Analyzing Factors Affecting to the Adoption of Sustainable Development on Rice Production in Vietnam

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Analyzing Factors Affecting to the Adoption of Sustainable Development on Rice Production in Vietnam

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Abbreviations

ADB	Asian Development Bank
MARD	Ministry of Agriculture and Rural Development
ATT	Average Treatment on the Treated
BCCV	British Chamber of Commerce Vietnam
CIAT	The International Center for Tropical Agriculture
CRS	Constant Return-to-Scale
DEA	Data Envelopment Analysis
FAO	Food and Agriculture Organization
IPWRA	Inverse Probability Weighed Regression
NNM	Nearest-Neighbor Matching
PSM	Propensity Score Matching
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency
USDA	United States Department of Agriculture
VHLSS	Vietnam Household Living Standards Survey
VRS	Variable Return-to-Scale
MTs	Million tons

ABSTRACT

Rice is an important crop and is the major source of living for farmers in many Asian countries, and Vietnam is one of the typical examples. However, rice farmers in Vietnam are still facing many difficulties and challenges in productivity and market. Those first to be mentioned are the lack of accessing technical efficiency in rice production, the in-optimal combination of production inputs and the influence of socioeconomic characteristics of households.

This study was thus mainly designed to estimate the technical efficiency using Stochastic Frontier Function approach and its determinants rice-farming households in Vietnam. As a means of obtaining the results, this study explores the effect of determined factors on rice production in Vietnam based on the secondary data – Vietnam household living standard survey (VHLSS); There are two types of data used in this analysis. A sample of VHLSS 2016 data extracted from cross-sectional data; other panel data (from 2004-2006 and 2006-2008) have also been collected from the public website that were done by Professor Brian Macaig to be used only on VHLSS in Vietnam.

By applying stochastic frontier analysis to raw data obtained from the VHLSS 2016 database, the results show that farmers in Vietnam achieved 87.6 percent technical efficiency and that most factors tested had significant effects on rice production. Instead of rice monoculture, four main factors with strong and positive effects on technical efficiency levels were intensive labor, irrigation, mixing crops instead of rice monoculture, and education.

Moreover, by applying Propensity Score Matching (PSM) between farmers who use with/without irrigation facility in rice production, this study also revealed that organic fertilizer plays a vital role in growing rice. While the government is in the process of building a system, the government should focus on rice producers to strive for maximum efficiency with regards to labor productivity, mixed-crop farming, and to take proper measures to improve rice productivity and quality using organic fertilizers.

Keywords: Rice production efficiency, Stochastic frontier, VHLSS, Organic fertilizer use, Propensity score matching, Vietnam

CHAPTER 1

INTRODUCTION

1.1. Background of Vietnam Agriculture

Vietnam has the third largest population in Southeast Asia with a population of over 90 million people and is expected to hit 100 million people by the end of 2024. In order to feed such a large population, Vietnam's agriculture has been a fundamental element of its socio-economic development policy for decades. Since the Doi Moi renovation policy reforms in the 1980s, Vietnam's economy has changed from a nation suffering from food scarcity to one of the world's leading producers and exporters of many agricultural products, such as rice, coffee, pepper, and cashew nuts. This program has boosted Vietnam's annual economic growth rate from 6% to 8% boosted early 1990s. The return to household agricultural production initially prompted a sharp growth from a rice – importing country into one of the world's top rice exporters (Pingali & Vo-Tong, 1992) (Linh, Vu Hoang, 2012) (Khue, 2019).

Vietnam has a diverse landscape of mountains, valleys, fertile deltas, and dense forests each with unique soil characteristics and microclimatic conditions. The eclectic range of habitats supports an equally wide array of production systems and agro-ecological zones. The climate is diverse from North to South, divided into three distinct zones, including a subtropical humid climate in the North, a tropical monsoon climate in Central and South-Central regions, and tropical savannah in the Central and Southern regions. The North has four seasons, the South has a rainy season and a dry season. Annual rainfall ranges from 1,200 mm to 3,000 mm (T. Le Toan et al., 2021). The terrain and climate of the country is favorable to agriculture, which includes rice, coffee, rubber, tea, pepper, soybeans, cashews, sugar cane, peanut, banana, and many other agricultural products. Each ago-ecological region has their own characteristics that influence agricultural production. A majority of cash crops are produced in the Central Highlands and Southeast, while rice production is concentrated in two delta regions (Red River Delta and Mekong River Delta). In the Northeast and Northwest, mountainous regions, agricultural production primarily serves household needs, with tea and rubber also being important industrial crops. In the North, only about 15% of the land is arable, mostly in the lowlands surrounding the Red River Delta. In the south, rice production is dominated by the Mekong Delta, one of the world's greatest rice producing areas. Maize, fruit trees, and perennial industrial plants are predominant in the Northern Midlands and Mountains. Both the North Central and South-Central Coast regions grow maize and cassava as their second crops after paddy. Highland's region is characterized by prevailing perennial industrial plants (coffee, tea, etc.) over paddy, maize, and cassava plantations. South East region is dominated by perennial industrial plants (rubber, pepper, etc.) and fruit trees (T. Le Toan et al., 2021).

Vietnam is now rank second in exporting coffee just after Brazil, rank fifth in tea exporter and is the leading country in pepper production which accounts for 55-60% of the global market share (Anh & Bo, 2019). It is reported that the average yield of major food crops except rice is 4.4 – 4.8 tons/ha for maize; and industrial crops is 19 – 19.5 tons/ha for cassava, 2.4 – 2.5 tons/ha for coffee, 2.2 – 2.5 tons/ha for rubber, 0.7 – 0.8 tons/ha for cashew. The average yield of Vietnamese pepper is 2.2 – 2.5 tons/ha and 2.6 fold higher as compared to average yield of pepper all over the world (P. Van Toan et al., 2019).

Vietnam's agriculture sector contributed 14.85% to the country's gross domestic product (GDP) in 2020 - the first time in recent years this sector has increased its GDP share. In 2019, 37.22% of employees in Vietnam were active in the agricultural sector, 27.44% in industry and 35.34% in the service sector. Despite this, its contribution to GDP decreased due to the increasing importance of Vietnam's industry and service sectors. As for 2020, the export value of Vietnamese agriculture's products reaches to \$41.2 billion, ranking 16th in the world's top agriculture exporters (British Chamber of Commerce Vietnam, 2021).

Table 1.1 Agriculture GDP growth rate in Asian countries (%/year)

Country	1990-1999	2000-2010	2011-2019
Bangladesh	3.42	4.20	3.50
Cambodia	4.25	4.96	1.45
China	4.30	4.05	3.92
India	3.03	2.80	3.67
Indonesia	2.38	3.32	3.95
Korea	1.09	1.40	0.89
Malaysia	0.15	3.23	1.92
Philippines	1.49	3.49	1.96
Thailand	0.63	2.62	1.34
Vietnam	3.90	3.53	2.85

Source: ADB, 2020

In recent years, Vietnam has become one of the leading rice exporters in the world, as a result of extensive land reforms and the introduction of new technologies (Pedroso et al., 2018). Although there has not been a rapid expansion in cultivated area, impressive growth in yield has resulted in rice production in Vietnam increasing fourfold from 11.6 (MTs) in 1980 to a peak of 45.1 (MTs) in 2015, dropping back to 42.8 (MTs) in 2017. Around 18% of milled rice production was exported, worth USD 2.7 billion and USD 2.2 billion in 2017 and 2018, respectively (The Anh et al., 2020). With the majority of its land area used for cultivating paddy rice, the Mekong Delta is often referred to as "Vietnam's Rice Bowl". There, rice production is organized and linked into an extensive and complex supply chain that connects around 1.5 million small-scale rice farmers to many types of traders, processors, wholesalers, retailers, and exporters. About 30% of production is sold on the domestic market and 70% goes overseas, resulting in more than 90% of the country's rice exports (Clauss et al., 2018; The Anh et al., 2020). Rice is related to the national food security strategy and is also a key export commodity of the country. At more than 5.5 tons/ha, average yield of rice production in Vietnam exceeds that of the region by over a ton (FAO, CIAT, 2021). Vietnam total rice output ranks fifth in global production, behind China, India, Indonesia, and Bangladesh. In Vietnam, rice is essentially cultivated year-round, however, seasonal weather drives planting cycles that are phased into three planting periods, Lua Mua (Winter), Winter-Spring and Summer-Autumn (USDA, 2020). Currently, Vietnam is exporting rice to about 150 countries and territories around the world.

The production of rice depends heavily on climatic conditions, but it should be remembered that the Vietnamese rice sector also faces severe environmental issues, which is why the Government and producers are seeking more sustainable methods (Demont & Rutsaert, 2017). In the past decade, agrochemicals and especially pesticides have been used primarily as part of production growth strategies in rice production (Salazar & Rand, 2020; Van Hoi et al., 2013). Furthermore, fertilizer application in rice production in Vietnam is critical high, accounts for approximately 65% of total fertilizer demand for crop cultivation (P. Van Toan et al., 2019). The overuse of fertilizer resulted in high pest and disease infestations, which led to an increased usage of pesticides (Demont & Rutsaert, 2017).

In Vietnam, it is not an exaggeration to say that policies on rice production play the most important role in the overall agricultural policy, because of the role that rice plays in the economic and social development of the country. Recent policies on rice cultivation focused on three main categories: the rice production polices, rice trade policies and developing rice chain value. Since 2012, the Government decided to provide significant supports for rice farmers to reduce input cost. According to this, farmers were supported 50 – 70% of the cost of agricultural materials based on the extent of damage caused by diseases or natural disasters, 70% of land reclaimed cost and 100% of cost for rice seeds on reclaimed land for the first year. The other 70% of cost for rice seeds on paddy land converted from other land in the first year is also covered. In addition to the support to rice producers individually, the Governments also response for public financing on agricultural infrastructure such as the canal and inter-and intra - village roads. Encouraging the private sector to invest in infrastructure in rural areas was also boosted. From 2013, the Government started a support of 20% of land and water rent in the first 5 years after basic construction for enterprises take invest on agriculture. Another remarkable benefit for rice farmers was the support for irrigation, famers who use water surface for agriculture purpose will be exempted from irrigation fee. This equivalents to 5-10% reduction of production cost for famers.

As for supporting access and develop the rice market, the Government has launched new measurements to facilitate the access to commodity markets and support producers as well as business in terms of trade promotion. For example, a support of 50% of advertising cost for mass media, domestic fair exhibition and market information service will be provided. To encourage the cooperatives between stakeholders and investments in large-scale agriculture production, a support of exempt land use charge and land rents for large field projects was released along with the priority to implement export contracts and temporary storage for agro-products. There are many other huge benefits such large-scale field cultivation will receive, such as a support for labors cost and machinery rentals or a deduction of 50% expenditure for organizing training for cadres and joint cooperatives in terms of management or economic contract. The Vietnamese Government also spent noticeable amount of budget on agricultural science including polices research and technology research (Dinh Thi Bao Linh & Tran Cong Thang, 2015).

As a summary, despite the amazing achievements over the years, Vietnam's agriculture still faces many challenges. Since these reforms have been implemented, total factor productivity and efficiency of the agricultural sector have lagged behind regional peers (Wold Bank, 2016). The majority of agricultural products in Vietnam are traded as low-value commodities without any visible branding or differentiation, even within the domestic market. Agriculture remains primarily a small-scale activity, with farm households producing food for consumption and their surpluses being sold. Agricultural businesses are still quiet to some extent, and private sector investments haven't taken place, as they have elsewhere in the economy - particularly manufacturing and services. As a result of low investment and factor productivity, agricultural growth has been dominated by more intensive input usage, which has adverse effects on the environment (Wold Bank, 2016). Climate change, trade wars between major countries as well as global disruptions in trading caused by epidemics are potential factors affecting the development of the agricultural sector in Vietnam. However, the Vietnamese government is making great efforts in promoting the sustainable development of agriculture with specific and practical policies that help ensure food security and social security towards the country’s environmental protection goals.

1.2. The role of Agriculture in Ensuring Food Security in Asian countries

Food security is a significant development and poverty-eradication priority for governments across the world. Food security is defined as "having enough, safe, nutritious food to live a healthy and active life at all times" by the World Food Summit of 1996. In recent years, Asia has gradually become the center and driving force of the world economy. It is home to about 4.6 billion people, accounts for nearly 60% of the world's population. Population growth means that the risk of food shortages is always present, and governments have made great efforts in formulating appropriate policies, promoting scientific research, and trading systems to solve the problem. In all countries of Asia, food security is considered a primary responsibility of the state. While governmental policies and programs are important, there is a growing recognition of the importance of local and international markets, as well as civil society institutions, in achieving this goal (Vyas, 2005).

Since the mid-1960s, Asia (and the Pacific) has benefited from a remarkable boost in agricultural output as a result of the Green Revolution, using new varieties of rice and wheat, along with the application of fertilizer and irrigation. The Green Revolution benefitted the rural poor to some extent, especially in its early phases. This was partially due to the fact that the new technology could be employed on tiny farms, and partly due to the fact that the new farming techniques, which sometimes entailed double or triple cropping, were labor demanding, resulting in extra work for the landless (ESCAP, 2009).

Rice, being the staple meal for more than half of the world population, plays a critical role in global food security. In many Asian nations, the phrases for food and rice, or rice and agriculture, are interchangeable, meaning that rice is a common staple food (Barthwal-Datta, 2014). Eleven Asian nations account for almost 87 percent of world rice output. The exports of eight of these nations account for almost 35% of worldwide rice exports. Rice production in Asia, particularly India and China, has a significant influence on world food security. These two Asia's biggest economies, together account for 37 percent of the world's population and 49% of global rice output (Barthwal-Datta, 2014). Thanks to the success of the Green Revolution in agriculture, some Asian countries such as India, Thailand and Vietnam have risen to play the role of important food suppliers to the world market. Accompanying the growth of food crop production, fruit, vegetable crops and livestock also witnessed a very rapid growth, in response to higher demand to these products consequent upon the dietary diversification resulting from improved living standard (Mukherjee, 2012).

Increased land productivity in Asia during the Green Revolution helped reduce food insecurity on the continent, however, future revenue growth now remains uncertain as it faces two major identifiable challenges. First, environmental damage, including land degradation, which pioneered the Green Revolution, does not appear to be declining. Second, the decrease in technological innovation, partly due to interrupt in agricultural research and development budgets, is showing no signs of reversal at this time (Mukherjee, 2012).

Although there have been many efforts made to reduce food shortages, the situation remains alarming. There are estimated 1.1 billion people in Asia and the Pacific experiencing moderate or severe food insecurity in 2020, an increase of 341.9 million, or 44.4%, compared with 2014. Most of those people reside in Southern Asia, which had 849.8 million moderately or severely food insecure people, compared with 130.8 million in Eastern Asia, 125.5 million in South-eastern Asia and 5.1 million in Oceania (FAO, 2021). Obviously, agricultural sector in Asian countries is facing many challenges in balancing between productivity to meet the needs of the people and securing the living environment at the same time.

Table 1.2 Number of moderate or severely food insecure people (millions)

	2014	2016	2018	2019	2020
World	**1645.5**	**1762.9**	**1978.7**	**2049.9**	**2368.2**
Asia and the Pacific	769.3	775.6	935.0	962.5	1111.2
Eastern Asia	98.0	104.1	159.5	124.6	130.8
East Asia excluding China	9.3	10.6	11.1	10.5	11.3
Oceania	4.5	4.8	5.5	5.7	5.1
South-eastern Asia	96.3	109.1	113.6	111.0	125.5
Southern Asia	570.6	557.7	656.5	721.4	849.8
South Asia excluding India	204.7	194.9	205.2	222.0	231.2

Source: FAO, 2021

1.3. Sustainable Development in Agriculture

The Food and Agriculture Organization (FAO) has been clearly defined sustainable agricultural development as the management and maintenance of the natural resource base, as well as the steering of technological progress to assure the continuous fulfilment of human needs for current and future generations. A sustainable agriculture should conserve land, water, and plant and animal genetic resources while being ecologically friendly, technically suitable, commercially successful, and socially acceptable (FAO, 2014). Nevertheless, there are several worldwide barriers to achieving sustainable agriculture. Overall food demand will continue to rise, despite rising scarcity of natural resources and significant changes in the structural composition of demand for food and agricultural products. Climate change and natural disasters are anticipated to become increasingly severe, contributing to natural resource degradation and scarcity, with negative consequences for people's livelihoods and food security. Simultaneously, transboundary plant pests and diseases, as well as other new threats, continue to cause crises in agricultural and food systems, affecting production and human health. Conflicts continue and may worsen in many regions of the world, with far-reaching economic and social implications that extend beyond the affected nations (FAO, 2017).

In Asia, farmers have been quite successful in numerous ways of developing agriculture. They have expanded output and have practically kept up with demand. However, in the future, they will confront increasing difficulties as a result of environmental deterioration, climate change, and a wide range of other challenges. Vast tracts of crops, pasture, woodland, and forest have already been destroyed and many more are under threat. Around 74% of agricultural areas in South and South-East Asia have been seriously impacted by erosion, wind, water, or chemical contamination. Farmland can become desert in the worst-case scenario, particularly in dry-land ecosystems in Central Asia (ESCAP, 2009). That means, sustainable agriculture is thus under critical dangers and the governments of these countries must step in more seriously.

Viet Nam has experienced spectacular economic growth since the Doi Moi reform, nevertheless, agriculture remains the backbone of the Vietnamese economy and is pivotal for poverty alleviation. However, the Global Climate Risk Index 2019 ranks Vietnam sixth out of the ten countries most risk from extreme weather (Eckstein et al., 2019). Temperatures increased by about 0.62 °C (about 0.10 °C per decade) since 1958, and daily records of the highest and lowest temperatures have risen steeply. Nearly 60 percent of the territory and 70 percent of the total population are exposed to hazards like floods, droughts and storms (World Bank, 2017). Being aware of these threats, as part of the nationally determined contributions, Vietnam highlighted a number of key strategies and priority actions that address both adaptation as well as mitigation, but also emphasized the government's priority to reduce climate change vulnerabilities and risks by adapting to climate change. The Government has already taken several measures to adapt to climate change and reduce disaster risk, which provides a solid foundation for integrating these measures into sustainable development and low-carbon economy goals for the future. Reiterated in the National Plan to Implement the Paris Agreement issued with Government Decision 2053/QD-TTg, the Viet Nam National Adaptation Plan will focus on adaptation to climate change with a priority focus on agriculture (FAO & UNDP, 2020). The involvement of the Government and international organizations is expected to ensure Vietnam becomes a transparent, responsible, and sustainable producer and supplier of food and agriculture products.

1.4. The Advantage of Organic Fertilizer Application in Asian Countries

The success of the Green Revolution in 1960s in increasing food production and reducing world hunger could be traced largely to the use of inorganic fertilizers (Erisman et al., 2008). However, the excessive use of inorganic fertilizers during and after the Green Revolution resulted in a number of environmental and ecological problems including soil acidification, degradation, and eutrophication, which severely undermined agricultural sustainability. The loss of applied nutrients into the environment resulted in the fertilizer-induced emission of Nitrous Oxide (N_2O) from agricultural production, a major source of anthropogenic greenhouse gas emissions (Sutton et al., 2018). According to some estimates, approximately 60% of nitrogen pollution results from crop production alone, particularly through Nitrogen (N) fertilizer application (Sapkota, n.d.). Therefore, agricultural development policies need to address these challenges, in addition to climate change adaptation and mitigation. Many farmers in Asia are unaware of scientifically recommended rates of fertilizer application. Fertilizers are applied when and where they are believed to be necessary and are often applied in quantities and with elements according to what is available and affordable. Heavy subsidies for N fertilizer relative to other nutrients, and the lack of adequate knowledge on fertilizer management have resulted in unbalanced fertilizer application (Kishore et al., 2021).

Organic fertilizers are mineral sources that are found in nature and include a reasonable amount of plant nutrients. They are capable of resolving issues caused by synthetic fertilizers. They decrease the need to apply synthetic fertilizers on a regular basis to maintain soil fertility. Meanwhile, organic fertilizers slowly release nutrients into the soil solution, maintaining nutritional balance for crop plant development and also serve as a good source of energy for soil bacteria, which improves soil structure and crop growth. Organic fertilizers are more environmentally friendly than chemical fertilizers (Shaji et al., 2021).

In Asia, governments have recognized the limitations of the Green Revolution and have adopted many policies to develop organic agriculture to improve the situation and to achieve higher economic value on agricultural products. Impressive efforts in the form of comprehensive national organic agriculture development strategies have been undertaken by several countries. An outstanding example for that attempt is India, where both federal government and individual states have taken unprecedented initiatives to support organic agriculture. In 2018, national organic standards were approved in such countries like Vietnam and Bangladesh, while Cambodia issued a roadmap to promote organic agriculture. National organic standards were revised in China, the Philippines, and South Korea. Meanwhile, in Indonesia the government is showing active support its "1000 Organic Villages" project. In Thailand, the government also launched a large-scale project which relies on support programs to convert 160,000 hectares to organic rice production (Willer et al., 2018).

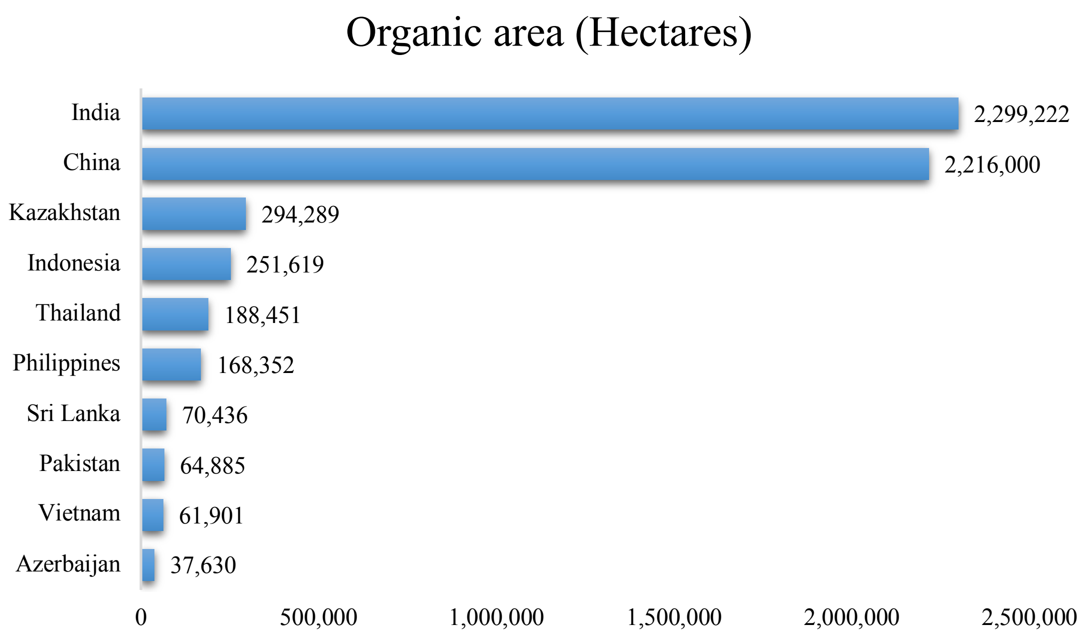

Figure 1.1 Top 10 Asian countries with largest organic area in 2019

(*Source: The world of Organic Agriculture – Statistic and Emerging Trends 2021*)

Organic agriculture is defined by the International Federation of Organic Agriculture Movement (IFOAM) as a production system that maintains the health of soils, ecosystems and people and relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of external inputs with adverse effects. Such agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a high quality of life (Willer et al., 2008). It is unquestionable that the use of organic fertilizers is one of the key elements on promoting organic agriculture. A great idea here is organic agriculture can use organic materials to supply nutrients and to control pests and diseases at the same time. There are many terms used to refer to the source of nutrients such as: organic materials, organic nutrients or bio-fertilizers and normally are interchangeable. The diversity in the structure of agricultural products is an advantage of Asian countries in the production and use of biofertilizers. The input materials of organic fertilizers are therefore also very diverse and can be listed in different categories. The first source is agricultural/biodegradable wastes such as crop residues (rice and wheat straw, maize stover, legume leaves and residues), rice hulls, wheat chaffs, weeds and grasses in farms, homesteads and farmsteads, biochar, biogas slurry, oilcakes, fruit, and vegetable peelings, biosolids and so forth. The second important source is farmyard manure and litters such as cattle manure, poultry manure, composts, vermicompost's and so forth. In some Asian countries, organic fertilizers can be produced from forest and grasslands wastes, such as tree leaves, branches and twigs, shrubs, and herbs underneath trees.

Other common sources of organic nutrients include growing food and non-food legumes as intercrops or rotational crops for current or residual N contribution, surface or residue recycling and in situ or ex-situ N_2-fixing green manure crops and so forth (Mamaril et al., 2009). It can be said that in the major growing regions of Asia, people from ancient times had the custom of using organic fertilizer sources before chemical fertilizers appeared. The current problem is how to promote the use of organic fertilizers in a scientific way, with high efficiency and in accordance with food safety and hygiene standards. To do this, Asian Governments need to successfully develop a system of quality standards for organic fertilizers, including quality standards in production, standards for use and management of product quality. Parallel to this, it is important to develop market development policies; promoting communication to raise consumers' and producers' awareness of sustainable agriculture. This is a huge amount of work and is not an easy task to do, however, the positive thing is that in most of the agricultural producing countries in Asia, organic farming is on the rise and promises a bright future because it will bring more sustainable values to both producers, consumers, and the entire ecosystem.

1.5. Objectives of the Study

This research aims to estimate the level of technical efficiency as well as investigate the determinants of technical efficiency on rice-farming households in Vietnam. This research applies a stochastic frontier analysis function and panel data analysis to approach the production function which suitable with the dataset and predicting technical efficiency of farm household. It was accomplished through the achievement of the underlisted specific objectives.

i) Identifying the important inputs of rice production in rice-farming households in Vietnam.

ii) Determinants of factors which affect technical efficiency in rice-farming households.

iii) Evaluating the impact of irrigation facility adaptation technical efficiency between rice-farming households.

1.6. Research Questions

There are several main questions which were raised in this thesis:

i. Which are the main factors explain the technical efficiency of rice production in Vietnam and choices organic fertilizer usage in rice production in Vietnam?

ii. Does Organic fertilizer affect rice production in the long term in panel data? How about rice farmer's perception in using organic fertilizer in rice production?

iii. Is it need to expand knowledge for farmers to get used to organic fertilizer in agriculture's production, advantage, and disadvantage implication in this study?

Based on the research questions, the thesis concentrates on two hypotheses as follows:

i. There is significant technical inefficiency affect to rice production in Vietnam

ii. Organic fertilizer does not affect the efficiency of rice production

1.7. Material and Methodology

1.7.1. Data collection

To attain our objective, this study used Vietnam Household Living Standard Survey (VHLSS) data that was provided by the General statistics office of Vietnam (GSO). This data has been conducted regularly by the GSO every two years from 2002 to 2010. From 2011 to 2020, VHLSS is conducted annually, however, the odd-number year surveys only collect data on demographics, employment, and income (Result of the VHLSS, 2018).

The purpose of VHLSS is to monitor systematically living standards of Vietnam population's group; monitor and assess the implementation of the Comprehensive Poverty Reduction and Growth Strategy; making contribution to evaluating results of realization of the Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs).

VHLSS includes the main content reflecting living standard of households in the entire country, and main socio-economic conditions of communes in the rural areas which affect living standard of population in their particular area.

VHLSS covers the whole country, there are three-stage stratified cluster design in sample design. Sample of the VHLSS is selected in the way to represent the entire country (in which: urban/rural areas), 8 regions (in which: urban/rural areas), and provinces/cities. The sample design enables to make use of panel data. For example, the questionnaire of 2006 included questions about the identification code of the VHLSS 2004, which were recorded by the enumeration leader.

The Socio-Environmental Statistics Department is responsible for selecting areas and sending the list of selected areas to Provincial Statistics offices for reviewing and updating attached with the map and list of areas of the Population Housing Census of the new areas.

The Provincial Statistics Offices select households for areas and for new areas, specifically:

- For areas which are re-select all 15 households in which 12 households were surveyed with income and 3 households were surveyed with income-expenditure. In the case of households which were surveyed in previous year moved to another area, find alternate households to be assured of 12 households for income and 3 households for income-expenditure in each enumeration areas (EAs).
- For new areas, select 20 households from the updated households' list. From these 20 households, select 15 households (12 official households, 3 spare households) for income survey, and the 5 remaining households (3 official 2 spare households) for income-expenditure survey.

In addition, it is an advantage of survey design of VHLSS to make use of panel data. The term panel data refers to observations obtained over multiple time periods for the same households or individuals

$$\{X_{ijt}\}\ i{:}\, household\ or\ individual, j{:}\, variable, t{:}\, year$$

In Statistical surveys, panel data is essentially a set of pairs of household identifiers and pairs of individual identifiers. Each identifier is uniquely linked with household or individual data.

Due to the scope of the study, a second research project will be based on Panel data for two periods (from 2014-2016). The panel data have also been withdrawn from the VHLSS data in year 2014 and 2016 in Vietnam. To make this study relevant to the unique characteristics of Vietnamese farmers, we have to use panel data that is the most recent version are available published. In the VHLSS, sample observations are updated as a rotation for panel data. Accordingly, the sample from 2016 will be recorded as around 50% of the sample in 2014 and 25% of the sample from 2012. Likewise, the scholar also wishes to extend the number of series years in the panel to over two years, but the difficulty is that the number of planting rice households combined over two periods is not enough to form an estimate.

1.7.2. Methodology

To estimate technical efficiency of rice production in Vietnam, the research in this study used a stochastic frontier production function.

A panel data model, particularly two logit models, is used in this study in order to analyze the utility of organic fertilizer on rice production.

1.8. Significance of the Study

The research aims to provide an understanding of the rice production in Vietnam. We discuss the advantages and disadvantages of using input variables for small households. Moreover, the research indicates that organic fertilizers are becoming increasingly popular in agriculture practice around the world and that home grown fertilizer is becoming increasingly popular.

This is due to the fact that organic farming is not only friendly with the environment in the long run but also significantly reduces the harmful effects on household life - that come along with chemical fertilizers and pesticides.

A further advance is that the current study provides an economic analysis of improved rice farming using panel data which can strong provide evidence for policymakers in supporting and popularizing effective practices within the local community. On the other hand, it provides a good opportunity to help farmers who want to use safety and friendly with the environment in the new trend toward organic product, a move aimed at tackling the environmental problems we face today.

1.9. Structure of the Study

The dissertation research was designed into five chapters as follows:

Chapter 1: A short introduction will introduce the background of the Vietnam's agriculture sector, the role of agriculture in ensuring food security in Asia, the advantages of using organic fertilizers in Asian countries, and the objectives, research questions, material and methodology, significance, and structure of the study.

Chapter 2: There is a need to review the theoretical literature and empirical studies that used Technical Efficiency, Propensity score Matching, and Panel data analysis.

Chapter 3: An in-depth empirical study is carried out to establish the findings and make discussion regarding the following topic: "Analyzing factors that affect rice production efficiency and organic fertilizer choices in Vietnam" using cross section data.

Chapter 4: The purpose of this chapter is to investigate the impact of the determinants of organic fertilizer use in Vietnam.

Chapter 5: Lastly, the dissertation concludes by suggesting implications and making continuous proposals for further research.

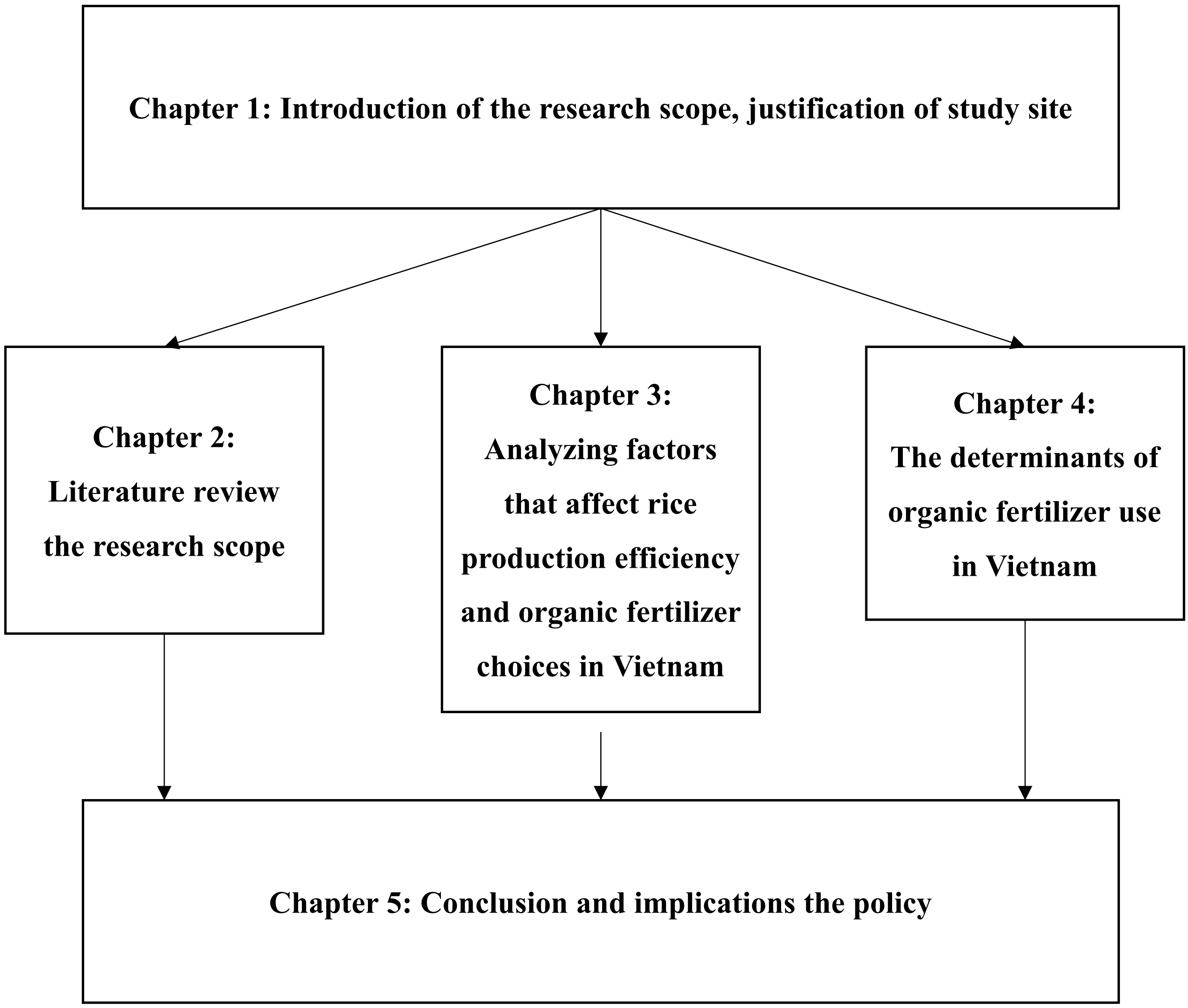

Figure 1.2 Dissertation structure

CHAPTER 2

LITERATURE REVIEW

2.1. Rice production in Vietnam

Vietnam is ideally suited to the production of rice. It is located in a tropical region that has a high humidity level, excellent weather conditions, and fertile land. In addition to this, Vietnam is also blessed with a well-developed water system, thanks to an extensive network of rivers, a favorable topography, and favorable weather patterns (Tom Kompas, 2004). There are six basic ecological regions in Vietnam where rice production is concentrated: the Red River Delta, the Northern Midlands, and the Mountains, the North Central Coast, the Central Highlands, Southeast, and the Mekong River Delta. Most of the rice cultivated in Vietnam is in the Mekong River Delta, the North Central Coast, and the Red River Delta. These three economic regions accounted for 84.8% of all rice areas in the country.

The Mekong River Delta is a region blessed by nature with fertile land and unlimited water resources. Rice farmers in the Mekong Delta are applying the direct-seeding method to reduce labor costs. The rice value chain in the Mekong Delta is a large and complex system, linking 1.5 million small-scale rice farmers to large numbers of traders, processors, wholesalers, retailers, and exporters. About 30% of production enters the domestic market and 70% is exported, accounting for over 90% of national exports (The Anh et al., 2020). Conversely, the cultivating land in the Red River Delta is often fragmented on a small scale due to a policy of allocating land equitably and the direct-seeding method is not appropriate for this region (MARD, 2017).

Based on the agricultural sector structure of farm households in Vietnam, rice is the most important crop. It provides food and is a traditional agricultural industry. The country possesses approximately 9.3 million hectares of agricultural land, the majority of which is used for rice farming. In 2016, the area under rice cultivation was approximately 7.79 million ha, representing a decrease of 0.5% over the previous year. The land area available for rice production is gradually diminishing as a result of civilization. The Vietnamese government aims to maintain a rice cultivation area of approximately 3.8 million hectares and a rice production of approximately 43 (MTs) by 2020 (Tran Cong Thang & Vu Huy Phuc, 2016). In fact, expanding rice planting areas is not an effective means of increasing rice production, as it negatively affects the natural ecosystem. Therefore, increasing rice production should be achieved by increasing productivity and quality.

Table 2.1 Rice land area and growth rate in Vietnam from 2005 to 2020

Year	Planted area (x1000.ha)	Growth rate (%)
2005	7,329.20	-1.6
2006	7,324.80	-0.1
2007	7,207.40	-1.6
2008	7,400.20	2.7
2009	7,437.20	0.5
2010	7,489.40	0.7
2011	7,655.40	2.2
2012	7,761.20	1.4
2013	7,902.50	1.8
2014	7,816.20	-1.1
2015	7,828.00	0.2
2016	7,737.10	-1.2
2017	7,705.20	-0.4
2018	7,570.90	-1.7
2019	7,469.50	-1.34
Prel. 2020	7,279.00	-2.55

(Data from the General statistics office of Vietnam)

Rice has long been a strategic crop for national food security in Vietnam. Through decades of government support, rice productivity has increased both for the domestic market as well as for export (Nguyen Le Hoa & Tran Cong Thang, 2016). Vietnam occupies a unique position in the international rice production arena. Rice is currently a significant contributor to Vietnam's social and economic development. Rice lands account for 82% of the country's arable land, according to the International Rice Research Institute (IRRI). The Mekong River Delta produces about 52% of Vietnam's rice, and the Red River Delta produces 18%.

In the Red River and Mekong deltas, over 15 million smallholder farmers produce rice as their sole source of income; however, the number of smallholders who are able to earn a living from rice is declining. According to Oxfam (cited in The Economist, 2014), an average An Giang family earns 100 USD a month from the cultivation of rice, a fifth of what coffee cultivators earn in Vietnam's Central Highlands (Rikolto Worldwide, 2019).

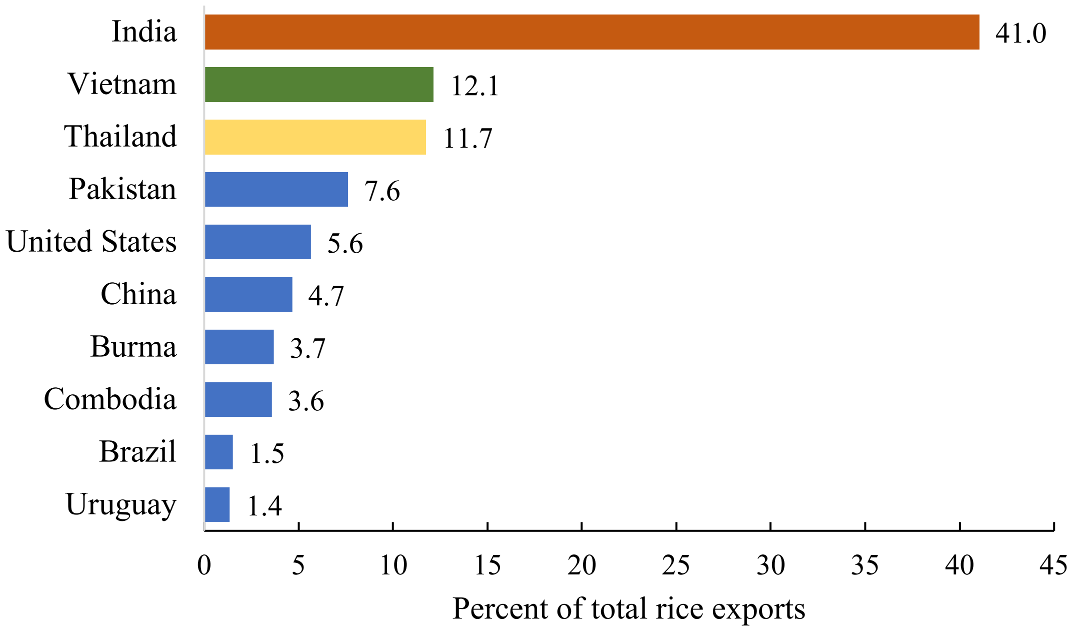

Figure 2.1 Share of global rice exports 2021

(*Source: USDA, Foreign Agricultural Service, April 2022*)

Rice cultivation has received considerable attention from the government in recent years, as well as the effects of policies on rice farms such as irrigation investment, trade liberalization, irrigation fee exemption, agriculturally intensive, partnership with scientists, and credit lending. Its significant incentives for rice farmers contribute to increasing Vietnam's rice productivity. Thus, the yields have remained high, holding a 10-year average (2006–2016) of 5.4 tons/ha. Vietnam’s yield greatly surpasses that of Thailand, another large rice producer in the region, with a 10-year average yield of only 3 tons per hectare (Maitah et al., 2020).

Table 2.2 Vietnam rice productivity and quantity from 2005 to 2020

Year	Quantity (x 1000 tons)	Productivity (tons/ha)
2005	35,832.90	4.89
2006	35,849.50	4.89
2007	35,942.70	4.99
2008	38,729.80	5.23
2009	38,950.20	5.24
2010	40,005.60	5.34
2011	42,398.50	5.54
2012	43,737.80	5.64
2013	44,039.10	5.57
2014	44,974.60	5.75
2015	45,091.00	5.76
2016	43,165.10	5.58
2017	42,738.90	5.55
2018	44,046.00	5.82
2019	43,495.40	5.82
Prel. 2020	42,760.90	5.87

(*Data from the General statistics office of Vietnam*)

In Vietnamese economy, agriculture sector contributes 24% of GDP and generates 20% of export revenues. More than 70% of the national labor force is employed in the agriculture sector, while 6% is employed in the agricultural postproduction sector (ADB, 2012).

As in many developing countries, rice farmers in Vietnam are viewed as inefficient rice producers because they use inefficient combinations of inputs, and these factors are affected further by the characteristics of rice farm households. Due to the importance of rice to the Vietnamese economy, the Vietnamese government has focused much attention on rice cultivation and on the effects of policy on rice farms. Therefore, the analysis of technical efficiency in rice production is necessary for policymakers, governors as well as rice farmers in designing and implementing policies. Yet very few studies have examined the effectiveness and the impact of such policies.

Table 2.3 Vietnam rice exports volume and value from 2010 to 2020

Year	Quantity (Millions of tons)	Value (Billion USD)
2010	6.89	3.25
2011	7.12	3.66
2012	8.02	3.67
2013	6.59	2.92
2014	6.33	2.94
2015	6.58	2.80
2016	6.58	2.16
2017	5.82	2.63
2018	6.11	3.06
2019	6.37	2.81
Prel. 2020	6.25	3.12

(Data from the General statistics office of Vietnam)

2.2. Overview of Government policies on Rice production in Vietnam

The COVID-19 pandemic has adversely affected global trade in goods, causing labor shortages and shortages of transportation in the exporting countries of the producing countries. The slow delivery of goods happened very seriously in the world such as largest rice exporters, India and Thailand. The waiting time for a train to carry rice is four weeks in India due to congestion at the port, hence the large demand from customers could not be met. For the first time in three decades, China, the world's largest rice consumer, needed to import rice from India, while Bangladesh, the world's third-largest rice producer, had to import rice as an importer (USDA, 2021). It is clear that the rice market in the world continues to expand both in terms of supply and demand. According to the FAO, the world's rice production in 2020 is expected to reach 508.4 (MTs), which represents an increase of 1.52% over 2019. The United States Department of Agriculture (USDA) estimates that global rice production in 2020 will be 501.1 (MTs), an increase of 1.21% from last year. Additionally, the Council of International Grains (IGC) estimates that global rice exports in 2020 will reach 503.4 (MTs), an increase of 1.31 percent over 2019. In accordance with FAO calculations, rice consumption is projected to reach 510.3 (MTs) in 2020, an increase of 1.52% over the same period in 2019. IGC has also estimated rice consumption at 500.7 (MTs), an increase of 0.83%.

To feed this enormous population, FAO estimates that annual cereal production will increase from 2.1 billion tons in 2009 to approximately 3 billion tons by 2050 (FAO, 2012). There has been a claim that a substantial increase can be achieved in food production if the necessary funds are provided, and agricultural policies are put in place to promote agricultural production. This target will not only be achieved by increasing production, but policies that reduce poverty, particularly in rural areas, as well as effective safety net programs must also complement this aim.

In 1989, Vietnam reemerges as a rice exporter after two decades of being a net importer (Pingali & Xuan, 1992). The country's conversion to exporter status can be explained in part by the de-collectivized policies that had resulted in imports of rice despite the rapid and widespread adoption of modern rice varieties and technology. Since 1989, rice exports have increased significantly with a growth rate of 7.8% per year, making Vietnam one of the largest rice exporters in the world and reaching record exportation of 8 (MTs) in 2012. The steady increase in rice production in Vietnam not only meets the domestic demand but also enables Vietnam to become a major rice exporter in the world. The world's rice production currently amounts to about 6% of Vietnam's exports, while its consumption is only approximately 4.5% of this volume (Tran Cong Thang & Vu Huy Phuc, 2016).

The Vietnamese government has proceeded agriculture policies and emphasized paddy rice crop as the most important staple. In revising the Vietnamese Land Law in

1998 (Circular No. 346/1998/TT-TCDC,1998), the Vietnamese government supported farm and plot consolidation by outlining procedures and designing responsibilities for land transactions to encourage efficient land use in areas like the North.

Since 2008, the government has issued a wide range of policies to support agricultural materials and services via measures which include: paying inputs cost for farmers on paddy reclaimed land, in case of disasters and diseases. In general, these policies have gradually improved agricultural input market both in terms of price stability and quality/food safety management and have helped to reduce influences of price shock on farmers' production and livelihood. Support for inputs has grown in importance in the context of rising price of major inputs. Decree No. 42/2012/ND-CP which strongly concentrates on rice farming. Farmers were supported based on the extent of damage caused by diseases and natural disasters 50-70% the cost of agricultural materials. MARD (Ministry of Agriculture and Rural Development) is responsibility developing paddy land, organizing and operating structural crops. Provincial People's Committees directly provided paddy lands' usage and report to MARD and Ministry of Natural Resources and Environment (MONRE). Besides, they provide farmers with indirect support (for instance: advanced farming techniques and market strategies).

In fact, prices of crucial inputs, such as insecticides and fertilizers for crop production, varied from 2007 to 2012, endangering agricultural production. For instance, during the past six years, the cost of nitrogenous and potash fertilizers has climbed by 12.6% and 3% annually, respectively. Meanwhile, the cost of rice bran and soybean increased by 13.2% and 5% per year respectively. Therefore, after a lack of cash, around 45.5% of communes ranked price volatility as their second biggest barrier.

Recently, the Vietnamese government launched a policy strategy for restructuring the rice sector which shifts the government's focus from quantity to quality, from food security to food safety, and from a supply-driven sector to a market-driven one. The Rice Restructuring Plan of Vietnam will be a major focus in order to improve the competitiveness of the Vietnamese economy and ensure sustainable development visions by 2025 and 2030. Following these policies, the government aims to maintain rice fields in a maximum area of 3.5 million hectares so that the minimum yield reaches 35 (MTs) of rice per year. Approximately 4 (MTs) of rice are exported each year. This results from the fact that over 90% of the rice production area is using certified seeds and implementing advanced farming processes such as ICM, IPM, SRP, SRI, 1P5G, VietGAP, GlobalGAP, organic rice farming, and intelligent rice in response to climate change. The total amount of chemical fertilizers and pesticides needed in rice production must decrease by approximately 40%. It is estimated that by the year 2030, the mechanical harvesting rate will reach 80 percent, especially in the Mekong River Delta, the rate is expected to reach 100 percent by then. Farmers will be able to increase profits by as much as 30% while simultaneously reducing greenhouse gas emissions (GHG) by approximately ten percent by implementing this plan. The export of rice from Vietnam ranks second in the world but the goal in the future is to increase the income of rice farmers, raise value-added and products and protect the environment. It is not only the main task for the agriculture sector in general but also for rice species in the future.

2.3 Challenges in the Vietnamese rice sector

There is growing pressure on smallholder farmers to meet the quality demands of quality rice markets. The trend of intensified land use in Vietnam, as in other Mekong countries, has coincided with a dramatic increase in the use of chemical fertilizers and pesticides. Smallholder farmers lack the necessary skills to produce quality rice. Ideally, rice plots should cover two to three hectares, but on average, Vietnamese rice farmers cultivate one acre (0.5 ha) of rice. The farmers' small farms and lack of organization make them less attractive as potential business partners, making them vulnerable players in the value chain. Farmers who organize themselves into farmer cooperatives have a better chance of earning a decent income from rice cultivation. Even farmer organizations, however, have difficulty meeting the needs of quality rice markets due to poor relationships with private actors, a lack of information about the market, and the lack of professionalism in their management.

Rice farmers are becoming increasingly vulnerable to the effects of climate change. The most recent 2015–2016 drought affected all the Mekong River Delta provinces and caused up to USD 360 million in damage, of which USD 300 million was agriculture- and aquaculture-related damage (Nguyen Ngoc Anh, 2017). The drought and related saltwater intrusion inundated at least 221,000 hectares of rice paddies in Vietnam's Mekong Delta, known as the country's "rice bowl". Nearly 2 million poor and smallholder farmers were affected (Rikolto Worldwide, 2015). Rice production in Vietnam is currently input-intensive, posing a threat to the environment and people. In rice-growing regions in Vietnam, soils are very poor in nutrients, which limits their use for other crops, such as maize. Rice paddies are a major source of methane, a greenhouse gas that contributes to global warming. Although there has been a recent push towards more sustainability in the industry, as demonstrated by the "3 Reduction/3 Gain and 1 Must do 5 Reduction" policies, environmentally friendly technologies and practices remain limited (R.M. Rejesus; A.M. Martin; P. Gypmantasiri, 2013). The traceability of rice products from Vietnam is very limited. The majority of rice enterprises depend heavily on collection systems for the supply of their paddy, which makes traceability difficult and negatively affects the quality of rice products.

Vietnam exports a large amount of white rice at the lower end of the market. Vietnamese rice sold in export markets is of lower quality than rice from other Mekong countries, therefore it is cheaper. Taking advantage of Vietnam's market niche - low quality and low prices - the country is able to easily export to and penetrate low-income countries around the world. In spite of this, Vietnam's reputation for offering low-quality rice and the absence of a meaningful national brand result in low prices for farmers.

2.4 Empirical Studies

Recent history of efficiency measurement begins with Farrell (1957) who defined a measure of firm efficiency. A firm's efficiency is defined as its actual productivity when compared to its maximal potential productivity. In this context, firms are measured by their ability to produce as much output as possible from a given set of inputs. Farrell also suggested that the economic efficiency of a firm or a farm consists of two elements, which are technical efficiency and allocative efficiency. Farms are measured in terms of their technical efficiency according to their ability to obtain maximum output from their inputs (output-oriented measures), meanwhile a farm's allocation efficiency refers to its ability to utilize inputs in an optimal proportion, based on both their prices and production technology (Farrell, 1957).

For measuring efficiency, Coelli (1995) proposed that frontier function models are a practical way to estimate farm efficiency due to its' two main advantages. First, it reflects the technologies used on the best performing farms. Second, the frontier function models can offer a measurement of farm efficiency base on the best practice technology (T. J. Coelli, 1995). Accordingly, many debates regarding future structural changes, supply responses, the size of agricultural labor forces, and international competitiveness have emphasized understanding why farms are different in their relative efficiency (Gorton & Davidova, 2004).

Agricultural production efficiency may be influenced by many factors, but only some of them were intensively accounted for in research including farm size, land fragmentation, and crop diversification. Most studies of agricultural productivity in developing countries in the past support the theory that smaller farms were more productive because land was used more intensively, or labor allocated more efficiently. However, there are several findings recently vary the relationship between farm size and efficiency (Giang Thi Ngan Dao, 2013). Some research has discovered that small and large farms were equally technically efficient (André Croppenstedt, 2005; Bagi, 1982; Ray, 1985); meanwhile several research have shown the differences in management input are more crucial than the size of the farm (Adesina & Djato, 1996; Charles Zelek & Gerald Shively, 2001; Hoque, 1988). On the other hand, fragmentation of farm's land is believed to have both private and social costs and benefits. Farm land fragmentation may result in cost increases, higher labor use, less mechanization, and difficulties in applying new technology to farms, but at the same time it may be beneficial to farmers, such as risk management, seasonal labor use and crop diversification (Giang Thi Ngan Dao, 2013). Works of Rahman (2008) in Bangladesh; Majunatha et al. (2013) in India revealed that farms with fragmented land had significantly lower efficiency levels than those who operated in a larger piece of land. In contrast, a study by Niroula and Thapa (2007) in the mountainous area of Nepal for its impact on input use, crop yield, and efficiency shown that small farms performed better and had higher technical efficiency than larger ones (Manjunatha et al., 2013; Rahman & Rahman, 2009; Niroula & Thapa, 2005). With the growth of economies, households tend to shift their focus from self-sufficiency to profit and income-driven decision making, leading farm output follows market trends more closely. Research on this issue which reveals the explicit relationship between crop diversification and technical efficiency at farm level are few but resulted in mixed conclusions. Some researchers revealed that crop diversification significantly improves technical efficiency on farms (T. Coelli & Fleming, 2004; Rahman, 2009), whereas, with crop diversification, a remarkable reduction in allocative and economic efficiency was observed elsewhere (Haji Jema, 2007). As rice is one of the most important crops in developing countries, many studies have concentrated on improving the efficiency of rice production in general as well as its technical efficiency.

According to the research of Dhungana, Nuthall, and Nartea (2004), DEA was applied to 76 farm households engaged in rice production in Nepal, where the average level of economic, technical, and allocative inefficiency was 0.34, 0.13, and 0.24 respectively. The purpose of this study was to describe the source of TE by using the Tobit regression model. Findings reveal that the degree of inefficiency was strongly related to farm households' demographics, level of education, and risk-taking attitude.

Dhungana et al. (2004) concluded that rice production was more efficient when led by elderly male family members. As reflected in the physical characteristics of the male labor force, the male labor force has a stronger ability and more skills in managing and organizing production; while the elderly was able to accumulate more farming experience in choosing appropriate rice varieties, factor inputs, or production methods. The education of family leaders also led to a positive impact on their decision-making processes by assisting them to acknowledge changes in the natural environment or combine inputs efficiently (Dhungana et al., 2004).

Javed et al. (2011) used DEA technique to investigate determinants of technical inefficiency of the rice-wheat system in Punjab, Pakistan. The results shown that mean technical efficiency of the system was 0.83, with minimum level of 0.317 and maximum of 1. This indicated the existence of substantial technical inefficiency in rice-wheat system in the research's site. The study further revealed that if sample farms in rice-wheat system operated at full efficiency level these could reduce their input use by 17 percent without any reduction in level of output and with existing technology (Javed et al., 2011).

Susan Chiona et al. (2014) investigated a primary data collected from 400 households in the Central province of Zambia. The study has examined the level and determining factors of technical efficiency in maize producers in Zambia. This study applied stochastic frontier analysis to estimate the technical efficiency for maize stakeholder and determine the factors effect on maize production in Zambia. The results showed that average technical efficiency of maize farmers at 50%, the level of technical efficiency was in arrange from 2% to 84%, expecting the opportunity for maize producers in Zambia to increase the actual output with current using inputs. Among these farmers, around 46% of them obtained efficiency above 50% of their potential output while 14% of them captured less than 30% or higher than 70% of the potential output. The author is also addressed the most determines affect to technical efficiency of maize farmers due to hybrid seed, access to credit and extension service as well as the age of household head. Thus, the study suggesting that, the Government and the maize farmers would concentrate to improve access credit and extension services and promoting use of certified hybrid seed as a way to improve the technical efficiency of maize producer in Zambia (Chiona et al., 2014).

Based on the panel data collected at the farm level, Koirala, Mishra, and Mohanty (2013) attempted to explain the determinants of technical efficiency among Philippine rice farmers. The data collected for this study are drawn from the Loop Survey conducted by the International Rice Research Institute between 2007 and 2012. A frontier production formula was formulated in the Cobb-Douglass model with the output being the total value of rice production and several inputs including land, seed, fuel, fertilizer, pesticide, labor, operation, property rental, irrigation, and planting season. Using the fixed-effect model, the technical score was estimated at 0.548 on average, ranging from 46% to 74%. While the cost of land rent and the price of fuel as well as fertilizers had a negative impact on these efficiency estimates, rice production had a positive impact. In this study, we investigated the source of technical efficiency from direct inputs and outputs of rice production in quantity as well as a dummy variable for planting season effects. Other farmers' characteristics, such as those related to demography, education, and finances, were not considered in this study (Koirala et al., 2013).

Based on the study conducted by Balde, Kobayashi, Nohmi, Esham, & Tolno (2014), there was an estimating that mangrove rice production in Guinea is dependent on the technical efficiency level as well as its determinants. The study estimates the technical score in mangrove rice in the Guinean coastal area with a mean of 0.23 using the stochastic frontier model. A frontier Cobb-Douglas production function has the output of mangrove rice production as the dependent variable and the independent input variables being fertilizer and pesticide cost, hired labor cost, depreciation cost of farm tools, seed quantity, and active family labors per family size, and farm area for rice production as the independent variables. However, the empirical findings indicated that only depreciation of the tools and the area of farmland directly contributed to the production of rice by farmers. Based on the explanation of the source of technical efficiency, the older and more experienced farmers, large households, and access to off-farm income and remittances tended to influence the technical scores positively. In contrast, in Guinea, the level of education, seed use, credit availability, and extended service provided by the government negatively affected the efficiency of mangrove rice production. Despite the fact that this study discussed government policies that could enhance technical efficiency, its results should not be generalized due to the limitations of using a small sample size (Balde et al., 2014).

Using data collected from 815 rice-farming households in Can Tho, Vietnam, Nguyen and Le (2014) estimated the economic efficiency of these farms by using the stochastic frontier profit function and by applying a Tobit regression model to investigate the source of technical efficiency. The empirical results revealed that rice-farming households in Can Tho obtained an average level of economic efficiency of 55.8%. Economic efficiency was significantly influenced by intrinsic factors such as farm size, method of selling rice, crop pattern, and location. Also, external factors such as access to market information and the possibility of receiving information on the use of inputs are positively correlated with the level of economic efficiency of rice-farming households (Nguyen Tien Dung & Le Khuong Ninh, 2014).

The stochastic frontier analysis was optimized in the study of Abebe (2014) to examine the impact of off-farm income on technical efficiency and farm output of smallholders in Ethiopia. Using the Ethiopian Rural Household Survey (ERHS) conducted by the Economics department of Addis Ababa University in collaboration with International Food Policy Research Institute in Ethiopia, this study used Cobb–Douglas model to test production function in four regions of Ethiopia. Furthermore, the result reveals an average level of technical efficiency at 53% in agriculture production among smallholders in Ethiopia. The determinants that were found in positive association with the technical efficiency were the household size, schooling year and gender of household leader, extension service, the practice of soil conservation as well as off-farm income. Among which, the role of off-farm income was emphasized in contributing to the investment for modern inputs in agriculture production. The spillover effect of off -farm income possibly improved the farm production in Ethiopia (Getahun Gemechu Abebe, 2014).

In addition to using both SFA and DEA separately, several studies have also combined both SFA and DEA, as a comparison. Wadud and White (2000) investigated the effects of rice farming characteristics, the environment, and irrigation schemes on the efficiency of rice production in Bangladesh at the farm level. Using 150 rice-farming households as a sample, the study estimated that the average technical score was 0.79 in the stochastic frontier model and 0.789, 0.858 in constant return-to-scale (CRS) and variable return-to-scale (VRS) DEA models, respectively. Using the stochastic frontier approach, the rice farmers were found to have slightly decreasing returns to scale. Rice production was positively associated with the elasticity of land, irrigation, labor, and pesticide, whereas fertilizers had a negative impact on production at an elasticity of 0.0392. In contrast, under the DEA approach, the decreasing returns to scale of rice farmers were increasing, indicating that the rice farmers were not operating at an optimal scale. The regression results for the source of technical inefficiency were completely different between the two approaches. Rice farmers who had more years of schooling tended to be less efficient in the stochastic frontier and CRS DEA models, while this factor had a positive correlation with efficiency in the VRS DEA model. In both the CRS and VRS DEA models, the land fragment demonstrated a negative association with technical inefficiency. However, the use of fuel when operating irrigation systems and the soil degradation demonstrated positive associations with technical inefficiency. This research raised questions about the differences between the two approaches and suggested a further investigation into these aspects (Wadud & White, 2000).

Most empirical studies on the technical efficiency of rice farmers in Vietnam imply that the existence of wide scope for improvement efficiency of Vietnamese rice production (Tom Kompas, 2004), , (Hoang, 2006), (Khai & Yabe, 2011), (Huynh-Truong, 2009), (Lewis, 2013).

In 2004, Kompas used the stochastic production frontier for the regional data panel to estimate technical efficiency of rice production in Vietnam. He showed that the level of technical efficiency of rice production in Vietnam was 0.65 in the whole nation and 0.78 for Red River Delta and Mekong River Delta. The empirical result showed that the farm size, proportion of used tractor and the major land areas indicator positively affected by the level of technical efficiency (Tom Kompas, 2004).

Dao and Lewis (2013) studied about analyzing technical efficiency utilized Data Envelopment Analysis (DEA) of the diversity in the annual crop in the Northern Vietnam. The study used farm-level; cross-sectional data represented by four provinces in Vietnam. A sample size of 423 farm households who cultivated rice, starchy crops, industrial plants, or vegetables was withdrawn from VHLSS 2008. In the findings, the mean of the pure technical efficiency estimated was 83% and the technical score of farmers who cultivated market-oriented product such as industrial crops have greater technical efficiency than those focusing on rice and maize. Although the author had not estimated analyze the determinant factors effect technical efficiency yet, the scholars attempted to discuss the important of crop diversification and emphasized the combination of rice and cash crops in the market-oriented context should be focused on making agriculture policies for agriculture productions in Vietnam (Giang Dao & Phil Lewis, 2013).

Based on the data from VHLSS 2006, Khai and Yabe estimated the technical efficiency of Vietnamese rice farming by using the stochastic frontier analysis as well as investigated the source of technical efficiency. The empirical result indicated that rice-farming households in Vietnam obtained an average level of economic efficiency at 81.6%. The level of economic efficiency was significantly influenced by the inherent factors including labor investment in rice land, irrigation system, ethnicity, and education. In that case, the most important factors affecting an increase of technical efficiency of households is the utility of intensive labor in rice cultivation. It means that the farmers need to invest in rice land more intensive labor (Khai & Yabe, 2011).

Dina Tri Utari et al. (2020) performed a panel data analysis focused on rice production in Ngawi Regency, East Java, Indonesia. The scholar concluded that food crops are an important subsector in the development of Indonesia among some subsectors of agriculture. The most widely consumed food crop in Indonesia is rice. The purpose of this study was to identify the impact of harvested area (X1), productivity (X2), machines/agriculture (X3), and extensive irrigation (X4) on rice production in Ngawi. The study found that the Fixed Effect Model with R2 values of 99% was the best model. In the Fixed Effect Model, every district is interpreted as having a different intercept without time effects. Harvested area and productivity are also factors that affect rice production (Utari et al., 2020).

In their study on inefficiency in rice production and land use, Kazuo Ogawa (2017) also used a panel of Japanese rice farmers. By using the Rice Production Cost Statistics from the Ministry of Agriculture, Forestry, and Fisheries, this study conducted an empirical analysis of the behavior of Japanese rice producers from the standpoint of production efficiency. This study estimates the stochastic frontier production function, which is comprised of four production factors (land, labor, capital stock, and material) and calculates the inefficiency indices of production. This data was used to identify efficient and inefficient rice producers, and to compare the factor demand behavior and characteristics of the arable land utilization for rice production. There was a finding that inefficient rice producers do not adjust employment levels in the short or long run, regardless of the changes in wages. In addition, efficient rice producers who hold a large % of the farms divided into small plots reduced the amount of arable land utilized for rice production and increased productivity. However, it was noted that the certified farmers, who should be focusing on the expansion of the scale and efficiency of agricultural productions, tend to reduce rice cultivation using arable land and switch to other crops; furthermore, the more efficient the certified farmers are, the greater the impact of such activities (Ogawa, 2020).

2.5 Measurement of Technical Efficiency

2.4.1 Efficiency

The stochastic frontier production function was independently proposed by Aigner, Lovell, and Schmidt (1977); and Meeusen and van den Broeck (1977), it has been a significant contribution to the econometric modeling of production and the estimation of technical efficiency of farms.

The stochastic frontier consists of two random components, one associated with the presence of technical inefficiency and the other being a traditional random error. Prior to the introduction of this model are Aigner and Chu (1968), Timmer (1971), Afriat (1972), Richmond (1974), and Schmidt (1976) considered the estimation of deterministic frontier models whose values were defined to be greater than or equal to observed values of production for different levels of inputs in the production process (Battese & Coelli, 1992).

There are two methods widely used in the literature to estimate technical efficiency, which are stochastic frontier analysis (SFA) and data envelopment analysis (DEA). SFA is an econometric approach which aims to develop stochastic frontier models based on the deterministic parameter frontier of Aigner and Chu (1968). DEA is a nonparametric approach or mathematical programming method that is useful for multiple-input and multiple-output production technologies.

SFA approach generates good estimating results of technical efficiency only for production with a single output and multiple inputs. Otherwise, the nonparametric method, DEA approach utilized to estimate technical efficiency for production with multiple inputs and multiple outputs. Nonetheless, this technique does not have the ability to separate the influences of noise and inefficiency during the estimating of the technical score. Furthermore, another advantage of the SFA approach is to determine the exogenous factors (e.g., irrigation, loan interest, labor intensive…) influencing the level of technical inefficiency of each farm. Therefore, this study aimed at parametrically analyzing technical efficiency of rice production at farm level using SFA approach.

Technical efficiency measuring will be used inputs and output quantity without comprising their prices. Technical efficiency can be decomposed into three components such as scale efficiency (the potential productivity gains an optimizing size of a firm), congestion (increase in some inputs could decrease output) and pure technical efficiency (Farrell, 1957).

It is supposed that a firm uses two inputs (X_1 and X_2) to produce a single output (Q) under the constant returns to scale in Figure 2.2. The SS' curve performs the isoquant of full efficient farms could allow measurement of technical efficiency. If a given farm uses quantities of inputs at point A to produce a unit of output, the technical inefficiency of that firm could represent as the distance AB. It is the amount by which all inputs need could proportionally reduce without a decline in output. This is usually expressed in percent terms by the ratio BA/OA, which represents the percent by which all inputs need to reduce to achieve technically efficient production. The technical efficiency (TE) of a firm is most measured by the ratio:

$$TE = OB/OA \quad (2.1)$$

The value of TE between 0 and 1 represents the degree of technical efficiency. If TE is equal to 1, the firm produces with fully technical efficiency. For instance, at the point B firm could gain full technical efficiency because point B lies in the efficient isoquant curve.

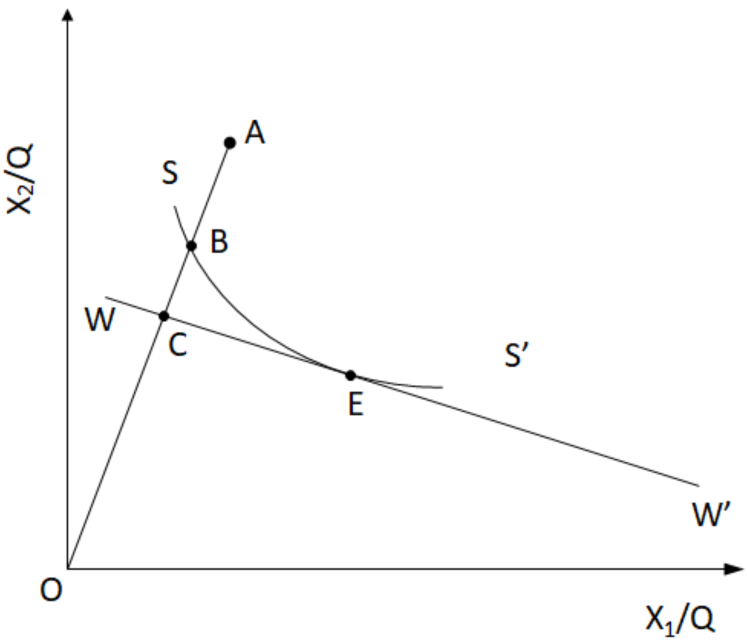

Figure 2.2 Technical, allocative, and economic efficiency

If the input price ratio, represented by the slope of the isocost line WW', allocative efficiency (AE) at A can be calculated and identified by the ratio:

$$AE = OC/OB \qquad (2.2)$$

The decrease in production costs with the distance from B to C would happen if production is performed at the allocative and technical efficient point E instead of at the technically efficient, but allocative inefficient point B.

The total economic efficiency (EE) is defined to be the ratio:

$$EE = OC/OA \qquad (2.3)$$

The distance from A to C also represents the cost cut in production if a firm produces at the point C with the technical efficiency and allocative efficiency instead of at the point A with technical inefficiency and allocative inefficiency. Economic efficiency is to combine technical efficiency and allocative efficiency.

2.5.2 Stochastic frontier approach

In 1997, Stochastic production frontier models were introduced by Aigner, Meeusen, Broeck and their colleagues. Since then, stochastic frontier production function become popular econometric tool in economic field (Aigner et al., 1977; Wim Meeusen and Julien van den Broeck, 1977).

Suppose that a farm has a production function $f(X_i, \beta)$. The i^th farm would produce $Y_i = f(X_i, \beta)$ in case of no error or inefficiency. The Stochastic production frontier model assumes that each farm potentially produces less than it might due to a level of inefficiency. Specifically,

$$Y_i = f(X_i, \beta)\varepsilon_i \qquad (2.4)$$

where, Y_i is output and X_i is input vector of farm i. β is the vector of parameter estimates. $f(X_i, \beta)$ is normally assumed either Cobb-Douglass production function or translog function. The study aims at choosing the Cobb-Douglass production function to be convenient in testing the return to scale hypothesis. ε_i represent the level of efficiency of farm *i.*

Output is also assumed to be subject to random error v_i, suggesting that

$$Y_i = f(X_i, \beta)\varepsilon_i \exp{(v_i)} \qquad (2.5)$$

Where v_i, is assumed to be independently and identically $N(0, \delta_v^2)$

The natural logarithm of the production function is expressed as

$$\ln Y_i = \ln[f(X_i + \beta)] + \ln \varepsilon_i + v_i \quad (2.6)$$

Assume that there are k inputs, and that the production function is linear in logs, and define technical inefficiency effect $u_i = -\ln(\varepsilon_i)$ which is assumed to be independently exponentially distributed with δ_u^2, the production frontier function in equation (2.3) becomes

$$\ln Y_i = \beta_0 + \sum_{k=1}^{k} \beta_{ik} \ln X_{ik} + v_i - u_i \quad (2.7)$$

The technical inefficiency effect can be determined by:

$$u_i = \alpha_0 + \sum_{j=1}^{j} \alpha_j Z_{ij} + \omega_{ij} \quad (2.8)$$

ω_{ij} is the stochastic noise, Z_{ij} is exogenous factors that are affecting rice production. α_0, α_j are parameter estimates, if α_j is negative that indicates a positive relationship between exogenous factors and technical efficiency of rice production, and vice versa. Technical efficiency (TE_i) under output-oriented of i^{th} farm is measured as $TE_i = \exp(-u_i)$ and is defined as a ratio of observed output and frontier output. TE_i must be in the interval (0,1]. If TE_i is equal to 1, the farm is considered as operating at the optimal output with the technology embodied in the production frontier.

CHAPTER 3

ANALYZING FACTORS THAT AFFECT RICE PRODUCTION EFFICIENCY AND ORGANIC FERTILIZER CHOICES IN VIETNAM

3.1 Introduction

Agriculture is an exceedingly important contributor to the Vietnamese economy, accounting for 24% of GDP and generating 20% of export revenues. Over 70% of the national labor force is employed in the agriculture sector, and an additional 6% is employed in the agricultural postproduction sector (ADB, 2012). Rice is the main crop in the farm household agricultural sector in Vietnam, with 9.3 million hectares (ha) of agricultural land that is primarily used for rice cultivation. The agricultural and rural development sector continue to set a target for rice production of 7.2 to 7.3 million hectares as the cultivated area in 2022. This will be achieved by intensive farming with increased productivity to reach production levels of 43 to 43.9 million tons (MTs). Rice production is also a vitally important component of food security in Vietnam as the first criterion the millennium development goal. In addition, the Nationally Determined Contribution (NDC), which is making institutional support for agricultural and all related sectors in Vietnam, was discussed by Nguyen Duc Trung (D. T. Nguyen et al., 2020). On the other hand, organic agriculture has been focused upon as one of the sustainable agricultural production systems, with low environmental impact and potential contribution to global food supply, while detrimental environmental impacts of conventional agriculture have been critically discussed. For example, Badgley (2007) insisted that an organic agricultural production system has the potential to contribute quite sustainability to the global food supply (Badgley et al., 2007). There are many organic-based fertilizer industries active in developed economies, but not active in agricultural production in developing countries.

However, as in many economically developing countries, Vietnamese rice farmers are regarded as inefficient rice producers because of non-optimized input combinations and the influence of rice farm household characteristics. In other words, the Technical Efficiency (TE) of rice production is closely related to sustainable rice farming practices because they share the same basic elements, such as the use of labor, seed, fertilizers, and pesticides. Rice farmers with high TE might achieve more sustainable production with enough reasonable inputs. Consequently, farmers can expect to expand the global market share for Vietnamese rice with higher quality produce and larger quantities and can improve farmers' livelihoods.

Several studies have emphasized economic efficiency in agricultural production, especially presenting analyses of TE in the agriculture sectors of economically developing countries. For instance, Watkins (2014) use a Data Envelopment Analysis (DEA) approach and report the TE of rice production in Arkansas, the top rice-producing state in the United States, as 0.803, with CRS 0.875 and scale efficiency of 0.92, implying that rice production in Arkansas is remarkably efficient in its use of inputs. Furthermore, the author estimates allocative efficiency and economic efficiency as 0.711 and 0.622, respectively (Watkins et al., 2014). Boubacar (2016) also use a DEA approach and report the TE of rice-producing farmers in southwestern Niger as 52%. The results show that farm size, experience in rice farming, membership in a cooperative, main occupation, and land ownership directly affect TE (Boubacar et al., 2016). By applying Stochastic Frontier Analysis (SFA), Chandio et al. (2019) examine the effects of agricultural credits and farm size on the TE of rice productivity in Sindh, Pakistan. The results show that these factors significantly influenced rice productivity in the area. The average TE was 0.97, which implies that about half of the rice farmers are as technically efficient (within 3%) as the most efficient farmers (Chandio et al., 2019). A study of the TE of rice production in Vietnam revealed TE of 0.65 nationwide and TE of 0.78 for the Red River and Mekong River Deltas (Tom Kompas, 2004).

This study uses the stochastic production frontier and regional cross-sectional data in order to explain productivity differences among firms by estimating TE of rice production in Vietnam. Giang (2013) reveals that the estimated mean TE of rice production in Vietnam was 83%, and the technical scores of farmers who cultivate market-oriented products such as industrial crops have greater TE than those growing rice and maize (Giang Thi Ngan Dao, 2013). However, the author does not discuss the determinants that affect the TE of rice production itself but discusses the importance of crop diversification, emphasizing that the combination of rice and cash crops in a market-oriented context can contribute to implementing policies for agriculture production in Vietnam. Khai and Yabe (2011) estimate the TE of Vietnamese rice farming using SFA and investigate its constituents. The empirical results indicate that rice-farming households in Vietnam obtain an average TE of 81.6%. They found that the level of TE is strongly influenced by inherent factors, including labor investment in rice land, irrigation systems, ethnicity, and education (Huynh Viet Khai & Mitsuyasu Yabe, 2011). However, their study uses national data from the Vietnam Household Standard Survey 2005–2006 (VHLSS 2006) to investigate the factors that affect rice output from the efficient use of the inputs to rice production. Rice production in Vietnam has since improved, and a newer version of the VHLSS is available. Therefore, following that approach, we employ the 2016 version of the VHLSS and use SFA to estimate the TE of Vietnamese rice farming. The results are expected to reveal the most crucially important element inputs for these farmers. We also discuss the differences between farmers in rice production efficiencies from the viewpoints of irrigation use and organic fertilizer choice by adapting the Propensity Score Matching (PSM) method to control for self-selection bias.

3. 2 Methodology

3.2.1 Stochastic frontier framework

The stochastic frontier production function, which was proposed independently by both Aigner et al. (1997), Meeusen and van den Broeck (1977), has been an important contribution to the econometric modeling of farm production and TE estimation (Aigner et al., 1977; Wim Meeusen; Julien van den Broeck, 1977). The stochastic frontier involves two random components: one associated with the presence of technical inefficiency and the other a traditional random error. Before the introduction of this model, Aigner and Chu (1968), Timmer (1971), Afriat (1972), Richmond (1974), and Schmidt (1976) considered estimating deterministic frontier models with values defined as greater than or equal to the observed values of production for different levels of inputs to the production process (Afriat, 1972; Aigner, D.J & Chu, S.F, 1968; Battese & Coelli, 1995; Richmond, 1974; Schmidt, 1976; Timmer, 1971).

Presuming that a farm has a production function $f(X_i, \beta)$, then the ith farm would produce $Y_i = f(X, \beta)$ if there were no errors or inefficiency. The stochastic production frontier model includes the assumption that each farm potentially produces less than it might because of a level of inefficiency. Specifically,

$$Y_i = f(X_i, \beta)\varepsilon_i \quad (3.1)$$

where Y_i represents output and X_i stands for the input vector of the ith farm. β is the vector of parameter estimates, and ε_i represents the efficiency of the ith farm. Output is also assumed to be subject to random error v_i, suggesting that

$$Y_i = f(X_i, \beta)\varepsilon_i \exp(v_i) \quad (3.2)$$

v_i is assumed to be independent and identical to $N(0, \delta_v^2)$.

$Y_i = f(X_i, \beta)$ is assumed in many forms of production functions, for example, the Cobb–Douglass production function, translog function, and others. Following Khai and Yabe (2011), we employ a Cobb–Douglass production function because using the same function and data from the same survey can help identify differences in the TE of rice production in Vietnam between 2006 and 2016.

The natural logarithm of the production function is expressed as:

$$lnY_i = ln[f(X_i, \beta)] + ln\varepsilon_i + v_i \tag{3.3}$$

Assuming that there are k inputs and the production function is log linear, we define the technical inefficiency effect $u_i = ln\varepsilon_i$, which is assumed to be independently exponentially distributed with δ_u^2 . Therefore, the production frontier function in equation (3) becomes

$$lnY_i = \beta_0 + \sum_{k=1}^{k} \beta_{ik} \, lnX_{ik} + v_i - u_i \tag{3.4}$$

The technical inefficiency effect can be determined as

$$u_i = \alpha_0 + \sum_{j=1}^{j} \alpha_j \, Z_{ik} + w_{ij} \tag{3.5}$$

In this equation, w_{ij} signifies stochastic noise, and Z_{ik} stands for exogenous factors that affect rice production. Both α_0 and α_j are parameter estimates such that negative α_j indicates a positive relationship between exogenous factors and the TE of rice production and vice versa. Technical efficiency (TE_i) under the output-oriented i^{th} farm is measured as $TE_i = exp(-u_i)$ and is defined as the ratio of the observed output and frontier output. TE_i must be in the interval (0,1). If TE_i equals 1, then the farm is regarded as operating at the optimal output with technology embodied in the production frontier.

3.2.2 Data collection

This study was conducted to examine national data from Vietnam obtained from VHLSS 2016. The VHLSS has been conducted every two years since 1993 to assess the living conditions in Vietnam. The survey is administered nationwide through face-to-face interviews by the General Statistic Office of Vietnam using household questionnaires, with consultation from the ministries and technical advice from the World Bank.

This study uses rice production data from VHLSS 2016, which includes data from 9,399 rural and urban households. Approximately 3,695 household rice farmers were interviewed. After discarding household data where information was missing or unreasonable, the data from a total of 3,444 were used for the study.

3.2.3 Data description

This study applies a Cobb–Douglas production function with a single output (summary rice quantity harvested in a year) and nine input factors: seed expenditures, pesticide expenditures, fertilizer expenditures (comprising chemical fertilizer and organic positive values (self-supplied organic fertilizer or bought)), machinery service expenditures (comprising rental cattle, rental equipment cost with only positive values in total), hired labor for rice production expenditures (individual persons employed by a household to perform rice cultivating tasks), small tools and energy expenditures, and other rice expenditures. Family labor for rice (labor devoted solely to rice farming) was calculated by multiplying the total family labor by the share of rice value in its farm's total revenue, and the rice land area (total land size in rice farming recorded in square meters), with the rice land area measured in hectares, as shown in Table 3.1. All inputs were calculated from expenditures in Vietnamese currency (thousand VND) except for the Total farming labor (hrs), Family labor for rice (hrs) and Rice land area (ha). That is because we cannot enjoy the information about both wage rate and land rent for self-supply regarding the fertilizer input variables, this study uses fertilizer costs to compare with fertilizer quantities in an earlier study because both studies calculate variables by the sum of cropping patterns in a year.

Table 3.1 Statistics of quantitative variables in the TE model

Variables	Mean	Std. dev.	Coeff. Var.	Min	Max
Output					
Rice quantity (kg/year)	4,906.2	11,973.1	2.4404	110.0	217,220.0
Inputs					
Seed expenditures (1,000VND/year)	1,385.3	3,545.7	2.5595	18.0	76,049.0
Pesticide costs (1,000VND/year)	2,343.0	8,176.2	3.4897	9.0	113,730.0
Fertilizer expenditures (1,000VND/year)	4,562.6	10,753.9	2.3570	47.0	181,428.0
Hired labor (1,000VND/year)	1,007.0	4,020.0	3.9920	1.0	101,677.0
Machinery service (1,000VND/year)	3,176.0	5,921.2	1.8644	49.0	67,674.0
Small tools and energy (1,000VND/year)	404.1	1,167.1	2.8881	1.0	31,024.0
Other rice expenditure (1,000VND/year)	231.5	792.5	3.4235	11.0	20,680.0
Total farming labor (hrs)	2,252.8	1,747.7	0.7758	20.0	13,096.0
Family labor for rice (hrs)	1,288.6	1,260.8	0.9784	0.4	9,909.6
Rice land area (ha)	0.9	1.8	2.1059	0.0	31.9
Farm-specific variables					
Percent of rice (%)	0.6	0.3	0.5763	0.0	1.0
Age of household (yrs)	51.0	12.5	0.2446	22.0	104.0
Education of farmers (yrs)	7.3	3.3	0.4467	0.0	12.0
Total farming income (1,000VND/year)	78,022.9	167,256.6	2.1437	971.0	4,053,214.0
Non-agricultural income (1,000VND/year)	37,734.4	151,526.2	4.0156	0.0	4,031,316.0

Source: Vietnamese Households Living Standards Survey 2016 (VHLSS 2016), n=3,444

Table 3.2 Definitions of qualitative variables affecting the TE model

Variables	Definition
Ethnicity	1 = Kinh, 0 = other ethnicity
Members per household	total number
Gender	1 = male, 0 = female
Education level of HH head	0 = no certificate, 1 = elementary school certificate, 2 = others
Age of HH head	0 = younger than 30, 1 = 31–40, 2 = 41–50, 3 = 51–60, 4 = 61–71, 5 = over 71
Marital status	1 = married, 0 = others
Using internet	1 = yes, 0 = no
Non-agricultural income	0 = 0, 1 = positive
Total agricultural income	0 = less than (mean - standard deviation), 1 = between (mean - standard deviation) and mean, 2 = between mean and (mean + standard deviation), 3 = greater than (mean + standard deviation)
Irrigation system	0 = did not employ, 1 = employed
Organic fertilizer use	0 = did not use, 1 = used
Borrowing funds for rice production	0 = did not borrow, 1 = borrowed
Income source	0 = income from other crops was positive, 1 = only rice
Labor–land ratio	Ratio of rice labor to land

Source: Vietnamese Households Living Standards Survey 2016 (VHLSS 2016), n=3,444

A Cobb–Douglas production function with nine input independent variables was used for this study. The Cobb–Douglas stochastic frontier model is written as follows:

$$lnY_i = \beta_0 + \sum_{k=1}^{9} \beta_{ik}\, lnX_{ik} + v_i - u_i \quad (3.6)$$

Subsequently, the Tobit function is applied with TE as the dependent variable to ascertain those factors that affect the TE of households, as shown in Table 2.

$$TE_i = \alpha_0 + \sum_{j=1}^{14} \alpha_j\, Z_{ik} + w_{ij} \quad (3.7)$$

The average land area used for rice production in Vietnam is quite small: around 0.85 ha, with a range of 0.034–31.88 ha. The average age of household heads is 51, with a range of 22–104 years old; their average year of education is only around 7 years, ranging from 0–12 years, which suggests that Vietnamese rice farmers have relied more heavily on experience than education. Among rice production inputs, fertilizer expenditure plays the most important role of all expenses, with an average value of around 4.5 million VND, accounting for 30% of all expenses. The total value of farming activities is about 78 million VND, a considerable increase from 2006, when the value was only 13.5 million VND. It is noteworthy that farmers are not only growing rice but also participate in growing other crops.

3.3 Results and Discussion

3.3.1 Technical Efficiency

The results presented in Table 3.3 show the OLS model estimates and the stochastic frontier function model for estimating TE. The coefficient of determination (R2) is equal to 0.96, indicating that around 96% of the dependent variable is explained by the independent variables included in the OLS model. All parameter estimates in both models are significant with the exception of the family labor for rice variable, which is not significant in the maximum likelihood estimation model.

Table 3.3 Estimated results of stochastic frontier production function

Variables	OLS Coefficient	Std. Err.	P>|t|	Stochastic Frontier Coefficient	Std. Err.	P>|z|
Seed expenditures	0.0159	0.0069	0.020	0.0146	0.0059	0.014
Pesticide costs	0.0474	0.0046	0.000	0.0473	0.0040	0.000
Fertilizer costs	0.1763	0.0073	0.000	0.1141	0.0073	0.000
Hired labor	0.0028	0.0011	0.010	0.0029	0.0010	0.002
Small tools and energy	0.0068	0.0026	0.009	0.0056	0.0023	0.012
Machinery services	0.0138	0.0014	0.000	0.0101	0.0012	0.000
Other rice expenditures	0.0073	0.0014	0.000	0.0030	0.0012	0.012
Family labor for rice	0.0057	0.0027	0.036	0.0022	0.0024	0.355
Rice land area	0.7503	0.0092	0.000	0.8257	0.0088	0.000
Constant	-0.5178	0.0358	0.000	-0.4593	0.0310	0.000
Adj R-squared	0.9608					
F-statistic model	9,369.49					
F-statistic CRTS	42.15					
sigma_v				0.1397		
sigma_u				0.1428		
Lambda				1.022	0.006	
Log Likelihood				749.06		

Note: LR test of sigma_u=0: chibar2(01) = 4.2e+02; Prob >= chibar2 = 0.000

Land area is the most important factor affecting rice production. Expanding the land area by 1% would increase output by 0.83%. Other factors, such as fertilizer, machinery, and pesticides, also have significant effects on rice farming. Increasing fertilizer, pesticide, and machinery costs by 1% can be expected to increase rice yields by 0.11%, 0.05%, and 0.01%, respectively. Additionally, the results obtained by H. Le Ngoc (2018) indicate that the expenditures on seed, land, and fertilizer are primary determinants of the TE of rice production. By contrast, hired labor and other costs (postage, advertisement, marketing, production insurance, plant protection fees, field improvement fees, extension fees, administrative management fees, and feed for working cattle) have the lowest effect on TE, with coefficient values equivalent to 0.003 (Le Ngoc, 2018). The results of this study demonstrate that rice land area and fertilizer have the same values as those obtained by Khai and Yabe (2011). However, the family labor for rice and hired labor variables in the two studies have significantly different values. As might be readily apparent, the respective coefficients of family labor costs and hired labor for rice in 2016 (0.0022 and 0.0029, respectively) were much smaller than those in 2006 (0.0229 and 0.0053, respectively). Furthermore, we found the same result as Hoa-Thi-Minh Nguyen et.al (2021) in that the strong economic growth and rapid expansion of non-agricultural sectors have moved a substantial amount of rural labor out of agriculture (H.-T.-M. Nguyen et al., 2021). Perhaps Vietnamese rice farmers have replaced human physical labor in agricultural production with machine power. Moreover, a great transformation might have occurred over 10 years (2006–2016) as machinery services were steadily replaced by newer technologies. Although the coefficient of human labor use was smaller in 2016 than in 2006, the coefficient of machinery services in 2016 was also slightly smaller than that in 2006. The results of the Likelihood-ratio test for the exponential model (chibar2(01)) = 4.2e+02, which is different from zero and significant at the 1% level. This result confirms that the null hypothesis of no technical inefficiency in the model can be rejected at the 1% significance level, which means that rice farm households have organized their rice production with a certain level of inefficiency. The restricted residual sum of squares was also estimated. The computed F statistic of 42.15 was larger than the critical F value at the 1 percent significance level. Consequently, the null hypothesis of constant returns to scale is rejected, suggesting that technology does not display constant returns to scale.

The result of the frequency distribution of technical efficiency of rice farmers is presented in Table 3.4 based on the estimate of the frontier function. The overall of mean score of technical efficiency was 87.6% with ranging from 21.6% to 99.2%. It indicates that the average farmer could save 0.8% of costs and the most technical inefficient could realize a 78.4% cost saving compare with TE level of their most efficient counterpart. Furthermore, the majority of rice farm households are operating at a high efficiency level of 90-100% (1850 households) which account for 53.72% of the total. There are less or equal than 1.57% of the households keep under 50% in technical efficiency.

Table 3.4 Frequency distribution of technical efficiency for rice farming

TE level (%)	Number of households	Percent
>90 ≤ 100	1850	53.72
>80 ≤ 90	1207	35.05
>70 ≤ 80	217	6.30
>60 ≤ 70	76	2.20
>50 ≤ 60	40	1.16
≤ 50	54	1.57
Mean TE (%)	-	87.6
Minimum TE (%)	-	21.6
Maximum TE (%)	-	99.2

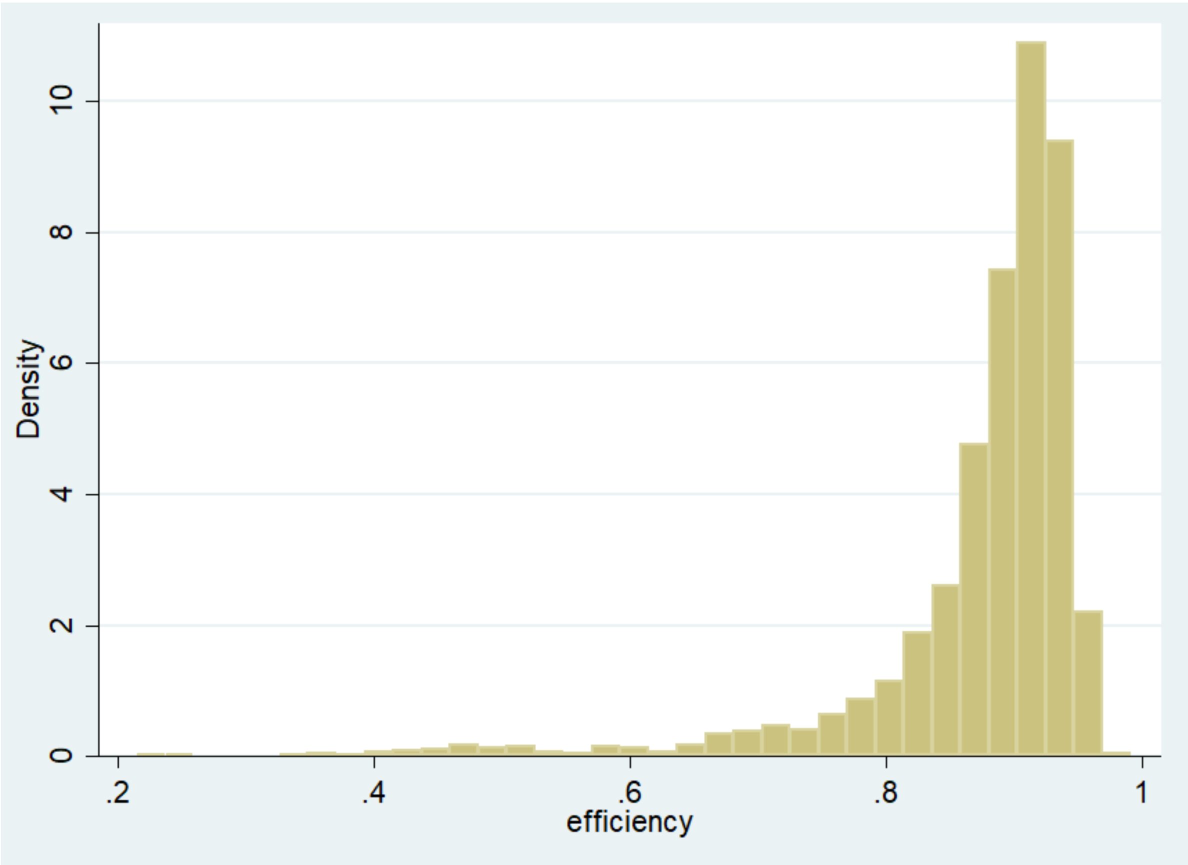

Figure 3.1 Distribution of SFA estimates of Technical Efficiency

3.3.2 Factors affecting technical efficiency

A Tobit model is applied to estimate TE using the crucially important socioeconomic independent variables presented in Table 3.5. The aim is to elucidate the factors that affect rice production technical inefficiency in Vietnam.

The estimation results for all farmers indicate all variables in the model are significant except loan, gender, age, marriage status, and internet use. The most important factor affecting farmers' incomes is the labor–land ratio, which has the highest positive coefficient value of 0.0197. The results suggest that the labor–land ratio factor plays an important role in the TE of households, as follows: the more intensively labor input can be applied to rice land, the higher the TE of households. Irrigation has a positive coefficient of 0.0178 in this model, with significance at the 1% level. The results also suggest that irrigation is the second most important factor that affects rice production TE. In this study, farmers who participated in an irrigation system achieved markedly higher rice productivity.

Table 3.5 Technical efficiency: a comparison between models with/without irrigation

Variables	All samples (3,444)		With irrigation (1,260)		Without irrigation (2,184)	
Organic fertilizer use	-0.0055	**	-0.0082	**	-0.0054	
Irrigation use	0.0178	***				
Loan	0.0143		0.0300	**	0.0110	
Ethnicity	0.0159	***	0.0034		0.0133	***
Education	0.0020	***	0.0005		0.0124	***
Gender	0.0035		0.0080		0.0017	
Age of household head	0.0009		-0.0024		0.0024	
Member	-0.0031	***	-0.0003		-0.0045	***
Marriage status	0.0034		-0.0030		0.0065	
Using internet	0.0014		-0.0092	**	0.0080	
Non-agriculture income	0.0098	**	-0.0033		0.0174	***
Total agriculture income	0.0093	***	0.0047		0.0123	***
Rate income from rice	0.0108	**	0.0047		0.0129	
Labor land ratio	0.0197	***	0.0108	***	0.0227	***
Constant	0.8289	***	0.8879	***	0.8200	***
Sigma	0.0871		0.5549		0.0555	

Note: ** significant at 5%; *** significant at 1%

3.3.3 Impact of irrigation facility evaluation

Based on the discussion of rice production efficiencies for all samples, the estimated production efficiencies among farmers who use irrigation and those who do not are also shown in Table 3.5. These results suggest that the factors that affect TE are approximately the same for the groups "All sample (3,444)" and "Without irrigation (2,184)." The size of the coefficients was also approximately equal in both groups. On the other hand, organic fertilizer use negatively affects both the "All sample (3,444)" and "With irrigation (1,260)" groups.

However, the rates of farmers who used organic fertilizer in the groups "With irrigation (1,260)" and "Without irrigation (2,184)" can be found in Table 3.8. They were, respectively, about 25.8% (325/1,260) and 42.9% (938/2,184). This result indicates that farmers who use organic fertilizer in the group "With irrigation (1,260)" might strongly influence the evaluation of TE related to the irrigation facility.

Table 3.8 Impact of using irrigation facility and organic fertilizer: PSM model

		Using Organic fertilizer	
		○ Yes	× No
Using irrigation facility	○ Yes	Farmers A: 325	Farmers C: 935
	× No	Farmers B: 938	Farmers D: 1,246

Source: Vietnamese Households Living Standards Survey 2016 (VHLSS 2016), n=3,444

3.3.4 Propensity Score Matching among farmers without using organic fertilizer

In the next step, we apply propensity score matching (PSM) to quantify the impact of an irrigation system on rice production by matching individual farmers who were or were not using the irrigation system. This applied only to farmers who did not use organic fertilizer, between farmers C and farmers D in Table 3.8, in order to evaluate the impact of using irrigation system properly.

In a randomized experiment context, the mean impact of a treatment on the treated group can be easily determined by measuring the difference between the mean values of the outcome variable for both the treatment and control groups (Van Ho et al., 2019). However, those methods cannot be applied in our case because the rice farmers included in the sample were not randomly selected. Thus, an appropriate method to evaluate the impact requires identifying a comparison group and a treatment group based on similar characteristics. According to Caliendo and Kopeinig (2008), PSM is six-step mathematical procedure, as described in the following (Caliendo & Kopeinig, 2008).

The main pillars of the study are the binary treatment T, which equals 1 if the irrigation facility is used and zero otherwise, and the potential outcome Y, which is defined as Y_i for the individual factors X_i. The average treatment effect for an individual farmer C_i or farmer D_i can be written as:

$$E[Y_i|T=1,X_i] - E[Y_i|T=0,X_i] = E[Y_{Ci}|T=1,X_i] - E[Y_{Di}|T=0,X_i]$$
$$= E[Y_{Ci}-Y_{Di}|T=1,X_i] + E[Y_{Di}|T=1,X_i] - E[Y_{Di}|T=0,X_i]$$
$$= E[Y_{Ci}|T=1,P(X_i)] - E[Y_{Di}|T=0,P(X_i)]$$
$$= ATT \qquad (3.8)$$

The difference between $E[Y_{Di}|T=1,X_i]$ and $E[Y_{Di}|T=0,X_i]$ in the second line of Equation (3.8) is called "selection bias" because the outcomes of the individuals from the treatment and the comparison group would differ even in the absence of the treatment (Caliendo & Kopeinig, 2008). However, the true parameter ATT (the average treatment on the treated) is identified as $E[Y_{Ci}|T=1,P(X_i)] - E[Y_{Di}|T=0,P(X_i)]$ in the third line of Equation (3.8).

To achieve a meaningful comparison between the treated and control groups, the two groups must be balanced. In this research, the balance was checked by comparing the standardized mean differences of each covariate. Most of them had been improved by the nearest-neighbor matching technique (NNM), especially as the caliper was reduced from 0.25 to 0.10. According to Rosenbaum and Rubin (1985), the mean standardized bias (the mean value of the standardized mean differences of all covariates) can be used as the corresponding values for the matched samples (Rosenbaum & Rubin, 1985). Caliendo and Kopeinig (2008) suggest that a mean standardized bias below 3% or 5% after matching may be seen as sufficient. In our results, the results of the matching satisfy this condition only when the NNM caliper = 0.10 (Table 3.9).

Table 3.9 Test of balancing for covariates with standardized differences

	Before Matching			NNM Caliper=0.25			NNM Caliper=0.10		
	Means Treated	Means Control	Std. Mean Diff.	Means Treated	Means Control	Std. Mean Diff.	Means Treated	Means Control	Std. Mean Diff.
Male labor between 15 and 55 years old	1.1604	1.3523	-0.244	1.1465	1.2777	-0.1668	1.2067	1.258	-0.0652
Ethnicity	0.9807	0.6525	2.3877	0.9771	0.9771	0.0000	0.975	0.975	0.0000
Education	1.5091	1.1011	0.5681	1.451	1.2662	0.2572	1.4078	1.319	0.1236
Gender	0.8118	0.8339	-0.0565	0.8025	0.8191	-0.0423	0.8197	0.8294	-0.0248
Age of household head	2.7626	2.4494	0.2623	2.8191	2.6892	0.1088	2.7365	2.724	0.0105
Non-agriculture income	0.3005	0.2343	0.1443	0.3032	0.293	0.0222	0.3218	0.2968	0.0544
Total agriculture income	1.369	1.4077	-0.0592	1.3936	1.4752	-0.1246	1.4438	1.4369	0.0106
Rate income from rice	0.6328	0.5701	0.1744	0.6229	0.6206	0.0064	0.6042	0.624	-0.055
All				935	1246		935	1246	
Matched				785	785		721	721	
Unmatched				141	429		205	493	
Discarded				9	32		9	32	

Source: Vietnamese Households Living Standards Survey 2016 (VHLSS 2016), n=3,444

The differences in the mean values of the outcome variables for the treated and control groups were calculated for rice production area, rice production quantity, and rice production efficiency (Table 3.10). All estimates of the ATT are significant, and the impact of using the irrigation facility is negative for rice production area and rice production quantity but positive for rice production efficiency. On the other hand, Inverse Probability Weighed Regression (IPWRA) is applied for covariate adjustment based on the biases from non-observable variables. The simulated values of ATE and Potential-Outcome mean (PO mean) for each outcome are depicted on Table 3.11.

Table 3.10 Impact Evaluation for use of irrigation facility; before and after matching

	Before Matching			NNM Caliper=0.25			NNM Caliper=0.10		
	Farmers using irrigation	Farmers not using irrigation	Difference (p-value)	Treated	Control	ATT (p-value)	Treated	Control	ATT (p-value)
Rice production area (sqm)	7,432.3	11,004.9	-3,572.7 (0.0000)	7,835.4	13,532.1	-5,696.7 (0.0000)	8,387.8	12,742.7	-4,354.8 (0.0000)
Rice production quantity (kg)	4,601.8	6,157.4	-1,555.6 (0.0057)	4,880.4	7,674.7	-2,794.2 (0.0001)	5,279.7	7,157.5	-1,877.8 (0.0090)
Rice productivity of land (kg/sqm)	0.5583	0.5169	0.0413 (0.0000)	0.5563	0.5343	0.0221 (0.0000)	0.5614	0.5313	0.0301 (0.0000)

Source: Vietnamese Households Living Standards Survey 2016 (VHLSS 2016), n=3,444 and 2,181

Table 3.11 Impact Evaluation for use of irrigation facility; by extensive simulation augmented IPWRA methods

	Estimate	Standard error	Z	P>|z|	95%.Confidence interval	
Rice production area (sqm)						
ATE	-4,178.6	1,157.5	-3.61	0.000	-6,447.3	-1,910.0
PO mean	11,239.0	477.8	23.52	0.000	10,302.6	12,175.4
Rice production quantity (kg)						
ATE	-1,881.9	689.0	-2.73	0.006	-3,232.3	-531.5
PO mean	6,300.0	296.8	21.22	0.000	5,718.2	6,881.8
Rice productivity of land (kg/sqm)						
ATE	0.0303	0.0076	3.97	0.000	0.0154	0.0453
PO mean	0.5229	0.0041	128.18	0.000	0.5149	0.5309

Source: Vietnamese Households Living Standards Survey 2016 (VHLSS 2016), n=2,181

In addition to these quantitative evaluations of these impact, to certify these results in detail, further investigation into farmers' rice producing behaviors in Vietnam, such as case studies, is needed for farmers who do and do not use the irrigation facility. For example, the DEA model, fractional regression model, and some other kinds of approaches should be applied to evaluate production efficiencies with consideration to a variety of perspectives in our target area. For examples, such an approach as meta-frontiers to assess ones to be applied (Villano et al., 2015).

On the other hand, as in the case in Malaysia, discussed by Kangayatkarasu Nagulendran (2016), conservation priorities must be discussed in case we pursue economic development based upon the enlargement of agricultural production efficiencies in developing economies (Nagulendran et al., 2016). Organic fertilizer choices especially can be one of the most crucial points for environmental conservation in these countries. These are also serious problems left for our future work.

3.4 Conclusion

This study explored the basic characteristics of Vietnamese rice producers and used SFA to find their rice production TE. The results demonstrate that Vietnamese rice farmers can be identified as small producers with limited land area whose cultivation might depend primarily on their experience. Furthermore, the household income revealed in this study has increased remarkably compared to results reported in earlier studies. The average total value of farm earnings is about 78 million VND per year. However, farmers are currently devoting a great deal of attention to non-agricultural activities to gain higher incomes.

Stochastic frontier production estimation and the factors associated with TE for rice farmers in Vietnam indicate that all variables employed in the model strongly affect the results. The average value of TE in rice production in this study was estimated as 87.6%. The estimation results suggest that farmers can earn greater benefits when they grow mixed crops rather than using rice monoculture. The study also examined the important role of labor in TE. According to the results, labor has strongly affected TE. Farmers can optimize their TE by intensive investment in labor.

In their role of constructing a system, governments should encourage rice producers to seek higher efficiency in terms of optimizing mixed-crop cultivation. Organic fertilizers now demand much attention worldwide because of their environmentally friendly characteristics. However, this study revealed that the use of organic fertilizers for rice production in Vietnam does not benefit households' TE. In the scope of this research, one could infer those self-provided organic fertilizers are of lower quality, but this supposition requires additional study.

Furthermore, this study has observed several issues related to rice production efficiency that are related to technical efficiency. We believe that it is especially important to acknowledge the fact that organic fertilizer has several important effects on harvesting rice, especially when farmers are using irrigation facilities. Due to the scope of this study, we are now conducting another study in order to draw more conclusion in relation to this study. Hence, in our next publication, we will suggest more implication policies related to this study.

Appendix in Chapter 3

The estimation of the stochastic frontier analysis with Translog form was also conducted in order to compare the results with the analysis with Cobb-Douglas function form.

$$\ln Y_i = \beta_0 + \sum_{k=1}^{n} \beta_k \ln X_{ki} + \frac{1}{2} \sum_{k=1}^{n} \sum_{l=1}^{n} \beta_{kli} \ln X_{ki} \ln X_{li} + u_i \qquad (3.7)$$

The results can be seen in Table 3.6 that the Translog form can be fitted with the stochastic frontier function when there are significant variables that affect the TE coefficient. On the other hand, from the Table 3.7 revealed that while almost all of the variables in the Translog function are not significant, the number of observations applied to the Translog function (2884) is smaller than the number of observations applied to the Cobb-Douglas function (3444). There is evidence to suggest that the Cobb-Douglas function is more efficient at observing the data than the Translog function. Upon completion of the first step, the next step would be to estimate the impacts of irrigation facilities on rice farmers.

Table 3.6 Estimated results of stochastic frontier production function with Translog form

Stochastic Frontier with Translog form						
Variables		Coefficient	Std. Err.	z value	Pr(>|z|)	
Constant	a_0	0.3757	0.1934	1.9432	0.0520	.
Seed expenditures	a_1	0.1129	0.0508	2.2248	0.0261	*
Pesticide costs	a_2	0.0983	0.0386	2.5465	0.0109	*
Fertilizer costs	a_3	0.2779	0.0637	4.3633	0.0000	***
Machinery services	a_4	0.1004	0.0480	2.0929	0.0364	*
Hired labor	a_5	0.0143	0.0086	1.6683	0.0953	.
Small tools and energy	a_6	-0.0016	0.0200	-0.0790	0.9370	
Other rice expenditures	a_7	-0.0111	0.0103	-1.0843	0.2782	
Family labor for rice	a_8	0.0462	0.0184	2.5037	0.0123	*
Rice land area	a_9	0.2220	0.0836	2.6566	0.0079	**
*1/2 * Seed expenditures ^2*	b_1_1	-0.0068	0.0141	-0.4842	0.6282	
*Seed expenditures * Pesticide costs*	b_1_2	-0.0081	0.0070	-1.1697	0.2421	
*Seed expenditures * Fertilizer costs*	b_1_3	0.0534	0.0133	4.0136	0.0001	***
*Seed expenditures * Machinery services*	b_1_4	0.0240	0.0086	2.7849	0.0054	**
*Seed expenditures * Hired labor*	b_1_5	0.0054	0.0018	2.9696	0.0030	**
*Seed expenditures * Small tools and energy*	b_1_6	0.0044	0.0039	1.1330	0.2572	
*Seed expenditures * Other rice expenditures*	b_1_7	0.0021	0.0023	0.9503	0.3420	
*Seed expenditures * Family labor for rice*	b_1_8	0.0020	0.0041	0.4973	0.6190	
*Seed expenditures * Rice land area*	b_1_9	-0.0781	0.0145	-5.3814	0.0000	***
*1/2 * Pesticide costs ^2*	b_2_2	0.0216	0.0076	2.8310	0.0046	**
*Pesticide costs * Fertilizer costs*	b_2_3	0.0415	0.0089	4.6423	0.0000	***
*Pesticide costs * Machinery services*	b_2_4	-0.0078	0.0065	-1.1884	0.2347	
*Pesticide costs * Hired labor*	b_2_5	-0.0024	0.0012	-1.9332	0.0532	.
*Pesticide costs * Small tools and energy*	b_2_6	-0.0017	0.0026	-0.6747	0.4998	
*Pesticide costs * Other rice expenditures*	b_2_7	0.0022	0.0016	1.3231	0.1858	
*Pesticide costs * Family labor for rice*	b_2_8	0.0036	0.0034	1.0401	0.2983	

*Pesticide costs * Rice land area*	b_2_9	-0.0486	0.0104	-4.6931	0.0000	***
*1/2 * Fertilizer costs ^2*	b_3_3	-0.0558	0.0136	-4.1003	0.0000	***
*Fertilizer costs * Machinery services*	b_3_4	-0.0789	0.0106	-7.4747	0.0000	***
*Fertilizer costs * Hired labor*	b_3_5	0.0016	0.0022	0.7529	0.4515	
*Fertilizer costs * Small tools and energy*	b_3_6	-0.0080	0.0048	-1.6585	0.0972	.
*Fertilizer costs * Other rice expenditures*	b_3_7	-0.0153	0.0036	-4.2378	0.0000	***
*Fertilizer costs * Family labor for rice*	b_3_8	-0.0156	0.0048	-3.2279	0.0012	**
*Fertilizer costs * Rice land area*	b_3_9	0.0485	0.0141	3.4312	0.0006	***
*1/2 * Machinery services ^2*	b_4_4	0.0217	0.0097	2.2384	0.0252	*
*Machinery services * Hired labor*	b_4_5	0.0059	0.0015	3.9823	0.0001	***
*Machinery services * Small tools and energy*	b_4_6	-0.0070	0.0038	-1.8634	0.0624	.
*Machinery services * Other rice expenditures*	b_4_7	-0.0038	0.0018	-2.1146	0.0345	*
*Machinery services * Family labor for rice*	b_4_8	0.0028	0.0036	0.7624	0.4458	
*Machinery services * Rice land area*	b_4_9	0.0359	0.0126	2.8462	0.0044	**
*1/2 * Hired labor ^2*	b_5_5	-0.0012	0.0018	-0.6460	0.5183	
*Hired labor * Small tools and energy*	b_5_6	-0.0021	0.0006	-3.4527	0.0006	***
*Hired labor * Other rice expenditures*	b_5_7	0.0005	0.0003	1.4201	0.1556	
*Hired labor * Family labor for rice*	b_5_8	0.0014	0.0006	2.1406	0.0323	*
*Hired labor * Rice land area*	b_5_9	-0.0100	0.0025	-4.0033	0.0001	***
*1/2 * Small tools and energy ^2*	b_6_6	0.0023	0.0020	1.1857	0.2357	
*Small tools and energy * Other rice expenditures*	b_6_7	-0.0017	0.0007	-2.4085	0.0160	*
*Small tools and energy * Family labor for rice*	b_6_8	-0.0009	0.0019	-0.4736	0.6358	
*Small tools and energy * Rice land area*	b_6_9	0.0138	0.0071	1.9522	0.0509	.
*1/2 * Other rice expenditures ^2*	b_7_7	-0.0031	0.0015	-2.1023	0.0355	*
*Other rice expenditures * Family labor for rice*	b_7_8	0.0014	0.0008	1.7600	0.0784	.

*Other rice expenditures * Rice land area*	b_7_9	0.0169	0.0033	5.0818	0.0000	***
*1/2 * Family labor for rice ^2*	b_8_8	0.0002	0.0020	0.1091	0.9131	
*Family labor for rice * Rice land area*	b_8_9	0.0022	0.0062	0.3602	0.7187	
*1/2 * Rice land area ^2*	b_9_9	0.0774	0.0216	3.5868	0.0003	***
	Determinant of inefficiency					
Variables		Coefficient	Std. Err.	z value	Pr(>|z|)	
Constant	Z_(Const.)	-0.0092	0.9805	-0.0094	0.9925	
Organic fertilizer use	Z_DORGF	-0.2755	0.8522	-0.3232	0.7465	
Irrigation use	Z_DIRRI	-0.2690	0.9289	-0.2895	0.7722	
Loan	Z_DLOAN	-0.0271	1.0000	-0.0271	0.9784	
Ethnicity	Z_DM.D2	-0.3158	1.0074	-0.3134	0.7540	
Education	Z_D5	0.1480	0.6658	0.2223	0.8241	
Gender	Z_D6Gend	-0.5661	1.0241	-0.5527	0.5804	
Age of household head	Z_D7	0.0217	0.0660	0.3282	0.7427	
Member	Z_Member	0.1962	0.6665	0.2944	0.7685	
Marriage status	Z_D8	-0.5499	1.0299	-0.5339	0.5934	
Using internet	Z_D9	-0.1021	0.7783	-0.1312	0.8956	
Non-agriculture income	Z_I6	-0.0043	0.0000	-569.72	0.0000	***
Total agriculture income	Z_TI	-0.0072	0.0000	-786.91	0.0000	***
Rate income from rice	Z_RateR	0.4314	1.0429	0.4137	0.6791	
Labor land ratio	Z_LLandR	0.5504	1.0546	0.5219	0.6017	
σ^2	sigmaSq	0.0631	0.0001	526.74	0.0000	***
γ	gamma	0.7331	0.0000	82,101.40	0.0000	***

Note: * Significant at 10%; ** significant at 5%; *** significant at 1%
LR test of sigma_u=0: chibar2(01) = 4.2e+02; Prob >= chibar2 = 0.000

Table 3.7 Technical efficiency: a comparison between models with/without irrigation

Variables	SF-CD (3,444)	SF-Translog (2,884)
Organic fertilizer use	-0.0055 **	-0.2755
Irrigation use	0.0178 ***	-0.2690
Loan	0.0143	-0.0271
Ethnicity	0.0159 ***	-0.3158
Education	0.0020 ***	0.1480
Gender	0.0035	-0.5661
Age of household head	0.0009	0.0217
Member	-0.0031 ***	0.1962
Marriage status	0.0034	-0.5499
Using internet	0.0014	-0.1021
Non-agriculture income	0.0098 **	-0.0043 ***
Total agriculture income	0.0093 ***	-0.0072 ***
Rate income from rice	0.0108 **	0.4314
Labor land ratio	0.0197 ***	0.5504
Constant	0.8289 ***	-0.0092

Note: * Significant at 10%; ** significant at 5%; *** significant at 1%

CHAPTER 4

THE DETERMINANTS OF ORGANIC FERTILIZER USE IN VIETNAM

4.1 Background

To attain our objective, this study relied on data from the Vietnam Household Living Standard Survey (VHLSS) that was provided by the General statistics office of Vietnam (GSO). This data conducted regularly by the GSO every two years from 2002 to 2010. From 2011 to 2020, VHLSS is conducted annually, however, the odd-number year surveys only collect data on demographics, employment, and income (Result of the VHLSS, 2018).

The purpose of VHLSS is to monitor systematically living standards of Vietnam population’s group; monitor and assess the implementation of the Comprehensive Poverty Reduction and Growth Strategy; making contribution to evaluating results of realization of the Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs).

VHLSS reflects the living standard of households in the entire country, and main socio-economic conditions in the rural areas which affect living standard of population in their particular area.

VHLSS covers the whole country, there are three-stage stratified cluster design in sample design. Sample of the VHLSS is selected in the way to represent the entire country (in which: urban/rural areas), 8 regions (in which: urban/rural areas), and provinces/cities. The sample design could make use of panel data. For example, the questionnaire of 2016 included questions about the identification code of the VHLSS 2014, which were recorded by the enumeration leader.

In addition to selecting areas, The Socio-Environmental Statistics Department is responsible for selecting areas and sending the list of selected areas to Provincial Statistics offices for reviewing and updating attached with the map and list of areas of the Population Housing Census of the new areas.

The Provincial Statistics Offices select households for areas and for new areas, specifically:

For areas which are re-select all 15 households in which 12 households were surveyed with income and 3 households were surveyed with income-expenditure. In the case of households which were surveyed in the previous year moved to another area, find alternate households to be assured of 12 households for income and 3 households for income-expenditure in each enumeration areas (EAs).

For new areas, select 20 households from the updated household list. From these 20 households, select 15 households (12 official households, 3 spare households) for income survey, and the 5 remaining households (3 official 2 spare households) for income-expenditure survey.

In addition, it is an advantage of survey design of VHLSS to make use of panel data. The term panel data refers to observations obtained over multiple time periods for the same households or individuals

$$\{X_{ijt}\}\ i\text{: }household\ or\ individual, j\text{: }variable, t\text{: }year$$

In Statistical surveys, panel data is essentially a set of pairs of household identifiers and pairs of individual identifiers. Each identifier is uniquely linked with household or individual data.

Due to the scope of the study, a second research project will be based on Panel data for two periods (from 2014-2016). The panel data have also been withdrawn from the VHLSS data in year 2014 and 2016 in Vietnam. In order to make this study relevant to the unique characteristics of Vietnamese farmers, we have to use panel data that is the most recent version are available published. In the VHLSS, sample observations are updated as a rotation for panel data. Accordingly, the sample from 2016 will be recorded as around 50% of the sample in 2014 and 25% of the sample from 2012. Likewise, the scholar also wishes to extend the number of series years in the panel to over two years, but the difficulty is that the number of planting rice households combined over two periods is not enough to form an estimate.

4. 2 Methodology

4.2.1 Farmers' decision making of organic fertilizer use

Data for this empirical study were from the panel date of VHLSS between 2014 and 2016, which obtained 1,633 rice producing households in total.

In the first stage, four categories purposively selected from the situations of each household behaviors related to organic fertilizer use in each year. For instance, the category which name is OF_Dm0 means that the farmers who did not use organic fertilizer neither 2014 nor 2016. The category which name is OF_Dm1 means that the farmers who did not use organic fertilizer in 2014 but start to use it in 2016. On the other hand, the category which name is OF_Dm2 means that the farmers who did use organic fertilizer in 2014 but quit to use it in 2016. Finally, the category which name is OF_Dm3 means that the farmers who did use organic fertilizer both 2014 and 2016.

The concrete idea of the empirical framework for analyzing the determinants of farmers' application of organic fertilizer on the panel data between 2014 and 2016 is depicted in Figure 4.1. For instance, the determinants of farmers' starting their application of organic fertilizer can be analyzed in comparison between OF_Dm0 and OF_Dm1. On the other hand, the determinants of farmers' quitting their application of organic fertilizer can be analyzed in comparison between OF_Dm2 and OF_Dm3.

2014	2016	N	Variable	
×	×	835	OF_Dm0	Logit model 01
×	0	133	OF_Dm1	
0	×	183	OF_Dm2	Logit model 02
0	0	482	OF_Dm3	

×: Farmer practices OF every year, 0: Farmer do not practice OF every year

Figure 4.1 The empirical framework for analyzing the determinants of farmers' application of Organic Fertilizer on the panel data between 2014 and 2016

The farmers' decision of whether to start (quit) to make application of organic fertilizer could be considered under the general framework of utility maximization framework. For instance, the utility of farmers cannot be observable, but the behavior of farmers could be observed through behaviors farmers are making. Supposing that U_j and U_k represent farmer's utility for two different behaviors; β_j and β_k respectively, the linear random utility model could then be specified as follows:

$$U_j = \boldsymbol{\beta}_j \boldsymbol{X}_i + \varepsilon_j \quad (4.1a)$$

$$U_k = \boldsymbol{\beta}_k \boldsymbol{X}_i + \varepsilon_k \quad (4.1b)$$

In this analysis, U_j and U_k are regarded as perceived utilities of starting (quitting) to use organic fertilizer or not. $\boldsymbol{X}_i$ is the vector of explanatory variables which influenced the perceived utilities of each behavior. Also β_j and β_k are the coefficients of estimated results and ε_j and ε_k are error terms assumed to be independently and identically distributed (Greene, 2000).

To describe the logit model1 and model2 implicitly, consider a rational farmer who wants to maximize the utility of the expected income of rice production over a specified period with using or not using organic fertilizer. The farmer $\boldsymbol{i}$ decide to start (quit) to use organic fertilizer, if the utility from starting (quitting) to use one must be greater than that of another option depicted as:

$$U_j > U_k \quad (4.2)$$

Finally, the probability that farmer $\boldsymbol{i}$ decide to start (quit) to use organic fertilizer can be defined as

$$Probability(U_j > U_k) = \mathrm{F}(\boldsymbol{\beta_j X_i}) = \sum_{j=1}^{n} \beta_j X_i + \varepsilon \qquad (4.3)$$

4.2.2 Data description

Basic statistics of quantitative variables in the category of OF_Dm0, OF_Dm1, OF_Dm2 and OF_Dm3 are depicted in Table 4.1, Table 4.2, Table 4.3 and Table 4.4, respectively.

From these variables, dependent variables are evaluated the differences in farmers' behavior in using organic fertilizer between 2016 and 2014. Therefore, these dependent variables are defined by the comparison of the information between 2016 and 2014. On the other hand, independent variables must be evaluated from the behaviors in 2014 just the situations before farmers' decision making. That is because we have to avoid the crucial effects based upon endogenous sample selection. The panel data of VHLSS was built up and samples selected from this data. The categorization between OF_Dm0, OF_Dm1, OF_Dm2 and OF_Dm3 was made on this panel.

According to the results of each category of starting (quitting) to use organic fertilizer, Table 4.2, Table 4.3, and Table 4.4 show a significant drop in output rice quantity from 6,257 kg in Table 4.1 to 2,261 kg, 2,589 kg, and 2,158 kg, respectively.

It may be one of the evident that farming intensively with organic fertilizer has not shown to be more productive than farming purely with chemical fertilizer.

The average land area used for rice production in Table 4.1 is 10,766 (m^2), compared to 4,626 (m^2), 5,201 (m^2), and 4,688 (m^2) in Table 4.2, Table 4.3, and Table 4.4 respectively. In Table 4.1, the total value of farming income is about 48 million VND, a significant increase from 28 million VND, 31 million VND, and 28 million VND in Table 4.2, Table 4.3, and Table 4.4 respectively. It can be seen that a farmer who has a large area also has a large income and vice versa.

It is the cost of hired labor that is the most expensive for farmers who do not wish to use organic fertilizer compared to farmers who wish to use organic fertilizer. Divide each category's fertilizer expenditure by rice land area to determine the proportion of fertilizer expenditure (including chemical and organic fertilizer). As a result, farmers who do not use organic fertilizer have a higher rate of fertilizer expenditure ratio than those who do. Additionally, the number of farmers who start using organic fertilizer is larger than the farmers who start quitting using OF (both logit models show this). In contrast to farmers who use organic fertilizer, those who use chemical fertilizer are not able to save input expenditures.

Furthermore, there is a smaller amount of family labor among farmers who do not use organic fertilizer in Table 4.1 than among farmers who do use organic fertilizer in Table 4.4. Therefore, the production technology with applying organic fertilizer requires more labor to achieve sustainable development in agriculture.

Table 4.1 Statistics of quantitative variables in the category of OF_Dm0

OF_Dm0 Variables	2014 Mean	 Std. dev.	2016 Mean	 Std. dev.
Output				
Rice quantity (kg/year)	6,257.0	11,752.8	6,170.8	13,610.8
Inputs				
Seed expenditures (1,000VND/year)	1,603.8	3,361.2	1,683.9	3,985.6
Pesticide costs (1,000VND/year)	2,281.3	6,610.8	2,394.3	6,957.1
Fertilizer expenditures (1,000VND/year)				
Chemical fertilizer	6,223.3	14,004.6	5,675.7	12,959.3
Organic fertilizer	0.0	0.0	0.0	0.0
Hired labor (1,000VND/year)	1,517.6	4,375.0	1,383.3	5,195.6
Machinery service (1,000VND/year)	39.4	165.5	47.5	189.3
Small tools and energy (1,000VND/year)	242.5	472.9	236.1	408.1
Other rice expenditure (1,000VND/year)	274.7	872.5	284.2	923.9
Total farming labor (hrs)	2,314.4	1,809.2	1,874.0	1,631.9
Family labor for rice (hrs)	1,571.0	1,272.8	1,212.6	1,088.6
Rice land area (m2)	10,766.6	17,875.1	10,513.6	19,274.8
Farm-specific variables				
Percent of rice (%)	76.5	27.5	75.1	29.0
Age of household (yrs)	49.1	12.6		
Education of farmers (yrs)	7.0	3.5		
Total farming income (1,000VND/year)	48,574.6	81,429.2	52,198.4	100,487.6
Differences between 2014 and 2016				
Rice quantity (kg/year)	-86.2	9,901.0		
Rice land area (ha)	-253.0	14,082.4		
Total farming income (1,000VND/year)	3,623.8	53,094.2		

Source: VHLSS 2014 and 2016, n=835

Table 4.2 Statistics of quantitative variables in the category of OF_Dm1

OF_Dm1 Variables	2014 Mean	 Std. dev.	2016 Mean	 Std. dev.
Output				
Rice quantity (kg/year)	2,261.6	2,313.6	2,245.6	2,231.9
Inputs				
Seed expenditures (1,000VND/year)	585.3	599.7	584.9	562.8
Pesticide costs (1,000VND/year)	481.5	888.8	453.1	839.4
Fertilizer expenditures (1,000VND/year)				
Chemical fertilizer	2,253.2	2,797.4	1,935.6	2,278.8
Organic fertilizer	0.0	0.0	323.4	351.6
Hired labor (1,000VND/year)	582.6	1,469.7	620.4	2,246.0
Machinery service (1,000VND/year)	8.7	36.7	21.4	115.1
Small tools and energy (1,000VND/year)	140.3	201.4	149.5	137.2
Other rice expenditure (1,000VND/year)	147.3	328.0	164.2	300.8
Total farming labor (hrs)	2,671.5	1,910.2	2,127.0	1,521.7
Family labor for rice (hrs)	1,635.4	1,339.4	1,300.7	948.0
Rice land area (m2)	4,626.5	4,192.7	4,701.4	4,160.0
Farm-specific variables				
Percent of rice (%)	67.5	28.5	66.6	27.2
Age of household (yrs)	48.0	12.5		
Education of farmers (yrs)	7.4	3.3		
Total farming income (1,000VND/year)	28,019.8	32,540.7	26,621.3	27,423.8
Differences between 2014 and 2016				
Rice quantity (kg/year)	-16.0	1,496.3		
Rice land area (ha)	74.9	2,869.7		
Total farming income (1,000VND/year)	-1,398.5	26,497.5		

Source: VHLSS 2014 and 2016, n=133

Table 4.3 Statistics of quantitative variables in the category of OF_Dm2

OF_Dm3 Variables	2014 Mean	 Std. dev.	2016 Mean	 Std. dev.
Output				
Rice quantity (kg/year)	2,589.1	3,199.6	2,598.9	3,690.9
Inputs				
Seed expenditures (1,000VND/year)	760.3	1,156.3	755.9	1,188.8
Pesticide costs (1,000VND/year)	522.9	1,110.4	522.5	1,122.8
Fertilizer expenditures (1,000VND/year)				
Chemical fertilizer	2,323.2	2,683.9	2,275.6	2,621.0
Organic fertilizer	392.0	767.1	0.0	0.0
Hired labor (1,000VND/year)	603.5	1,198.6	542.6	996.7
Machinery service (1,000VND/year)	20.1	72.4	24.2	110.9
Small tools and energy (1,000VND/year)	160.5	242.4	145.6	222.1
Other rice expenditure (1,000VND/year)	204.0	611.2	158.9	346.9
Total farming labor (hrs)	2,607.8	1,857.4	2,184.4	1,737.8
Family labor for rice (hrs)	1,540.6	1,256.2	1,256.6	1,274.9
Rice land area (m2)	5,201.8	5,920.6	4,922.1	5,366.3
Farm-specific variables				
Percent of rice (%)	65.2	27.7	65.6	29.7
Age of household (yrs)	47.6	12.3		
Education of farmers (yrs)	7.8	3.5		
Total farming income (1,000VND/year)	30,978.9	35,570.0	32,004.5	44,120.8
Differences between 2014 and 2016				
Rice quantity (kg/year)	9.9	2,576.2		
Rice land area (ha)	-279.8	2,365.0		
Total farming income (1,000VND/year)	1,025.6	34,176.5		

Source: VHLSS 2014 and 2016, n=183

Table 4.4 Statistics of quantitative variables in the category of OF_Dm3

OF_Dm4 Variables	2014 Mean	 Std. dev.	2016 Mean	 Std. dev.
Output				
Rice quantity (kg/year)	2,158.3	1,817.8	2,111.4	1,917.3
Inputs				
Seed expenditures (1,000VND/year)	677.6	560.0	698.3	599.1
Pesticide costs (1,000VND/year)	289.5	453.8	289.1	484.1
Fertilizer expenditures (1,000VND/year)				
Chemical fertilizer	1,834.9	1,580.8	1,806.2	1,790.9
Organic fertilizer	434.9	525.2	450.6	646.1
Hired labor (1,000VND/year)	418.7	961.6	446.4	1,144.9
Machinery service (1,000VND/year)	27.2	73.2	32.8	96.3
Small tools and energy (1,000VND/year)	148.0	136.7	156.5	161.3
Other rice expenditure (1,000VND/year)	132.5	228.3	133.1	256.6
Total farming labor (hrs)	3,452.8	2,151.9	2,930.0	2,058.3
Family labor for rice (hrs)	2,002.6	1,456.9	1,623.0	1,283.9
Rice land area (m2)	4,688.1	3,996.0	4,458.2	3,726.0
Farm-specific variables				
Percent of rice (%)	60.6	24.3	59.6	25.0
Age of household (yrs)	47.5	12.2		
Education of farmers (yrs)	7.1	3.4		
Total farming income (1,000VND/year)	28,012.8	26,123.8	28,351.5	27,310.7
Differences between 2014 and 2016				
Rice quantity (kg/year)	-46.9	1,488.5		
Rice land area (ha)	-229.9	2,886.2		
Total farming income (1,000VND/year)	338.7	23,561.4		

Source: VHLSS 2014 and 2016, n=482

4.2.3 Estimation Results and discussion

Table 4.5 shows the estimation results of logit model 1. There are four significant variables: marriage status of household heads, rice land area (ha), percentage of rice (%) and family labor for rice (hours). It is only family labor that has a positive effect on using organic fertilizer. On the other hand, the use of organic fertilizer is negatively affected by marriage status, rice land area and percentage of rice. The estimation outcomes demonstrate that the glutinous rice variety's production variable, which is not statistically significant but 13% has a favorable impact on applying organic fertilizer.

Table 4.6 shows the estimation result of logit model 2. There are two significant variables: rice land area (ha), and percentage of rice (%). There are two variables that have negative effects are marriage status, and family labor for rice (hours). The greatest positive coefficient value of 1.1160 of the percentage of rice variable. It implies that the higher income from rice, the more intensely organic fertilizer input.

The results of the estimation in both models show that farmers who have a large area of rice cultivation do not want to use organic fertilizer, in contrast to farmers who have a smaller area of cultivation. The percentage of rice variable in both models who those farmers who started using organic fertilizer have a negative influence while after quitting using it is positive to use organic fertilizer. On the other hand, family labor for rice shows that the labor force in each farmer's household tends to use organic fertilizer. This could also mean that the production technology with applying organic fertilizer requires much more family labor. The marital status variable in both models implies that farmers who have a wife or husband do not want to change the status of using OF to start (quit). In addition, the variable for the production of glutinous rice variety in both models implies that the use of organic fertilizer is necessary because of its higher quality.

Table 4.5 Estimated results of Logit model 1

dependent variable: OF_Dm1=1, OF_Dm0=0, *independent variables in 2014*	Coefficient	Std. Err.	P>|t|
Ethnicity (Dummy)	0.0058	0.0157	0.7126
Sex of HH head (Dummy)	-0.2085	0.3211	0.5161
Age of HH head (years)	0.0011	0.0078	0.8849
Marriage status of HH head (Dummy)	**-0.5243**	**0.2537**	**0.0388**
Education level of HH head (Dummy)	0.0264	0.0279	0.3437
Rice land area (ha)	**-0.0001**	**0.0000**	**0.0002**
Irrigation facilities (Dummy)	-0.0003	0.0005	0.4828
Percent of rice (%)	**-0.7976**	**0.3611**	**0.0272**
Family labor for rice (hrs)	**0.0002**	**0.0001**	**0.0169**
Production of Glutinous rice variety (Dummy)	**0.3304**	**0.2223**	**0.1373**
Difference of Rice production quantity (kg)	0.0000	0.0001	0.7622
Difference of Rice producing area (ha)	0.0000	0.0001	0.7013
Difference of total farming income *(1,000VND/year)*	0.0000	0.0000	0.1314
AIC	743.92		
Pseudo R-squared	0.4650		
Adj. Pseudo R-squared	0.4442		
N	969		

Source: VHLSS in 2014 and 2016

Table 4.6 Estimated results of Logit model 2

dependent variable: OF_Dm3=1, OF_Dm4=0, *independent variables in 2014*	Coefficient	Std. Err.	P>|t|
Ethnicity (Dummy)	-0.0028	0.0195	0.8856
Sex of HH head (Dummy)	-0.0860	0.3001	0.7743
Age of HH head (years)	-0.0015	0.0075	0.8417
Marriage status of HH head (Dummy)	**-0.5076**	**0.2550**	**0.0466**
Education level of HH head (Dummy)	0.0169	0.0252	0.5012
Rice land area (ha)	**0.0000**	**0.0000**	**0.0945**
Irrigation facilities (Dummy)	0.0001	0.0005	0.8222
Percent of rice (%)	**1.1160**	**0.3887**	**0.0041**
Family labor for rice (hrs)	**-0.0004**	**0.0001**	**0.0000**
Production of Glutinous rice variety (Dummy)	-0.0329	0.1970	0.8672
Difference of Rice production quantity (kg)	0.0001	0.0001	0.3680
Difference of Rice producing area (ha)	0.0000	0.0000	0.6522
Difference of total farming income *(1,000VND/year)*	0.0000	0.0000	0.8912
AIC	772.36		
Pseudo R-squared	0.1904		
Adj. Pseudo R-squared	0.1600		
N	665		

Source: VHLSS in 2014 and 2016

4.3 Conclusion

As the rice land area in Vietnam is fragmented, the results show that farmers who has large area also has large income and vice versa. Furthermore, farmers who have a larger area of rice cultivation do not want to use organic fertilizer than farmers who have a smaller area of cultivation.

Farming intensively with organic fertilizer has not shown to be more productive than farming purely with chemical fertilizer.

Vietnamese rice farmers' trend in the use of organic fertilizer are increasing, and the results show that farmers using chemical fertilizers are unable to save on their input costs.

Applying organic fertilizer technology requires more labor to achieve sustainable development in agriculture.

The percentage of rice variable in both models who that farmers who started using organic fertilizer have a negative influence while after quitting using it is positive to use organic fertilizer.

The marital status variable in both models shows that farmers who have a wife or husband do not want to change the status of using organic fertilizer to start (quit).

The variable for the production of glutinous rice variety in both models implies that the use of organic fertilizer is necessary because of its own higher quality.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The study has been exploring the basic characteristics of Vietnamese rice producers and determining their technical efficiency on rice production by using Stochastic frontier analysis method. Results show that Vietnamese rice farmers can be recognized as small producers with limited land area, and their cultivation might depend mostly on their experiences. In addition, the household's income revealed in this study has a remarkable increasing comparing with results in previous research. The average total value of farming earn is about 40 million VND per year. However, the farmers are currently paying much attention to non-agricultural activities in order to have better income. It also indicated that growing rice is less attractive to farmers than others crop.

In Stochastic frontier production estimate and factors associated with technical efficiency for rice farmers in Vietnam, all of the variables employed in the model are significantly affected to the result. The average value of technical efficiency in rice production in this study was estimated as 87.6%.

The results suggest that the farmers can get more benefits when they grow mixing crops instead rice monoculture. In addition, invest on irrigation also can help increasing rice productivity.

The study also examined the important role of the labor in the technical efficiency. According to the result, the labor has significantly affected to technical efficient. Farmers can optimize their technical efficiency by intensively investing in labor.

In this study, the usage of organic fertilizer did not bring any benefit to rice production. It can be explained by the fact that organic fertilizer in Vietnam is almost self-provided under un-controlled quality and quantity.

As the rice land area in Vietnam is fragmented, the results show that farmers who has large area also has large income and vice versa. Furthermore, farmers who have a larger area of rice cultivation do not want to use organic fertilizer than farmers who have a smaller area of cultivation.

Farming intensively with organic fertilizer has not shown to be more productive than farming purely with chemical fertilizer. Vietnamese rice farmers' trend in the use of organic fertilizer are increasing, and the results show that farmers using chemical fertilizers are unable to save on their input costs.

Applying organic fertilizer technology requires more labor to achieve sustainable development in agriculture. The variable for the production of glutinous rice variety implies that the use of organic fertilizer is necessary because of its own higher quality in their structure of production.

5.2. Recommendations

Based on the result of the study, to obtain higher technical efficiency the Vietnamese rice producers should pay more attention to self-educating to approach new agricultural technology progress by participating in trainings or workshops which have been operating by the government or research organizers.

Organic fertilizers now take a lot of attention around the world due to their environmentally friendly characteristics. However, this study revealed the fact that the use of organic fertilizers in rice production in Vietnam did not bring any benefit to technical efficiency of households, but it is the trend in producing agricultural products in Vietnam.

As a role of constructor, the government should encourage rice producers to have higher efficiency in terms of optimizing mixed-crop cultivation, pay attention to produce special varieties rice with high quality. Furthermore, policies should focus on investing in irrigation systems and enhancing the level of farmer's education.

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