = 1, no = 2, difficult to answer = 9) Hybrid seed or nursery stock Artificial fertilizer Organic fertilizer Herbicides/pesticides Something else	
16. If you use contemporary inputs, where do you obtain them from? List up to three places. (government store = 1, farmer market = 2, my household = 3, other store = 4, acquaintance or relative = 5, do not use = 6, difficult to answer = 9)	

17. Which products did you grow, how much was produced, and how was sold last year? (in kilograms) (difficult to answer = 9)	Produced	Sold
Tea	____	____
Rice	____	____
Vegetables	____	____
Fruit	____	____
Forest product	____	____
Meat (include birds)	____	____
Other	____	____
	____	____
	____	____
	____	____

18. Tell me, please, the amount of income each adult household member received last year and its source? (difficult to answer = 1, not receive = 0)	Labor 1	labor 2	labor 3	labor 4	labor 5
Sales of produce					
Income from off farm activities					
Other money income					
Total for each column					
Total for household:					

19. Please tell me, in generally, what is your total annual household income?	
20. In which group would you place your household? (very poor = 1, poor = 2, middle = 3, more than middle = 4, high income = 5, difficult to answer = 9)	

21. Tell me how many people in your household?

22. How long has the head of the household been in tea farming (in years)?

23. How long has the head of the household been producing other crop (in years)?

24. When did you convert your tea farm to organic/clean tea production?

Please tell me how land has been used for agricultural production in your household?

25. Tea field(s)

Tea field (s)	Tea stand	Ownership		Area (m^2)	Irrigation status		Applied production method		
		1. Owned	2. leased		irrigated	non irrigated	Organic	IPM (clean)	conventional
Field # 1									
Field # 2									
Field # 3									
Field # 4									

26. Other crops

Tea field (s)	Crop	Ownership		Area (m^2)	Irrigation status		production			
		1. Owned	2. leased		irrigated	.non irrigated	unit	Quantity	Price VND	Total VND
Field #										
Field #										
Field #										
Forest										
Fish pond										

27. Tell me how much did you pay for your land?

Land use	Thousand VND/tea year		
	2004	2005	2006
Rent			
Irrigation maintenance			
Land preparing			

28. Tell me how much did you pay machinery and equipment use?

Land use	Thousand VND/tea year		
	2004	2005	2006
Tea dryer			
Crumpling machine			
Plowing machine			

TEA PRODUCTION AND MARKETING

29. Please tell me what inputs were you using on your tea field in 2004?

No	Description of inputs used	1= Organic 2= Non-org.	Amount applied	Unit	Unit cost VND/unit	Total Cost VND/tea year
Fertilizer						
Pesticide Rodenticide or Fungicides						
Herbicide						
Mulch/ others						

30. Please tell me what inputs were you using on your tea field in 2005?

No	Description of inputs used	1= Organic 2= Non-org.	Amount applied	Unit	Unit cost VND	Total Cost VND
Fertilizer						
Pesticide Rodenticides or Fungicides						
Herbicide						
Mulch/ others						

31. Please tell me what inputs were you using on your tea field in 2004?

No	Description of inputs used	1= Organic 2= Non-org.	Amount applied	Unit	Unit cost VND	Total Cost VND
Fertilizer						
Pesticide Rodenticides or Fungicides						
Herbicide						
Mulch/ others						

32. Please tell me how labors were used to process tea in your household?

Labor used	Number of days processing tea			Paid per day			paid total (VND)		
	2004	2005	2006	2004	2005	2006	2004	2005	2006
Household LB 1									
Household LB 2									
Household LB 3									
Household LB 4									
Hired 1									
Hired 2									
Hired 3									

33. Tell me proximately labors were used for marketing and selling tea products?

Labor used	Number of days for marketing tea			Paid per day			paid total (VND)		
	2004	2005	2006	2004	2005	2006	2004	2005	2006
Household LB 1									
Household LB 2									
Household LB 3									
Household LB 4									
Hired 1									
Hired 2									
Hired 3									

35. Tell me how far is from your home to closest local market (1 for < 1km, = 2: 1-2 km and = 3 for more than 2 km)

36. Please tell me proximately how labors were employed for managing your tea farm?

Labor used	Number of days processing tea			Paid per day			paid total (VND)		
	2004	2005	2006	2004	2005	2006	2004	2005	2006
Household LB 1									
Household LB 2									
Household LB 3									
Household LB 4									
Hired 1									
Hired 2									
Hired 3									

37. Tell me how far is from your home to your tea farm (1 for < 200 m, = 2 for 200-500, =3 for 500 -1000m and =4 for > 1000m

38. Please tell me how much fuel, electricity and water were used in the past three years?

5. Fuel, Electricity and water		Unit cost (th.VND/unit			Amount used			Total cost (th.VND)		
	Unit	2004	2005	2006	2004	2005	2006	2004	2005	2006
Fuel	litter									
Electricity	Kwh									
Water	m^3									
Total										

39. Health care related costs?

Health care expenses	Unit	For whole household					Total
		Labor1	Labor2	Labor3	Labor4	All other	
Days off from work	Day						
Visit local clinics	Day						
hospital/medical charges	VND						

40. Have you received any assistance for organic tea production from: = 1 if government support, = 2 if INGO, = 3 if others, and = 4 if receiving more than 2 supports.

41. What kind of assistance have you received from about mentioned people and how much?

- Borrowing money
- Trading goods and services
- Extension service
- Price support
- Income support

42. According to your opinion, please rank from 1-5 how likely the following tea production method will lower your tea yield or profit (net return): = 5 for the highest probability and = 1 for the lowest probability.

- Conventional method
- Clean tea (e.g. IPM) method
- Organic tea production method

43. How do you evaluate the environment around your home?
= 1 if very bad, = 2 if bad, = 3 for moderate, = 4 if good, and 5 if very good

44. In order to have a healthy and clean environment, how much would you accept in a reduction of your tea yield?

= 1 if <10%, = 2 if 10- 20%, = 3 if 20- 30%, = 4 if 30- 40%, = 5 if more than 40%, and = 6 if difficult to answer.

45. How satisfied are you with each of the areas of support/assistance you receive?
(not satisfied = 1, moderately =2, satisfied = 3, difficult to answer = 9)

- Borrowing money _____
- Trading goods and services _____
- Extension service_____
- Price support______
- Income support________

46. .Are you willing to be interviewed again in 2007? _____
(yes = 1, no = 2, difficult to answer = 9)

Thank you for taking part in our study.

INTERVIEWER NOTES:

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