



**INVESTIGATING EFFICIENCY AND TOTAL FACTOR
PRODUCTIVITY OF RICE PRODUCTION IN
THAILAND: PROVINCIAL AND
SPATIAL ANALYSIS**

BY

NUTTHAPOJ SNANSIANG

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER DEGREE OF ECONOMICS
(INTERNATIONAL PROGRAM)
FACULTY OF ECONOMICS
THAMMASAT UNIVERSITY
ACADEMIC YEAR 2022
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ENTITLED

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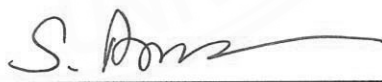
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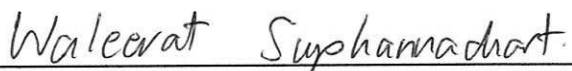
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Thesis Title	INVESTIGATING EFFICIENCY AND TOTAL FACTOR PRODUCTIVITY OF RICE PRODUCTION IN THAILAND: PROVINCIAL AND SPATIAL ANALYSIS
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ABSTRACT

Rice is an important commodity in Thailand for domestic consumption and for exportation. However, the yield of rice in Thailand is lower than that of many rice exporter countries and the average yield of the world. This study aims to investigate the performance of rice production and its improvement at the provincial level for the period 1997-2018 and for both rice seasons in Thailand. To this objective, this study employs the Malmquist productivity index using the Data Envelopment Analysis (DEA) approach to measure production efficiency and TFP change, as well as its decomposition, of rice production. Then the TFP changes will be further investigated for some determinant variables and for the spatial influences using panel spatial regression.

Results from the performance measurement of rice production show that (1) there is a difference in production efficiency between the main rice and the second rice, where the latter is more efficient. (2) there are regional differences of the production efficiency of rice where provinces in the Central and the Northern regions are more technically efficient than that of the Northeastern and the Southern regions. (3) correlation matrix suggests that the main rice may operate under the decreasing return to scale of production. (4) both rice seasons faced average TFP regress during

the period of the study while there are differences in the decomposition of TFP changes for each season.

Results from the TFP determinant model show that (1) natural shocks, climate change, and global warming have detrimental effects on the TFP growth of rice in Thailand. (2) irrigation development and the amount of rainfall have positive effects on the TFP growth of the second rice. (3) adoption of high-yield rice variety has a positive effect on the TFP growth of the main rice. This study also found the spatial influence of TFP growth among provinces of Thailand which is suggest the existence of spillover effects of technology and improvement.

The findings of this study suggest that in the short-run policymaker should utilize the spillover effects in order to improve performance of rice production. Reconsidering the objective and position of rice farming while incorporating climate change issues should be another important decision to be made in order to maintain food security as well as improve the resilience and economic condition of the rice farmers in Thailand in the long-run.

Keywords: Rice production, Production efficiency, TFP growth, DEA, Malmquist index, Spatial econometrics, Thailand

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Third, my parents who also being patient and keep supporting me, in their own way, for this long period of my academic journey.

Besides the people mentioned above, I would like to thank many more people who are not mentioned but also have contributed to this thesis in one way or another. I hope this study fulfills its objectives and become a useful piece of study in this field for both policymakers and other researchers for further studies. Any flaw or mistake that remains in this study was on me alone.

Nutthapoj Snansiang

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LIST OF ABBREVIATIONS

Symbols/Abbreviations	Terms
AE	Allocative efficiency
BOT	Bank of Thailand
C	Central region of Thailand
CE	Cost efficiency
EE	Economic efficiency
FAO	Food and Agriculture Organization of the United Nations
MOAC	Ministry of Agriculture and Cooperatives
OAE	Office of Agricultural Economics
PFP	Partial factor productivity
N	Northern region of Thailand
NE	Northeastern region of Thailand
S	Southern region of Thailand
TC	Technical change
TE	Technical efficiency
TEC	Technical efficiency change
TFP	Total factor productivity
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 Motivation

According to the World Population Prospects 2019 Data published by the United Nations, global population will increase by 9.735 billion in 2050 and 10.875 billion in 2100. This raised concerns about food security in many countries given the need to provide sufficient nutrition for their citizens. As a result, research on agricultural productivity and efficiency has gained popularity as it enables policymakers to identify factors that influence productivity and efficiency and eventually make effective policy designs and decisions. (Arnade, 1994; Fulginiti & Perrin, 1997; Suhariyanto & Thirtle, 2001; Trueblood and Coggins, 2003; Coelli and Rao, 2005; Luh et al., 2008; Rungsuriyawiboon & Wang 2009; Rungsuriyawiboon & Wang, 2012)

One of the most important food commodities is rice which is an important staple food for many countries, especially for Asia countries. Rice is predicted to still be consumed by over half of the world's population up until 2065 while maintaining its significance as the estimated ratio remains at more than 40 percent in 2100 (43%).

Moreover, even though rice consumption per capita could fall as a result of income growth, from 56.3 kg per year in 2009-2011 to between 39.1 to 56.1 kg per year in 2050, the total demand for rice could still rise due to population growth. Global rice consumption projected in 2012 could be between 442 to 466 million tons in 2030 and between 374 to 536 million tons in 2050 (FAO, 2014). A more recent projection of global rice demand by the International Food Policy Research Institute had projected that global rice demand could rise to 550 million tons a year—about two-thirds of this demand will come from Asia (Tongwaranan, 2018).

Thailand seems to have stable food security because agriculture sector is a vital role and accounts for a big proportion of labor force since the past.

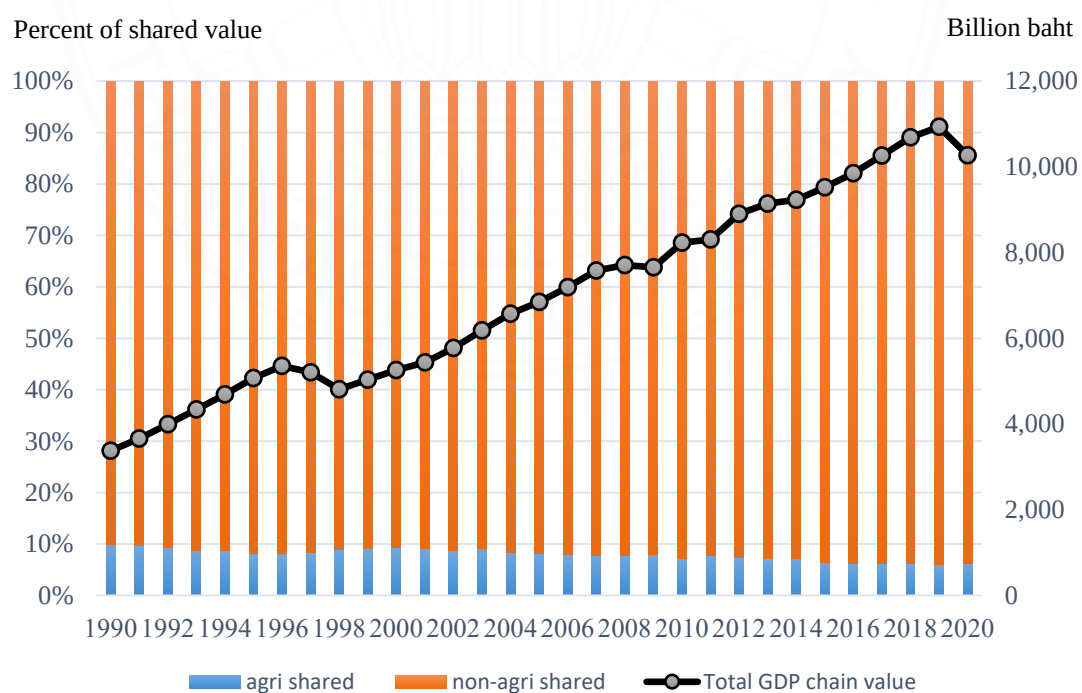
Although Thailand appears to be quite strong with regards to food security, given the agricultural sector's historical significance and taking up a big portion of the

country's population as its labour force; the situation continues on a gradual change as represented by the decline in shares of GDP represented by the agricultural sector. On the other hand, non-agricultural sector continues to expand with an annual average growth of 3.94% (Rerkkasem, 2014). The non-agricultural sector has outgrown the agriculture sector by 2.2% annually over the course of 31 years as seen in Figure 1.1.

The rapid growth of non-agricultural sector in Thailand is a result of the National Economic and Social Development Plan that acts as the basis of many of the country's national policies. Although the first plan implemented in 1961 to 1966 puts emphasis on improving agricultural infrastructure, subsequent plans highlighted developments in non-agricultural sector, such as mining and quarrying, industrial, and manufacturing. These sectors have more potential and proved to have substantial contributions to GDP growth and GNP per capita of the Thai people (Isvilanonda et al., 2009)

Figure 1.1

GDP chain value and shares of GDP



Note. Author's visualization based on data from the Bank of Thailand

The rice industry proves to be a significant sector for Thailand, serving as a major staple crop and the main source of income for rural areas. In 1997, there were 3.71 million farmer households who cultivated main rice and 0.34 million farmer households for second rice with cultivation areas of 56.96 million rai and 6.44 million rai for main rice and second rice, respectively. In 2018, there were 4.29 million households using 59.98 million rai to cultivate main rice. There were also 0.62 million households with 12.07 million rai to cultivate second rice in 2018.

The dramatic increase in farmer households (84.2%) and land (87.4%) used for cultivated second rice over the two decades was due to the adoption of fertilizer responsive, high-yielding, and non-photoperiod sensitive variety of rice and an increase in irrigated area (Rerkkasem, 2014; Isvilanonda et al., 2009).

Moreover, rice is one of the major export commodities for Thailand. Thailand exported, on average, 27 percent of rice that have been produced in each year since 1995. The value of rice export was 1.959 billion US dollars in 1995 and has increased to 5.676 billion US dollars in 2018, accounting for 22.67 percent of the value of total agricultural commodities exported¹.

Thailand is one of the major rice exporters in the world. Thailand was the biggest exporter until 2011 and remains in the second or third place of the biggest rice export up to the present. The United States Department of Agriculture (USDA) reported that in 2001/02 Thailand exported 7.521 million tons of rice and was the biggest rice exporter, followed by Vietnam, Pakistan, India, and China with an amount of 3.528, 2.417, 1.936, and 1.847 million tons respectively. Thailand was the biggest rice exporter until 2010/2011 when India beats it out of the first place. Nevertheless, the USDA predicts that Thailand will continue to maintain its significance as the global rice export with forecasts that in 2020/2021, Thailand will be the second-largest global rice exporter with 6.5 million tons exported, only one-rank after India and the third place will be taken by Vietnam with an amount of 15.5 and 6.4 million tons respectively (USDA, 2021).

¹ Author calculated using quantity and value of rice export from the Bank of Thailand and quantity of rice produced from Office of Agricultural Economics.

Despite being one of the top rice exporters, Thai's rice yield is not much compared to other countries. According to the FAOSTAT dataset from the Food and Agriculture Organization of the United Nations, Thailand has the lowest rice yield among the six biggest exporter countries in 2019 which is 29,188 hectogram per hectare (Hg/Ha) compared to China 70,601 Hg/Ha, Viet Nam 58,165 Hg/Ha, India 40,577 Hg/Ha, Burma 37,957 Hg/Ha, and Pakistan 36,637. Moreover, the yield of rice in Thailand is also substantially lower than the average yield of the world, which is 46,618 Hg/Ha. From 1990 to 2019 Thai rice yield increased by 49% which is greater than the increasing rice yield of China (23%), Burma (29%), and the average of the world (32%). However, an increase in the yield of rice in Thailand is still lower than that of Viet Nam (83%), Pakistan (58%), and India (55%) over the same period (FAO, 2021).

Even it is important to employ the performance of other countries as a benchmark, systematic insights about Thai rice production are also required to improve production performance and the yield of rice.

Although many studies have already investigated the efficiency of rice production in Thailand, these studies are conducted in terms of the farmer household of some provinces or some areas of Thailand (Sriboonchitta & Wiboonpongse, 2001; Champhech, 2003; Krasachat, 2004; Chaovanapoonphol et al., 2005; Songsrirote & Singhapreecha, 2007; Kiatpathomchai, 2008; Rahman et al., 2009; Butso & Isvilanonda, 2010; Taraka et al., 2010; Sansri et al., 2014; Osti, 2016; Ebers et al., 2016; Panpluem et al., 2019; Jirarud & Suwanmaneepong, 2020). As for the productivity of rice production in Thailand, most studies focus on the partial productivity of rice, such as land productivity (yield) and labour productivity (Sriboonchitta & Wiboonpongse, 2001; Sriboonchitta & Wiboonpongse, 2005; Songsrirote & Singhapreecha, 2007; Isvilanonda et al., 2009; Rahman et al., 2009; Taraka et al., 2010; Taraka et al., 2012; Rerkkasem, 2014; Sansri et al., 2014). Only a few studies try to investigate the total factor productivity of rice (Suphannachart, 2013; Suphannachart, 2018).

Location may influence rice farming performance. Difference areas have different natural conditions such as climate, terrain, and soil quality as well as influenced by human activities such as the availability of agricultural infrastructures, breed of rice, or farming technique. Past studies reveal evidence of the impact of spatial aspect on the differences in efficiency scores (Krasachat, 2004; Kiatpathomchai, 2008;

Butso & Isvilanonda, 2010; Sansri et al., 2014). Total factor productivity of rice in each province got an influence from neighbour provinces (Suphannachart, 2018) and the TFP growth rate of rice also differs among four regions of Thailand (Suphannachart, 2013). Therefore, location and spatial aspects should be taken into account when assessing the performance of rice production.

Measurements of total factor productivity and production efficiency applied in this study will provide useful information about rice production in Thailand. First, efficiency measurement provides information about the relative performance of the decision-making unit (DMU). The efficiency score shows how efficient each DMU uses inputs in order to produce output compared with other DMUs. Second, the total factor productivity provides information about output growth that cannot be explained by the growth of traditional inputs in the production and it is considered to be the crucial part that contributes to substantial long-run output growth. The Malmquist productivity index employed in this study allows researcher to extend the investigation into two more details that contributed to the growth in total factor productivity. The first component is technical efficiency change which reflects the ability of the DMU to improve its efficiency of production over the period. The second component is technological change which reflects the ability to adopt new technology and improve efficient frontier over period. These two components can be used as crucial information for policymakers to promote sustainable growth of total factor productivity of rice in Thailand.

This study will be the first to investigate the efficiency and total factor productivity growth of rice production for Bangkok and 76 provinces of Thailand over 22 years period by applying Data Envelopment Analysis and the Malmquist Productivity Index.

With the provincial data set, this study will also employ spatial analysis to investigate the influence of location and neighborhood aspects in the TFP growth of rice production. Efficiency score and total factor productivity growth as well as its two components will provide valuable information for improving the performance and productivity of rice in Thailand.

1.2 Statement of the problem and research question

Rice is one of the crucial export commodities in Thailand. However, the yield of Thai rice is lower than many rice exporter countries and lower than the average yield of the world. To investigate this issue, measuring efficiency and total factor productivity of rice production will provide some insights to improve the gap in Thai's rice industry.

In the past, many studies measure production efficiencies of rice production in terms of farmer household level in specific areas or provinces. Total factor productivity of rice is usually studied as per region or as of the whole country. This leaves a gap for the performance comparison among provinces. Thus, investigating production efficiency and total factor productivity growth of rice production at the provincial level could help to fill the gap in this topic.

Moreover, this study will employ spatial analysis to the provincial level data to investigate the location and neighborhood aspects of rice production in Thailand.

1.3 Objectives of the study

1. To investigate provincial production efficiency of rice production in Thailand using Data Envelopment Analysis (DEA) approach.
2. To investigate provincial total factor productivity growth of rice production in Thailand using the Malmquist Productivity Index.
3. To identify whether there is a spatial influence of the total factor productivity growth of rice among provinces in Thailand.

1.4 Scope of the study

This study focuses on the provincial rice production of main and second rice in Bangkok and other 76 provinces over the period 1997 to 2018 by applying Data Envelopment Analysis and the Malmquist TFP index.

1.5 Organization of the study

This thesis contains six chapters. The first chapter provides the introduction including the problem statement, objectives, and scope of the study. Chapter two provides an overview of rice production in Thailand. Chapter three reviews the literature of related theory and empirical studies. Chapter four presents theoretical frameworks and specifies research methodology. Chapter five discusses the results of the study. Finally, chapter six provides the conclusions and recommendations of this study.



CHAPTER 2

OVERVIEW OF RICE PRODUCTION IN THAILAND

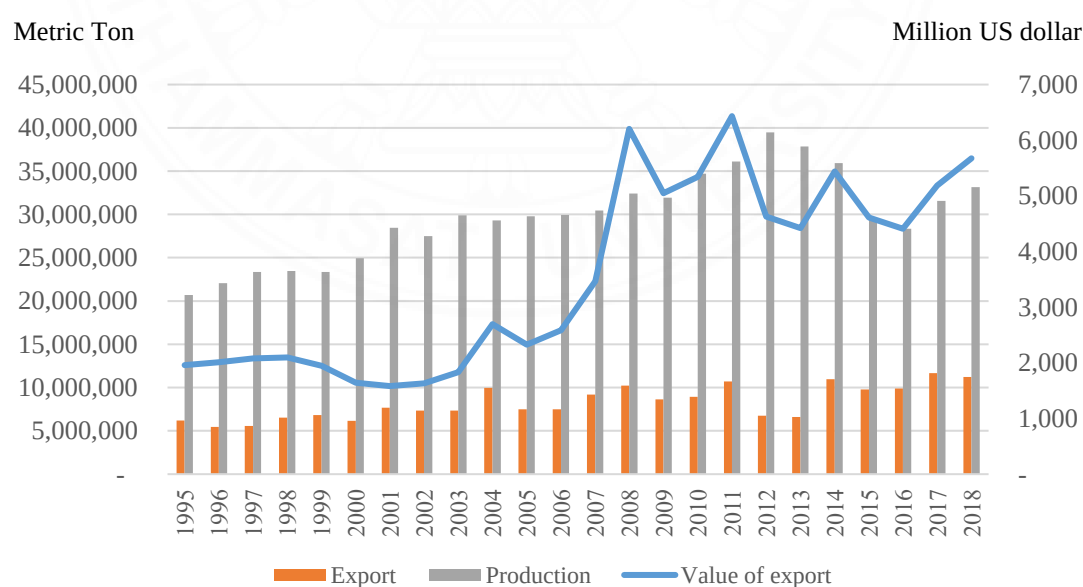
This chapter provides an overview of rice in terms of exportation, production development, and the difference in production in each region in Thailand.

2.1 Rice exportation

Rice industry remains an important sector for Thailand throughout history as a major staple crop and source of income in many rural areas. Moreover, rice is one of the major export commodities in Thailand. Thailand exported on average 27 percent of rice that had been produced each year since 1995. The value of rice export gradually increased from 1.959 billion US dollars in 1995, reaching a peak at 6.432 billion US dollars in 2011 before falling to 5.676 billion US dollars in 2018. Figure 2.1 demonstrates the quantity of rice production and the export value of rice since 1995.

Figure 2.1

Rice production and exportation of Thailand

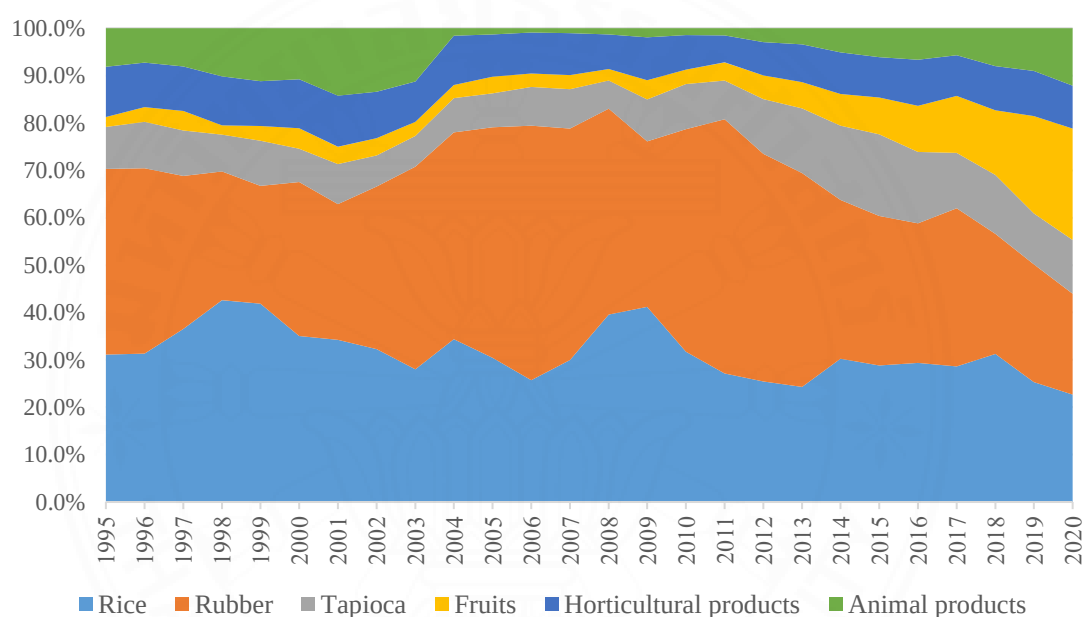


Note. Author compiled and visualized data from the Office of Agricultural Economics and the Bank of Thailand.

However, rice exports as part of the shared value of agricultural exportation –excluding fishery, forestry, and agricultural manufacturing products–has been on a gradual decline. The chart below in blue reflects such a downward trend. The share of rice export value was 31.1 percent in 1995, reached its peak in 2009 (41.2 percent), and fell to 22.7 percent in 2020 (Figure 2.2).

Figure 2.2

Value share of agricultural exported products



Note. Author's visualization based on data from the Bank of Thailand.

2.2 Dynamics of rice production in Thailand

The Green Revolution in the 1960s had an impact on the modern agricultural sector throughout Asia. Rice production in Thailand also benefited from the Green Revolution through the accumulation of new technologies. A modern variant of rice, IR8 also known as “miracle rice”, was developed and disseminated in 1965 by the International Rice Research Institute (IRRI). The variant has contributed to major improvements in rice production across the world. It increases yield of rice through two of its attributes 1) non-photoperiod sensitivity which allows it to be cultivated in all seasons and 2) high responsiveness to modern fertilizers which increase the quantity and

yield of production (IRRI, 2016). Thailand adopted this variant and then modified it to be more compatible with the local environment and taste of Thai people by creating a hybrid between IR8 and the native varieties. For example, RD1, RD7, RD11, etc. The subsequent hybrids that were created later were named after the province where the rice research institute that developed the variant was located such as Pathumthani 1, Suphan Buri 60, Chai Nat 1, etc. (Isvilanonda et al., 2009). Traditionally, rice is cultivated once a year because it is rain-fed, so it requires water in the rainy season. With modern varieties and well irrigation system, rice can be cultivated in two different cropping seasons.

According to the Office of Agricultural Economics, rice in Thailand is cultivated in two cropping seasons. The first cropping season is the main rice that cultivates between May and October. Exceptions are some provinces in the southern region of Thailand, of which the period is between mid-June to February of the next year. The main rice is generally rain-fed rice, the so called 'in-season' rice. The yield depends on the amount of rainfall and cultivation could be performed once a year. Another cropping season is the second rice which is cultivated between November to April of the next year. Except for some provinces in the south, the growing period of the Second rice is between March to mid-June. The second rice is grown outside of the rainy season, as its name 'off-season' rice. The yield relies on other sources of water besides rain such as irrigation (OAE, 2014).

Another way to categorize rice is to differentiate types of rice into fragrant rice, non-fragrant white rice, and glutinous rice. Fragrant rice and non-fragrant white rice are cultivated and utilized in all locations of Thailand. They are important and intensively grown in the central region. Glutinous rice is mostly cultivated in upper-northern and upper-northeastern regions because it is the main type of rice consumed by people in these locations. While fragrant rice and non-fragrant white rice can grow in both seasons, glutinous rice is mainly grown as the main rice or rain-fed seasons because the areas in the upper-northern and upper-northeastern are not well irrigated. Still, fragrant rice and non-fragrant white rice account for two-thirds of the total amount of the main rice produced (Isvilanonda et al., 2009).

People in the upper northern and upper northeastern regions grow glutinous rice for domestic consumption while they grow other types of rice for commercial

purposes. However, cultivation of fragrant rice and non-fragrant white rice in these regions have increased over time owing to growing market demands, especially in the northeastern region where farmers have been allocating more land to grow Khao Dawk Mali 105. Even the cultivated areas of glutinous rice in the northern and northeastern regions have declined, the yield of this rice still increased due to non-photoperiod sensitivity and fertilizer responsive varieties that are developed and used pervasively (Isvilanonda et al., 2009).

Thailand has been implementing policies and promoting new technologies and infrastructures to improve the performance of agriculture production for a very long time. The first three plans of The National Economic and Social Development had invested in agricultural infrastructures such as dams and irrigation systems especially in the central region and then extend to the lower-northern region (Isvilanonda et al., 2009). The non-photoperiod sensitivity and fertilizer responsive varieties gained their popularity and are widely cultivated in the irrigated areas because they can be grown throughout all cropping seasons of the year given a sufficient source of water.

Rice farming in irrigated areas is mostly concentrated in central and lower-northern regions of Thailand. With well-developed irrigation systems and new varieties, farmers in these areas can do farming multiple times a year, up to 5 crops within 2 years (Isvilanonda et al., 2009). It was estimated that modern rice farming had more labor productivity compared to the period before 1967. This was 5 times higher in rain-fed areas and 12 times higher in irrigated areas (Rerkkasem, 2014). Rice farming in irrigated areas also has greater land productivity. The average yield of rice under irrigation areas was 3 to 5 times higher compared to the rain-fed areas (Rerkkasem, 2014). Nevertheless, more than 70% of rice cultivation areas are not under the irrigation system and much depended on rain. The main objective of rice farming in non-irrigated areas is mostly for domestic consumption.

Adopting new technologies, modern variety of rice, and machines are needed in replacing human and animal labor to improve the performance and reduce time used in many stages of rice farming. Expanding and growing of other economic sectors pulled the labors out of agriculture and rice farming (Table 2.1).

Table 2.1

Thai labor force in agricultural sector

year	Total labor (million persons)	Agricultural labor		Rice farming labor	
		Amount (millions person)	Proportion (%)	Amount (millions person)	Proportion to total labor force (%)
1973-1977	22.80	15.28	67.03	10.83	47.50
1978-1982	26.91	17.24	64.04	11.74	43.63
1983-1987	31.83	18.45	57.98	12.05	37.86
1988-1992	32.25	19.36	60.04	11.75	36.43
1993-1997	32.44	16.94	52.21	11.89	36.65
1998-2002	32.99	15.77	47.80	10.53	31.92
2003-2006	36.29	15.29	42.15	9.83	27.09

Note. Reprinted from *Dynamics of Thailand's Rice Production Economy and The Future Outlook* (p 25) by Isvilanonda et al., 2009, Thailand Research Fund.

With lower labor left in the agricultural and rice sector, real wages for the labor were raised. To reduce the high cost of labor and time used in farming, farmers adopted new technologies, new techniques of farming, and replaced human and animal labor with machines (Isvilanonda et al., 2009). For example, the combined harvester that developed and can be produced within the country since 1987 can harvest and thresh rice at 3-6 rai per one hour. Combined with the paddy drying machine, farmers can harvest the paddy at high moisture as 30%.

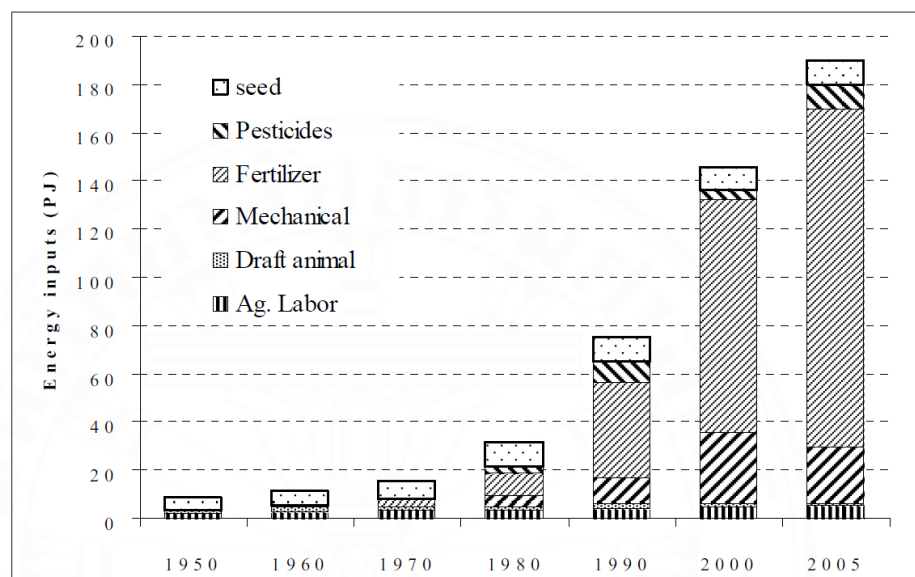
The shift in adopting technologies could be captured in terms of the energy unit of inputs used in the agricultural sector. From 1950 to 2005, the energy used in crop production increased drastically. The major increase comes from new technologies such as machines, pesticides, and, the most importantly, fertilizer which accounted for three-fourths of energy input used in 2005 (Figure 2.3).

As a result, the cropping time was reduced significantly, and farmers could grow more than one circle of rice in a year. According to Isvilanonda et al. (2000),

farmers in irrigated areas in Suphan Buri province used 9.3 man-day per rai in crop year 1987/88 and was 3.8 man-day per rai in crop year 1998/99.

Figure 2.3

Contribution of different energy inputs in crop production in Thailand during 1950-2005



Note. Reprinted from “Agricultural mechanization development in Thailand” by Thepent, V. and Chamsing, A., 2009, Paper presented at the 5th Session of the Technical Committee of APCAEM, Los Banos, Philippines.

The objective of rice farming in irrigation areas became more and more commercialized. Nowadays, rice farming in the central and lower north of Thailand are run on a fully commercialized basis. Farmers can outsource many activities of rice farming, including sowing, fertilizing, pesticide application, harvesting as well as renting land and machines. This reduced the cost of buying land and big machines that relates to high initial investment. These changes allow modern farmers to become “remote farmer” who can perform rice farming from somewhere else by managing most of the process through phone calls (Rerkkasem, 2014).

Bank of Agriculture and Agricultural Cooperatives, founded in 1996, plays a crucial role in facilitating low-interest loans for farmers. These loans enable farmers to be able to invest to improve their production performances. Despite inadequate loans during the early period of the operation, this system can provide a large amount of loans

after some adjustments. With these loans, farmers can access modern technologies and improve their farming systems, especially in irrigated areas (Isvilanonda et al., 2009). It has been reported that more than 90% of agriculturists can get loans through the group guarantee system (Rerkkasem, 2014).

New technology is disrupting all economic areas today. Agricultural information is collected more systematically so that it can use for providing better guidelines in farming. The government and private sectors developed databases and applications to provide useful data to the farmer such as the market price of agricultural input and output, rain prediction and water management, soil quality map, etc. (NSTDA, 2020). For example, the Ministry of Agriculture and Cooperatives (MOAC) cooperates with the Ministry of Higher Education, Science, Research and Innovation (MHESI) in developing Agri-Map database. Data from 20 departments under MOAC is combined into big data and connected to the Google Map. This database shows current land used, land suitability, and suitable crop for each location based on the agricultural needs of the crop. This information assists policymakers in determining agricultural zoning and farmers in selecting a crop that is appropriate for their land, resulting in increased production and lower costs.

Farmers may collect various data in deep detail about their farm and crops from a distance using more advanced sensors that can be embedded in agricultural tools and drones, a process known as "Remote sensing". These devices form sensor networks in gathering data and communicating with one another when connected to the Internet of Things (IoT); nations with sophisticated technology employ robots to automate many farming tasks and can manage their farm remotely via smartphone. Farmers that embrace these new waves of technology are referred as "smart" or "digital" farmers. The farming process becomes, so-called, "Precision farming/agriculture" in which more details of crop, soil, moisture, and temperature data allows the farmer to regulate the standard of yield in term of quality and quantity and also allows traceability of their product to identify any anomalies or issues. Precision farming improves the accuracy of applying pesticide and fertilizer at optimum quality and time. This saves resources, lower production cost, and improves productivity (NSTDA, 2020).

In the Bio-Circular-Green Economic Model (BCG) transforming conventional farming into smart farming through innovation and technology is a

fundamental strategy for creating value in the food and agriculture industry. The Thai government has been promoting this model as a new economic model for inclusive and sustainable growth, and it will be extensively influenced at all levels of policy from 2021 to 2027.

2.3 Investment in research and development of rice in Thailand

Yield of rice in Thailand increased over the decades. Data from OAE shows that the average yield of the main rice was 295, 336, 408, 456, and 453 kilograms per rai in 1981, 1991, 2001, 2011, and 2018 respectively. But there is little improvement for the second rice and even some fluctuation. The average yield of the second rice was 615, 628, 697, 639, and 656 kilograms per rai in 1988, 1991, 2001, 2011, and 2019 respectively.

An increase in rice yield is highly influenced by Research and Development (R&D). Thailand has been consistently promoting and encouraging farmers to use new non-photoperiod sensitive and fertilizer responsive varieties since 1969. One of the most successful rice that was developed by the government and is widely adopted by farmers is Khao Dawk Mali 105. Other popular non-photoperiod sensitive varieties were mostly developed before 1997, which was the period that Thai government has invested more R&D in the agricultural sector compared to the present.

However, R&D in the agricultural sector in Thailand is small. The proportion of investment in R&D in agriculture to GDP is less than 1% while the return on investment is high. A study by Suphannachart (2019) shows that the returns on the public, private, and public-private collaboration investment in agricultural R&D were 40.84%, 9.47%, and 8.49%, respectively. This highlights the under-investment of government funding towards R&D in this sector.

The investment in R&D from the government in rice sector was also curtailed after 1997. The average annual supporting fund for R&D in rice used to be 134.23 million baths during 1968-1972 with a peak at 356.84 million baths during 1993-1997 and lower to 127.67 million baths in 2003-2005. The annual growth of supporting funds for R&D in rice was at 3.63% during 1968-1987 but at -3.04% during 1988-2007 (Isvilanonda et al., 2009).

There are many issues that have an influence on the yield of rice including the spread of weedy rice and brown planthopper, lack of nutrients in soils, and unstable weather due to climate change. The resistance to pests of rice declined since pests can evolve over time while new varieties of rice with pest resistance traits take a long time to develop, not to mention the cost of development. With low funding in R&D from the government, an improvement in the yield of rice is low. The increase in yield of the new rice varieties that developed nowadays was not over 0.2 kilograms per rai per year (Rerkkasem, 2014).

2.4 Rice production in four regions of Thailand

Thailand has many systems in dividing its regions. The one that is widely used for studying the agricultural sector is the four-region system, which is for administrative and statistical contexts. The four-region system divided Thailand into Northern, Central, Northeastern, and Southern regions. Each region has different topography, climate, and cultural identity.

The northern region has a tropical savanna climate, a relatively high elevation and latitude, and more pronounced seasonal temperature variations. The upper-northern is geographically characterized by several mountains and generally has crop rotation. The lower part of the north is the lowland area connecting to the central region.

Lower-northern and central regions, covering the broad alluvial plain of the Chao Phraya River, have rich fertilized soil and well-developed agricultural infrastructures. Rice that is cultivated in these regions is generally non-photoperiod sensitivity varieties. Rice farming in this region is one of the most intensive and industrialized - with up to 5 crops within 2 years. This translated to a decline in household and land use for the main rice, but an increase for the second rice.

The northeastern region is located on the Khorat Plateau and bordered by the Mekong River. The northeastern region has low fertility in soils, low water resources, and unpredictable rainfall, but rain is concentrated in the rainy season. With this topography and a small area under the irrigation system, major rice cultivation in this region is the main rice, i.e., rain-fed rice, and only cultivated once a year.

Glutinous rice is widely cultivated in the upper-northern and upper-northeastern regions of Thailand because of its traditional staple status in these areas, where cultivations are performed mostly for domestic consumption purposes.

But with a relatively poor irrigation system, glutinous rice cropping mainly depends on rainfall, which made it mostly considered as main rice. However, more and more people in the upper-northern and upper-northeastern are shifting and allocating their land to growing more fragrant and non-fragrant white rice over time due to higher demands in the market. Particularly in the northeastern region, more land had been allocated to grow Khao Dawk Mali 105 (Isvilanonda et al., 2009). There is an increase in land used for the main rice and second rice but the latter grew in relatively small size due to limitations in the irrigation system area, which is crucial to growing second rice.

Lastly, the southern region is located on the Malay Peninsula with many mountain ranges and has a tropical monsoon climate. The geography and climate of this region is suitable for perennial plants, especially rubber trees and oil palms. Rice cultivation in the southern region is limited due to lack of adequate irrigation systems and suitable cultivation areas. Many areas are either preserved for the forest or impacted by the flood resulting in a decline in the number of households and land used for rice farming as second rice farming reached its peak in 2011-2012 and continued on a downward trend ever since.

These four regions have their differences in the characteristics of rice production due to the environmental conditions and the disparity in agricultural infrastructure development.

2.4.1 Irrigation development

Irrigation system is the basic and crucial agricultural infrastructure for improving agricultural performance. Irrigation development in early plans of The National Economic and Social Development is in accordance with the Green Revolution. Table 2.2 shows that big and medium irrigation projects implemented in the first to fifth plan (1961 to 1986) greatly increase irrigation area. The rate of expansion is lower since the sixth plan and especially after the ninth plan. Today, the total irrigation area from big and medium projects is 25,752,169 rai, and these areas are managed by the Royal Irrigation Department.

Table 2.2

Development of the big and medium irrigation project

Plans (year)	Big Irrigation Project		Medium Irrigation Project		Total irrigation area (rai)
	Number of project(s)	Irrigation area (rai)	Number of project(s)	Irrigation area (rai)	
Before the plans	19	4,789,842	110	557,833	5,347,676
1 st (1961-1966)	13	2,417,521	32	348,514	2,766,035
2 nd (1967-1971)	4	835,466	40	316,724	1,152,191
3 rd (1972-1976)	10	2,670,225	36	327,135	2,997,360
4 th (1977-1981)	6	2,057,844	61	457,554	2,515,398
5 th (1982-1986)	15	2,257,990	99	590,018	2,848,007
6 th (1987-1991)	4	984,044	85	580,419	1,564,463
7 th (1992-1996)	11	1,270,208	83	567,814	1,838,022
8 th (1997-2001)	8	834,306	55	727,813	1,562,199
9 th (2002-2006)	4	730,705	50	528,949	1,259,654
10 th (2007-2011)	2	199,786	56	440,622	640,408
11 th (2012-2016)	2	407,216	77	273,603	680,819
12 th (2017-2021)	3	46,400	109	533,618	580,018
Sum	101	19,501,552	893	6,250,616	25,752,169

Note. Reprinted from *Information about irrigation projects 2563* (p 23) by RID, 2020.

Big and Medium irrigation projects are concentrated and developed in central and lower northern regions. Whilst small projects including Kaem Ling and pumping stations are dispersed into the northeastern region. The total irrigation area, data in 2020, is 34,935,041 rai where the central regions have the most irrigation areas followed by northern, northeastern, eastern, and southern regions (Table 2.3). Irrigation development has a significant impact on the pattern of rice farming and caused substantial differences in the inputs used and the yield of rice in Thailand.

Table 2.3

Irrigation area by regions

Regions	Big Irrigation project		Medium Irrigation project		Small Irrigation project (+Kaem Ling+pumping station)		Total	
	Irrigation area (rai)	Benefit area (rai)	Irrigation area (rai)	Benefit area (rai)	Irrigation area (rai)	Benefit area (rai)	Irrigation area (rai)	Benefit area (rai)
North	4,480,268	1,658,678	2,590,366	533,437	3,054,871	8,889,997	10,125,504	11,082,112
Upper North 1	599,138	342,578	500,323	69,940	876,568	2,346,745	1,976,028	2,759,263
Upper North 2	365,624	-	499,234	39,250	681,565	1,731,579	1,496,423	1,770,829
Lower North 1	854,748	1,316,100	763,252	94,850	754,617	2,134,245	2,372,617	3,545,195
Lower North 2	2,660,759	-	877,557	329,397	742,121	2,677,428	4,280,437	3,006,825
Northeast	2,595,394	361,569	1,372,675	410,185	4,185,353	6,505,215	8,153,422	7,276,968
Upper Northeast 1	197,120	127,227	88,539	89,759	105,515	807,623	391,174	1,024,609
Upper Northeast 2	304,789	80,514	271,901	32,760	477,533	1,109,286	1,054,243	1,222,560
Middle Northeast	890,503	338	366,066	31,325	1,160,271	1,093,179	2,413,840	1,124,842
Lower Northeast 1	831,484	153,490	369,438	81,968	1,446,574	2,129,028	2,647,495	2,364,486
Lower Northeast 2	371,498	-	276,731	174,373	995,440	1,366,099	1,643,669	1,540,472
Central	9,119,909	269,850	460,040	343,707	699,758	4,677,130	10,279,708	5,290,687
Upper Central	3,887,827	-	213,051	158,310	211,678	2,774,767	4,312,556	2,933,077
Middle Central	1,642,100	269,850	22,178	30,000	183,844	267,187	1,848,122	567,037
Lower Central 1	2,987,688	-	64,799	79,937	219,736	834,078	3,272,223	914,015

Table 2.3

Irrigation area by regions (Cont.)

Regions	Big Irrigation project		Medium Irrigation project		Small Irrigation project (+Kaem Ling+pumping station)		Total	
	Irrigation area (rai)	Benefit area (rai)	Irrigation area (rai)	Benefit area (rai)	Irrigation area (rai)	Benefit area (rai)	Irrigation area (rai)	Benefit area (rai)
Lower Central 2	602,295	-	160,012	75,460	84,500	801,098	846,807	876,558
East	1,622,135	115,830	864,039	138,915	407,970	1,816,837	2,894,144	2,071,582
East 1	823,917	17,915	291,510	10,175	104,787	507,780	1,200,214	535,870
East 2	798,218	97,915	578,529	128,740	303,183	1,309,057	1,673,930	1,535,712
South	1,030,230	413,866	906,744	344,641	707,055	1,797,139	2,644,029	2,555,646
South-Gulf of Thailand side	1,030,230	403,341	663,422	331,641	535,017	1,289,829	2,228,669	2,024,811
South-Andaman side	-	10,525	243,322	13,000	172,038	507,310	415,360	530,835
Border South	653,616	139,285	56,752	426,812	127,866	1,095,105	838,234	1,661,202
Sum	19,501,552	2,959,078	6,250,616	2,197,697	9,182,872	24,781,422	34,935,041	29,938,196

Note. Adapted from *Information about irrigation projects 2563* (p 35-36) by RID, 2020.

2.4.2 Rice farming household

The total number of rice farmer household increases in both rice seasons. However, the main rice is still the major type of the farm with 4,288,092 households cultivating it compared to 618,997 households for second rice in 2018. But when focusing on each region, we can see the different patterns. In the central region, the household that cultivates main rice decreased from 496,158 households in 1994 to 398,293 households in 2018. While the household that cultivates second rice increased from 103,366 to 214,251 households over the same period. From 1994 to 2018, households that cultivated main rice in the northeastern region grew by about 46 percent while the number was almost unchanged for the northern region. The number of households that cultivates second rice grew significantly except for the southern regions where farmer household declined in both cultivating seasons.



Table 2.4

Number of rice farmer household

Year	Main rice					Second rice				
	C	NE	N	S	Total	C	NE	N	S	Total
1994	496,158	1,956,198	942,208	359,986	3,754,550	103,366	14,718	38,110	20,355	176,549
1995	433,607	1,864,761	891,198	394,913	3,584,479	140,910	19,983	55,032	14,880	230,805
1996	352,278	1,946,116	949,577	357,689	3,605,660	180,242	41,639	88,846	16,301	327,028
1997	467,052	1,980,166	919,193	340,632	3,707,043	172,045	42,373	103,301	18,306	336,025
1998	447,776	2,022,274	935,614	320,067	3,725,731	167,376	56,116	132,915	13,864	370,271
1999	452,861	2,044,857	936,497	314,145	3,748,360	147,430	61,894	111,602	24,004	344,930
2000	450,710	2,092,927	922,267	306,735	3,772,639	168,992	65,220	126,022	21,192	381,426
2001	437,011	2,122,967	939,065	284,570	3,783,613	182,480	84,739	134,360	21,358	422,937
2002	436,755	2,092,989	918,533	277,517	3,725,794	187,556	67,001	115,624	17,688	387,869
2003	440,190	2,077,220	916,909	272,800	3,707,119	191,292	82,690	138,269	14,536	426,787
2004	445,554	2,087,362	922,087	269,986	3,724,989	196,549	75,170	128,399	24,189	424,307
2005	448,652	2,087,464	921,675	268,604	3,726,395	186,576	66,901	133,418	22,604	409,499
2006	449,031	2,088,857	923,331	267,472	3,728,691	194,726	62,291	133,754	21,367	412,138
2007	448,418	2,093,251	921,442	237,418	3,700,529	190,711	74,152	139,566	21,201	425,630
2008	449,521	2,101,428	926,795	237,580	3,715,324	207,793	90,697	151,984	26,030	476,504
2009	360,891	2,297,898	899,674	158,897	3,717,360	208,306	96,111	151,725	26,883	483,025

Table 2.4

Number of rice farmer household (Cont.)

Year	Main rice					Second rice				
	C	NE	N	S	Total	C	NE	N	S	Total
2010	394,541	2,298,512	896,671	153,843	3,743,567	217,699	211,536	210,721	25,889	665,845
2011	384,708	2,355,539	884,017	106,995	3,731,259	228,353	216,429	235,010	26,428	706,220
2012	396,512	2,363,100	887,169	81,763	3,728,544	252,288	234,682	289,703	28,113	804,786
2013	402,810	2,348,138	898,394	81,944	3,731,286	243,087	140,938	294,624	21,411	700,060
2014	399,495	2,336,926	894,784	79,238	3,710,443	225,184	192,528	268,134	12,351	698,197
2015	396,623	2,333,621	892,381	78,853	3,701,478	129,428	118,166	190,823	19,928	458,345
2016	385,841	2,353,527	888,830	81,627	3,709,825	81,848	73,439	107,830	14,179	277,296
2017	387,193	2,624,639	928,252	66,364	4,006,448	159,464	126,435	227,651	17,678	531,228
2018	398,293	2,858,641	944,139	87,019	4,288,092	214,251	160,354	232,698	11,694	618,997

Note. Farmer household data from OAE

2.4.3 Land used for rice farming

Land used for cultivating rice increased for both main and second rice however the growth in the latter is much greater than the former. The number increased to the peak in 2011 to 2012 then gradually decreased until the present. Comparing between 1994 and 2018, land used for cultivating main rice was increased by 6.4 percent while land used for cultivating second rice was increased by 289.5 percent.

Central and southern regions changed from cultivating main rice to second rice while there was an increase in cultivation in both rice for northern and northeastern regions. The highest number of growth in land used for cultivating second rice is the northeastern region followed by the northern and central.

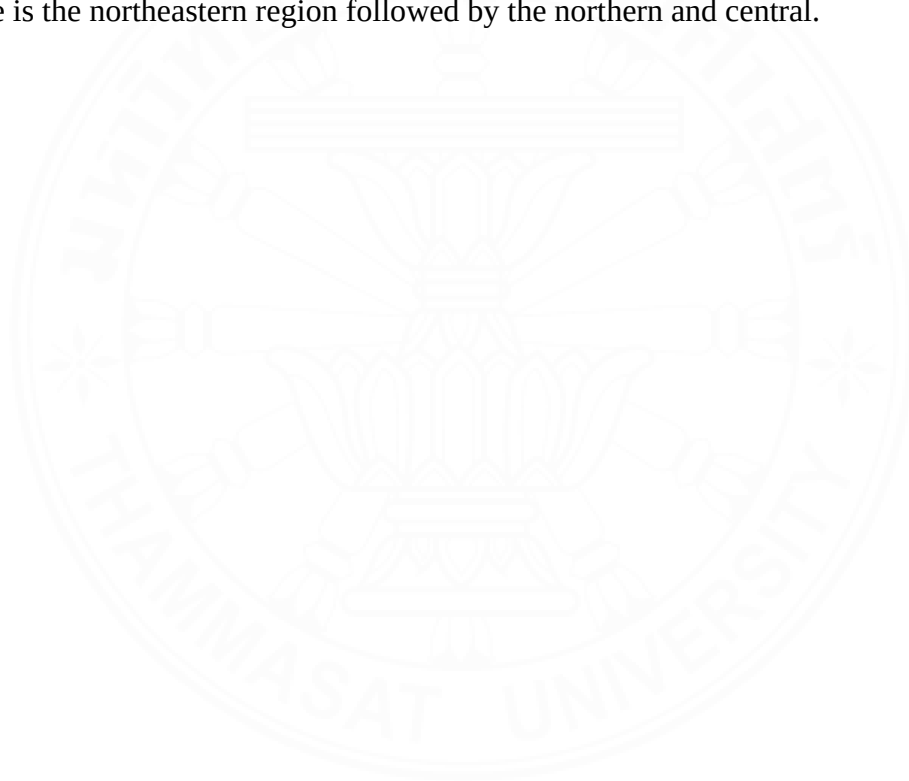


Table 2.5

Land used in rice farming (rai)

Year	Main rice					Second rice				
	C	NE	N	S	Total	C	NE	N	S	Total
1994	9,886,193	31,040,327	12,526,986	2,919,666	56,373,172	2,323,518	93,699	543,685	137,289	3,098,191
1995	9,762,606	32,024,711	12,772,740	2,846,934	57,406,991	3,045,489	160,358	968,201	129,923	4,303,971
1996	9,856,922	31,688,587	12,863,685	2,881,889	57,291,083	3,752,438	334,358	1,743,644	115,572	5,946,012
1997	9,683,472	32,144,320	12,363,686	2,766,554	56,958,032	3,782,316	401,394	2,074,991	177,895	6,436,596
1998	9,837,378	31,420,066	12,371,214	2,611,662	56,240,320	3,843,303	501,633	2,745,518	140,710	7,231,164
1999	9,817,805	31,858,692	12,374,656	2,531,342	56,582,495	3,429,397	443,675	2,296,776	288,009	6,457,857
2000	9,697,033	33,090,626	12,515,977	2,471,017	57,774,653	4,110,685	639,739	2,869,908	240,724	7,861,056
2001	9,857,928	32,997,722	12,754,163	2,228,192	57,838,005	4,632,115	871,875	2,985,859	227,628	8,717,477
2002	9,782,036	32,410,958	12,598,802	2,115,782	56,907,578	5,093,134	628,516	2,593,866	118,551	8,434,067
2003	9,844,593	32,429,265	12,622,497	2,075,871	56,972,226	5,142,212	879,440	3,360,384	150,633	9,532,669
2004	9,856,720	32,951,626	12,747,030	2,096,473	57,651,849	5,339,820	804,599	3,046,502	241,010	9,431,931
2005	9,910,249	33,002,755	12,758,306	2,102,534	57,773,844	5,032,837	721,371	2,967,764	191,600	8,913,572
2006	9,946,075	32,711,384	12,786,349	2,098,017	57,541,825	5,716,711	658,058	3,331,086	196,930	9,902,785
2007	9,814,339	32,773,544	12,779,212	2,018,826	57,385,921	5,485,903	900,130	3,477,315	210,800	10,074,148
2008	9,820,320	33,071,286	12,606,460	1,924,271	57,422,337	6,725,838	1,263,292	4,476,226	335,870	12,801,226
2009	9,392,651	34,121,687	12,740,322	1,242,781	57,497,441	6,180,701	1,460,401	4,375,853	385,475	12,402,430

Table 2.5

Land used in rice farming (rai) (Cont.)

Year	Main rice					Second rice				
	C	NE	N	S	Total	C	NE	N	S	Total
2010	9,213,059	39,841,420	14,331,994	1,187,598	64,574,071	6,144,519	3,024,086	5,716,625	337,284	15,222,514
2011	9,544,587	39,565,392	15,154,331	1,039,401	65,303,711	6,507,365	3,032,856	6,191,026	371,046	16,102,293
2012	9,553,265	39,487,220	14,927,584	982,524	64,950,593	7,095,692	2,946,744	7,615,783	443,020	18,101,239
2013	9,395,366	37,066,629	14,673,698	944,211	62,079,904	6,915,306	1,681,868	7,089,884	400,236	16,087,294
2014	9,156,546	37,030,335	13,715,723	887,995	60,790,599	6,316,361	2,266,838	6,228,205	243,672	15,055,076
2015	8,261,445	36,193,410	12,768,145	840,476	58,063,476	3,269,586	1,180,436	3,716,623	294,114	8,460,759
2016	8,286,984	36,574,140	13,026,882	757,468	58,645,474	2,226,989	785,755	1,906,810	218,131	5,137,685
2017	8,522,252	36,636,516	13,328,429	733,626	59,220,823	4,260,318	1,413,871	4,524,296	258,061	10,456,546
2018	8,507,059	36,878,181	13,814,978	780,513	59,980,731	5,311,948	1,766,573	4,819,308	169,151	12,066,980

Note. Land used in rice farming from OAE

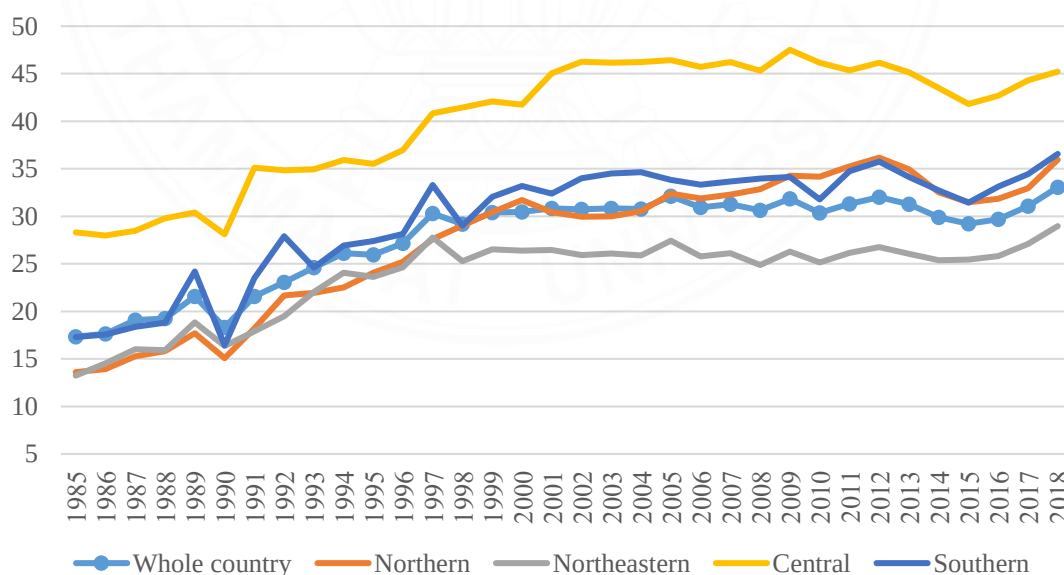
2.4.4 Chemical fertilizers used in rice farming

Data from OAE show that chemical fertilizer used per rai increased over time. Except for the farmers in the central region who cultivates second rice that seems to overuse chemical fertilizers since 1995 and try to adjust it to the optimal proportion. On average, second rice farmers are using more chemical fertilizer per rai than main rice farmers. The average chemical fertilizer of the whole country in 1991 was 21.57 kilograms per rai for main rice and 44.34 kilograms per rai for second rice. The number increased to 33.06 and 49.32 kilograms per rai for the main and second rice, respectively, in 2018. The second rice uses more chemical fertilizer per rai because it is generally fertilizer responsive varieties.

In the central regions, most farmers cultivate second rice using the highest fertilizer per rai followed by the northern region because the irrigation in the central and the lower part of northern regions are well developed and made it suitable for cultivating second rice.

Figure 2.4

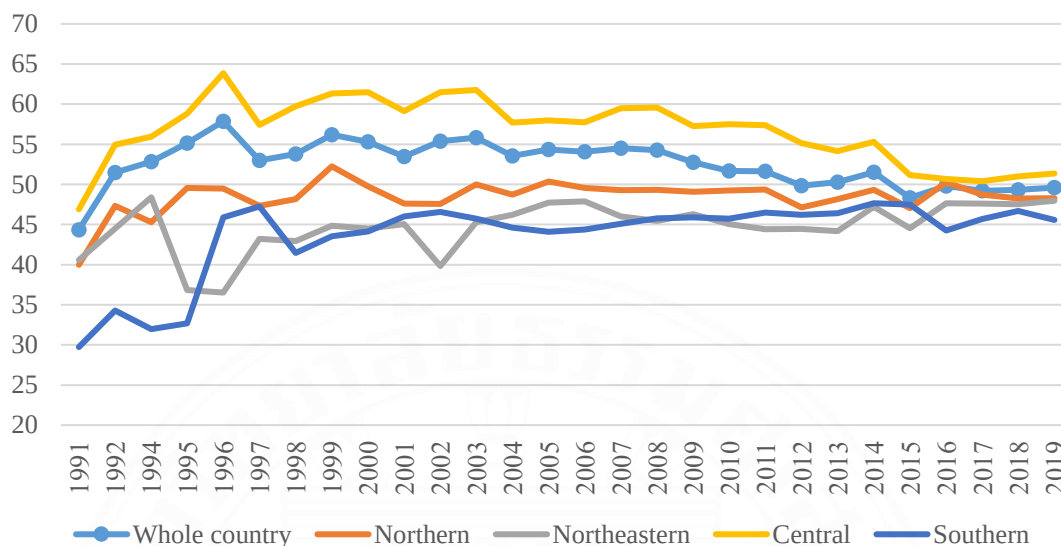
Chemical fertilizer used in the main rice (kg/rai)



Note. Author's visualization based on OAE data.

Figure 2.5

Chemical fertilizer used in the second rice (kg/rai)



Note. Author's visualization based on OAE data.

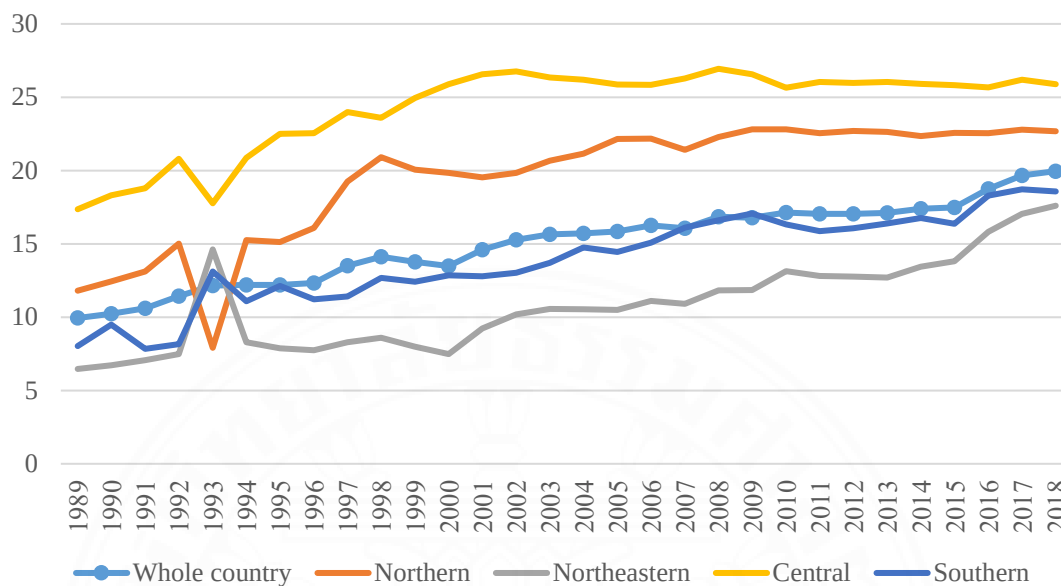
2.4.5 Seed used

Seed use per rai for main rice increased in all regions. The region that has the highest seed use per rai is the central region followed by the northern region. This may be due to land limitations and farmers trying to maximize yield of the main rice by increasing the use of seeds and fertilizers.

However, there was a different pattern in seed use for second rice across the regions. The seed used in central and northern regions is higher compared to northeastern and southern regions. This is because the central and northern (lower northern to be more specific) are more suitable for cultivating second rice and have already adopted new varieties for a long time. Farmers in these regions have been farming rice in an industrial manner, which uses their inputs more intensively. Northeastern and southern regions were relatively less developed in the irrigation system and slower in adopting the new varieties. However, the farmers in these regions are transitioning to the modern varieties over time and this caused an increase in seed use per rai in these regions to catch up with the central and the northern region.

Figure 2.6

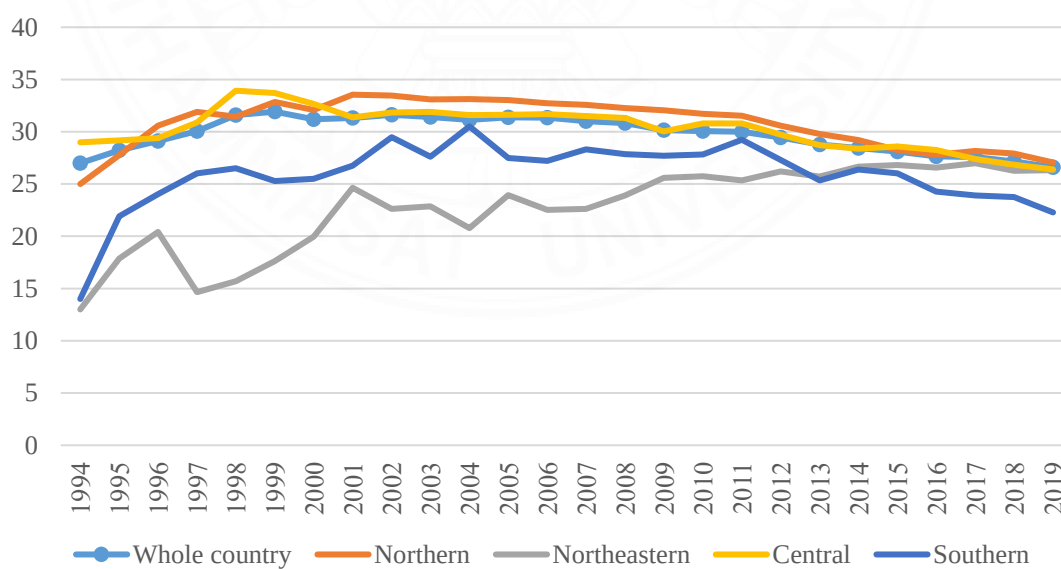
Seed used in the main rice by regions (kg/rai)



Note. Author's visualization based on OAE data.

Figure 2.7

Seed used in the second rice by regions (kg/rai)



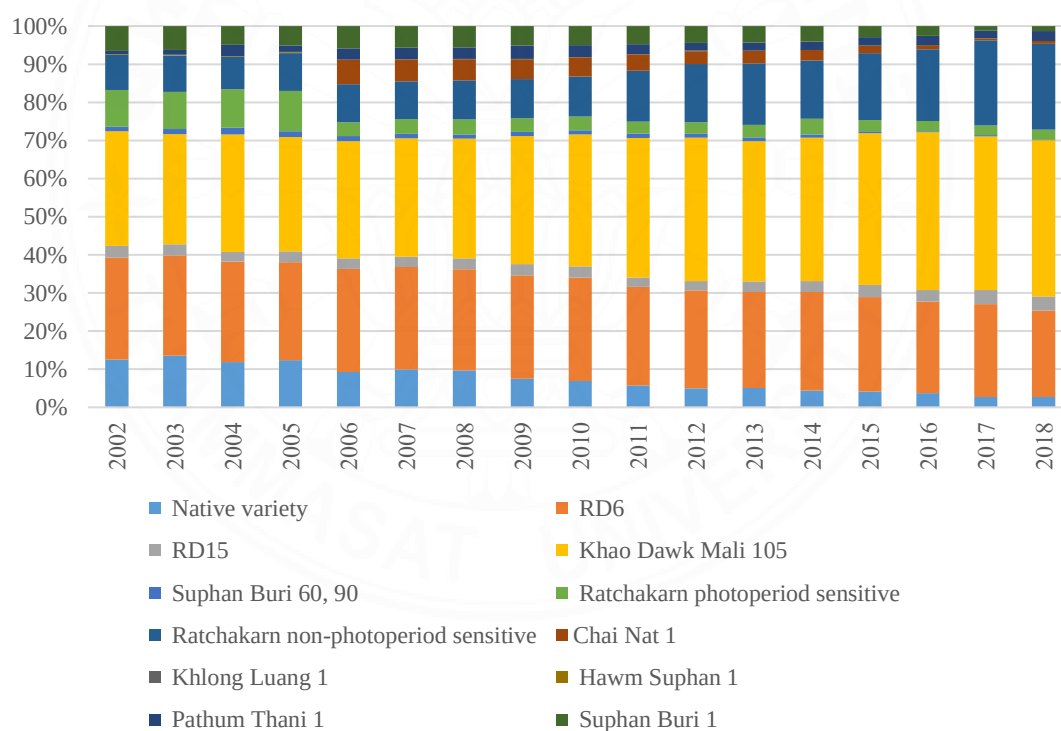
Note. Author's visualization based on OAE data.

2.4.6 Variety of rice

Rice farmers in Thailand are changing to cultivate modern varieties of rice over time. For the main rice, the shared area of cultivation for native varieties declined from 12.51% in 2002 to 2.70% in 2018. Meanwhile, the share of Khao Dawk Mali 105, mostly cultivated in northeastern regions, increased from 30.06% to 40.94% over the same period. Other popular varieties which account for a large share of cultivation land were RD6 and Ratchakarn non-photoperiod sensitive varieties. And the least popular rice but still cultivated in 2018 were Hawm Suphan 1 (0.03%), Suphan Buri 60 & 90 (0.13%), and Chai Nat 1 (0.77%).

Figure 2.8

Variety of the main rice (share of total planted area)

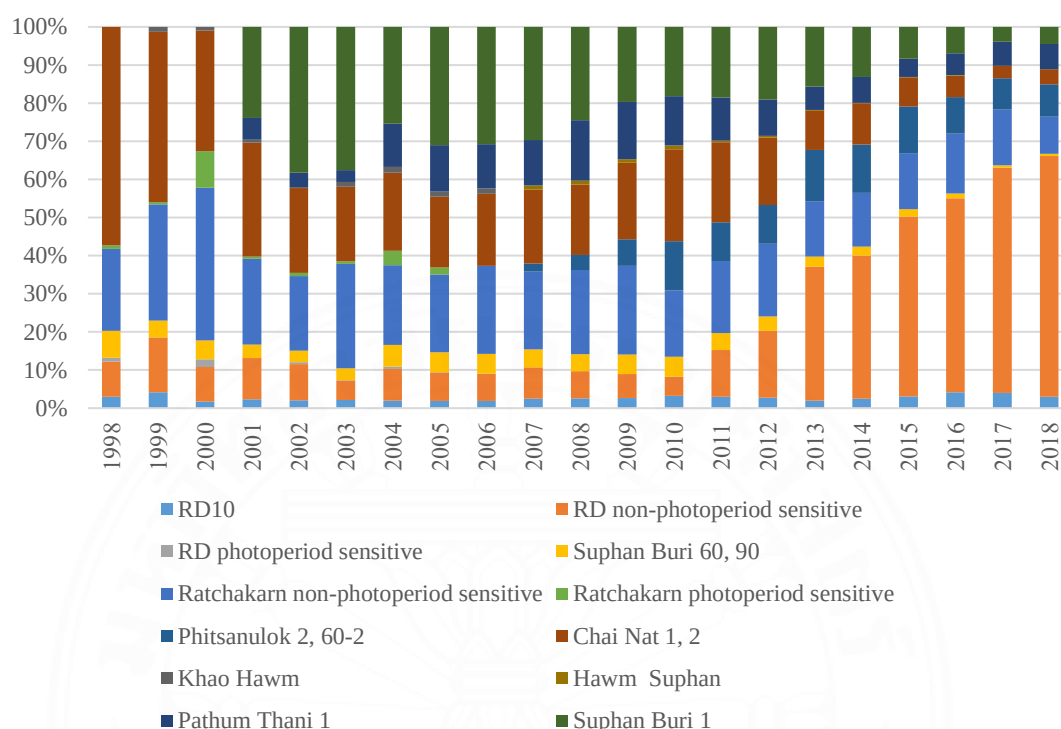


Note. Author's visualization based on OAE data.

Rices cultivated as the second rice are already the modern varieties. The most common variant is RD non-photoperiod sensitive, which shared 63.12% of cultivation land in 2018. This variant replaced Chi Nat 1&2, Suphan Buri 1, and Ratchakarn non-photoperiod sensitive that used to be the dominant varieties.

Figure 2.9

Variety of the second rice (share of total planted area)



Note. Author's visualization based on OAE data.

2.4.7 Technology adoption

Modern technology and machine are used in rice farming including knapsack sprayers for applying fertilizers and pesticides, tractors for plowing the soil, combined harvesters for harvesting and threshing paddy, and transplanter. These technologies can help to reduce labour and time use in the farming process. However, some of these technologies require a high amount of initial investment and need certain scale of operating to reach the break-even point. The majority of the farmers is the small farm owners who have limited resources (Kwanmuang et al., 2020). As a result, the farmer or entrepreneur who owns these machines lends them out or works as outsource of a partial part of the farming process. Especially, the owner of the combined harvester may take the harvesting and threshing job across the province or even across the region.

Drone is considered as one of the new wave technology that is widely adopted in the agriculture sector including rice farming. It can use for sowing, applying fertilizer and pesticide, and monitoring the field. Drone with AI can map the field and

create routes of operation to work automatically. In comparison to a knapsack sprayer, these drones require less time and labor, and they also perform more efficiently in terms of precision and evenness in applying fertilizer and pesticides. Except for the price, drones have a few limitations in terms of use. Thus, they are growing in popularity and being adopted in all locations.

IoT is a useful system for connecting data from various sensors and devices into one operating hub. With robots, IoT can automate many farming tasks. Many private companies attempt to utilize the IoT, big data, and introduce precision farming/agriculture. ListenField, for example, is a company that uses satellite data to assert the growth stage and anomalies of rice. The company also collects soil quality data, forecasts the weather and rain, and uses AI to create a rice-growing model. The model can provide recommendations that farmers can use for planning their farming to improve their productivity. The company already operates in Japan, Thailand, India, Vietnam, and the United States, with more than 10,000 farmers using the services (SME Thailand Club, 2022).

Another example of a private company that promotes smart farming is SIAM KUBOTA. This company has developed a one-stop agriculture system that utilizes new technologies called KUBOTA Agri Solution (KAS). KAS uses IoT and robots (such as drones) to reduce labor and cost of farming as well as improve efficiency. They also employ sensors to collect data in order to create a crop calendar for farm management. For example, they use chlorophyll meter to determine whether there is enough fertilizer in the soil and the appropriate time to reapply it. The company founded a learning center, KUBOTA Farm, on an area of 220 rai in Chon Buri province (Dasree, 2020).

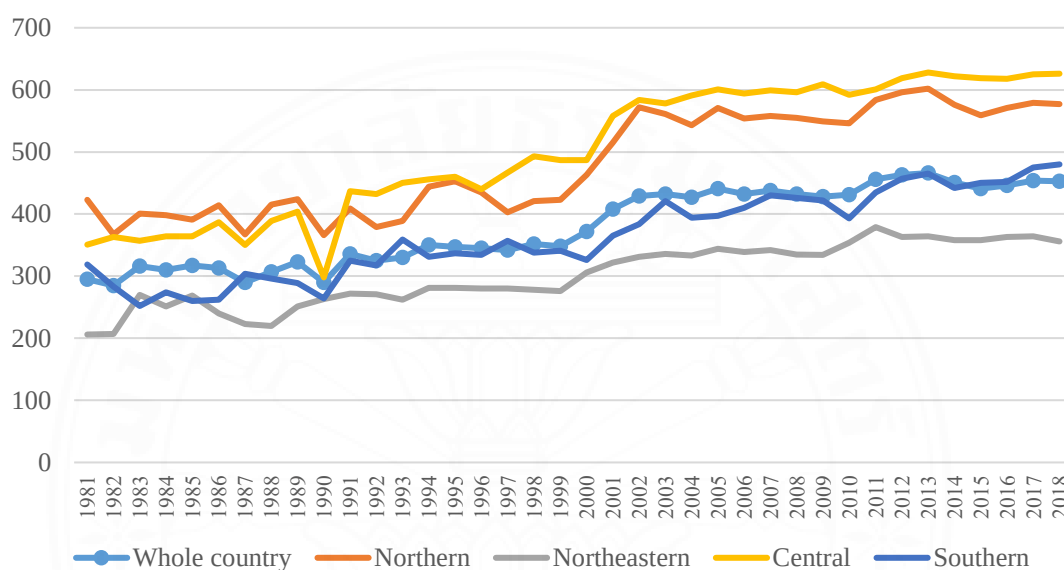
2.4.8 Yield of rice

There is a substantial difference in yield between the main rice and the second rice. Second rice has a higher yield than main rice in all regions. This is because second rice is the modern variant with non-photoperiod sensitive and fertilizer responsive characteristics. Together with the well-developed irrigation system, these contributed to the high yield of second rice in the central and northern regions. Moreover, the yield of the main rice in the central and northern are also higher than other regions and are approaching the number of second rice.

However, the yield of rice in Thailand has little improvement over the three decades. From 1988 to 2018, the average annual growth in yield is 1.41% for main rice and is 0.6% for second rice.

Figure 2.10

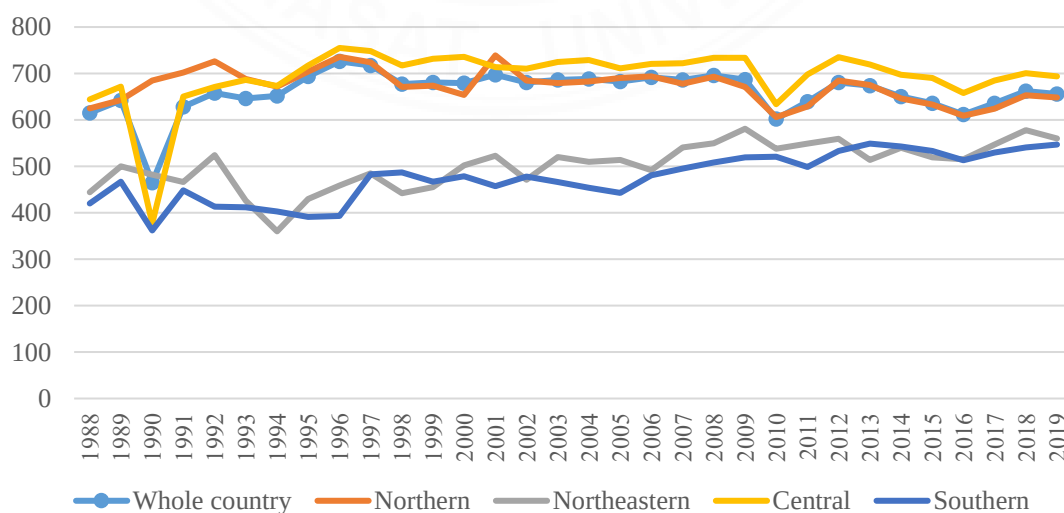
Yield of the main rice (kg/rai)



Note. Author's visualization based on OAE data.

Figure 2.11

Yield of the second rice (kg/rai)



Note. Author's visualization based on OAE data.

CHAPTER 3

REVIEW OF LITERATURE

This section provides the review literature on the method used in this study and also provides empirical research on the topic of efficiency and total factor productivity of rice at the international level, country level, and in the case of Thailand.

3.1 Production efficiency

Farrell (1957), following the work of Debreu (1951) and Koopmans (1951), defined a simple measure of firm efficiency which is radial efficiency measurement based on the production frontiers. The efficiency of a firm or economic efficiency consists of technical efficiency and allocative efficiency. The first component reflects the ability of the firm to obtain maximal output from a given set of inputs. The second component reflects the ability of the firm to optimize the proportions of the inputs given their respective process and production technology.

Measuring the efficiency of firms has become popular because the concept of decision-making units (or firms) can apply to many other activities. The most popular methods employed in the literature include Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA).

3.1.1 Stochastic Frontier Analysis

Stochastic Frontier Analysis (SFA) is based on the production frontier proposed by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1997). The SFA model is called the stochastic production frontier because the output values are bounded from the above by stochastic variables. The SFA is a parametric approach that requires a specified functional form to represent the production process. The functional form commonly used in SFA include Cobb-Douglas and Translog. Besides specifying the functional form, the SFA also requires the specification of the probability distribution of noises (i.e., random and external shocks) and inefficiency incorporated in the model. Assuming a functional form of frontier and the distribution of inefficiency and random shock becomes the drawback of this

method. However, the SFA has its advantage because this method allows the statistical testing of the estimated frontier.

3.1.2 Data Envelopment Analysis

Data Envelopment Analysis is a non-parametric approach for measuring a firm's efficiency by using the linear programming method. The first DEA model was proposed by Charnes, Cooper, and Rhodes (1978), the so-called CCR DEA model. It is an input-oriented and assumed constant return to scale (CRS) production technology. Subsequently, Banker, Charnes, and Cooper (1984) proposed an alternative assumption of variable returns to scale (VRS) production technology, the so-called BCC DEA model.

The advantage of DEA is in its nature of the nonparametric method. First, DEA does not require a prior functional specification to proxy the relation of input and output in the production process. Second, DEA does not require assumptions on the distribution of inefficiency. However, DEA employs the exact value of each DMUs to construct and measure the efficiency score. Hence the noise and measurement errors are ignored in calculating the efficiency score. Therefore, the efficiency score obtained from the DEA method is generally lower than the SFA method

3.2 Malmquist Productivity Index

Malmquist Productivity Index (MPI) is an index representing Total Factor Productivity (TFP). According to Comin (2010), TFP is defined as “the portion of output not explained by the amount of inputs used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in production.”

In the literature, TFP is related to technology and innovation and plays a critical role in economic fluctuations, economic growth, and the differences in cross-country income per capita. The concept of the MPI was first introduced by Malmquist (1953) and was redefined by Caves, Christensen, and Diewert (1982). The MPI can be decomposed to reflect progress or regress in efficiency as well as progress or regress of the frontier technology over time.

Caves, Christensen, and Diewert (1982) established a certain relationship between the Malmquist index and the Törnqvist index. Under translog production

structures, Törnqvist output and input indexes are equal to the geometric mean of two Malmquist indexes. When measuring the MPI, Caves, Christensen, and Diewert (1982) described it as

“There are two natural approaches to the measurement of productivity differences. One approach treats productivity differences as differences in maximum output conditional on a given level of inputs. This approach leads to output-based productivity indexes. The alternative approach treats productivity differences as differences in minimum input requirements conditional on a given level of outputs. This view leads to input based productivity indexes.”

Growth in the MPI can be decomposed into two major components: 1) changes in the level of efficiency or “catching-up” which reflects the ability of the decision-making unit to improve its efficiency over the period and 2) changes in the frontiers, or “technical change” which reflects the ability of the decision-making unit to adopt new technology and improve efficient frontier over time.

After Caves, Christensen, and Diewert (1982) defined the MPI using a distance function. Then, Färe et al (1994) applied the MPI by using Data Envelopment Analysis (DEA) framework and it becomes the standard approach in productivity measurement.

3.3 Empirical research

This section presents a review of empirical research in the literature on efficiency, TFP, and MPI measurement in the agricultural sector and rice production at the cross-county level, national level, and in the case of Thailand.

3.3.1 Efficiency of rice production in other countries

Efficiency measurement is a useful approach for understanding the efficiency of production and investigating the factors that are affect production’s performance. The insight from this approach makes it popular and widely employed in many types of production and operation including the rice industry.

Xu and Jeffrey (1998) applied a dual stochastic frontier efficiency decomposition model to study the efficiency of hybrid and conventional rice production

in China. Using the sample of 90 hybrid rice households and 90 conventional rice households, they found that hybrid rice production was much more elastic with respect to modern inputs (chemical fertilizer, and pesticides) than conventional rice production. Conventional rice has an average higher economic, technical, and allocative efficiency than the hybrid rice. Lastly, they investigated the determinants of rice efficiency and found that farm size had a positive influence on rice production efficiency for modern agricultural regions but had a negative influence in traditional farming areas.

In the literature, there exist many studies of the production efficiency of rice in Bangladesh. Coelli et al. (2002) applied the DEA method to measure the efficiency of 406 Bangladesh rice farms. The average technical efficiency, allocative efficiency, and cost efficiency score for Aman rice (Boro rice) in 1997 were 66.2% (69.4%), 78% (81.3), and 51.7% (56.2%) respectively. The study also found that older farmers were more cost-efficient in Boro rice production but more farming experienced farmers were less technical and cost-efficient. The finding may be explained by that experienced farmers who already have high knowledge about their land and traditional practices are less willing to adopt new technique and technology. Poor infrastructure was found to have negative effects on technical, allocative, and cost efficiency scores for both Aman and Boro rice.

Wadud (2003) employed 150 farm surveys from two villages in the High Barind region of Bangladesh to measure farm efficiencies. By applying both SFA and DAE methods in the study. The results of the SFA showed that the averages technical efficiency, allocative efficiency, and economic efficiency for the first approach were 80%, 77%, and 61% respectively. Average technical efficiency, allocative efficiency, and economic efficiency obtained from the DEA method were 86%, 91%, and 78%, respectively for the constant return to scale specification, and were 91%, 87%, and 79%, respectively for the variable return to scale specification. The results were in contrast to the main suggestion in the literature that the mean technical efficiency scores of the SFA method should be greater than the DEA. Inefficiency analysis shows that year of schooling was negatively and significantly related to allocative inefficiency but the positive relation with technical inefficiency was insignificant. Average farmers with greater plot sizes operated at a higher level of technical, allocative, and economic efficiencies. Land degradation was an obstacle in

improving technology efficiency and hindered the cost-minimizing input. Thus, policies that aim to reduce land degradation could enhance efficiency of farming.

Balcombe et al. (2008) employed the double bootstrap DEA method to estimate the technical efficiency of rice farming in Bangladesh. The results from 295 farmers showed that average technical efficiency scores were 64% for CRS and 59% for VRS. Age of the farmer affects the efficiency score; older farmers are more likely to be technically inefficient. A positive relationship between education and technical efficiency was found to be statistically significant. Ownership of land, access to credit, and farm size proved to be positively related to technical efficiency albeit statistically insignificant. And off-farm income had a negative impact on technical efficiency but was not significant.

In Pakistan, Abedullah and Musgtaq (2007) employed the SFA approach to measuring the technical efficiency scores of 200 farmers in Punjab. The average technical efficiency score of the sample in the study was 91% with 182 farmers operating between 80% to 100% of the score level. Farm size has a significant negative relation to the efficiency score while the year of schooling, owning a tractor, and plant to plant distance were significantly and positively related to the efficiency score.

Huynh et al. (2011) applied the SFA approach to measuring the technical efficiency of rice farmers in Vietnam. Using the survey in 2005-2006 of 3,733 rice farmers, they found that the average technical efficiency of Vietnamese rice farmers is 81.6%, which is ranging from 16.5% to 98.5%, and more than half of the sample (67.3%) operated at more than 80% of technical efficiency level. The most important factor that affects Vietnamese rice technical efficiency was the intensity of labour in farming; the more intensive the labour investment in rice land is related to a higher level of technical efficiency. And the farmers in well-irrigated areas produced rice more efficiently compared to those in non-irrigation areas.

The decision-making units (DMUs) in measuring efficiency can be applied in the aggregate level to examine the impact of the difference in policy or the characteristic that govern the DMUs. Hossain et al. (2012) applied the SFA approach to measuring the technical efficiency of three types of rice (Aus, Amam, and Baro) in Bangladesh. They found that Boro rice, which is dry season rice, was the most efficient among the three types of rice produced. Technical efficiency scores from half-normal

were 51%, 42.3%, 98.3%, and 63.9% for Aus, Aman, Boro, and overall rice production respectively. And for truncated-normal specification, the technical efficiency was 47%, 37.6%, 87%, and 57.2% for Aus, Aman, Boro, and overall rice production respectively.

In India, Pradhan (2018) measured rice's technical efficiency of 30 districts in Odisha using the DEA approach. The mean technical efficiency score for all 30 districts is 79.1%, with 5 districts are at 100% and the lowest is 54.4%.

Sun and Li (2021) used data from 22 Chinese rice production provinces to study the technical efficiency of chemical fertilizer use (TEFU). The result from the SFA shows that the average TEFU had been fluctuating during 1997–2005 and rising during 2006–2018. TEFU in 2018 was 65.1%, 59.7%, 62.3%, and 53.8% for early indica rice, intermediary indica rice, late indica rice, and japonica rice respectively. While natural disasters and fertilizer prices had a significant negative impact on TEFU, the government's financial support for agriculture, agricultural labor productivity, agricultural mechanization, efficient irrigation, and implementation of the Soil Testing and Formulated Fertilization Program had a significant positive impact on TEFU.

3.3.2 Cross-country agricultural TFP growth

Many empirical studies measured agricultural total factor productivity of cross-country by using the Malmquist productivity index (Arnade, 1994; Fulginiti & Perrin, 1997; Suhariyanto & Thirtle, 2001; Coelli & Rao, 2005; Luh, Chang & Huang, 2008; Rungsuriyawiboon & Wang, 2009; Rungsuriyawiboon & Wang, 2012)

Arnade (1994) studied technical efficiency and total factor productivity during 1961-1987. He classified 77 countries into 4 groups of agricultural technology; advanced technology, middle technology, low technology, and Asia rice technology. He found that even most of the Asian countries were considered efficient, these countries experienced declining agricultural total factor productivity, except for Japan, Malaysia, North Korea, and Taiwan. Most of the advanced-technology countries that have positive productivity are driven by technological progress. For many middle-technology countries, changes in productivity and technology have fluctuated. And with exception of Egypt, Honduras, Iraq, Sudan, and Zimbabwe, productivity was declining for all low-technology countries.

Trueblood and Coggins (2003) measured the total factor productivity of agriculture in 115 countries over the period of 1961-1991. They found that while North America and Western Europe experienced high growth, Asia and Sub-Sahara Africa showed average negative growth during the period of study. The reason behind these results is the global decline in agricultural productivity during the 1960s and 1970s but it rebounded in the 1980s. The results consist with Fulginiti and Perrin (1997) who found that on average 18 developing countries, including 5 Asia countries, experienced negative productivity growth during 1961-1985.

In contrast to Trueblood & Coggins (2003) and Fulginiti & Perrin (1997) studies, Suhariyanto and Thirtle (2001) found that on average 18 Asia countries experienced agricultural TFP growth of 0.31% annually from 1965 to 1996. Still, about half of the countries were experienced negative productivity growth in which influenced by both losses in technical efficiency and stagnation in technological progress.

Coelli and Rao (2005) investigated technical efficiency and total factor productivity growth in agriculture of 93 countries around the world in 1980-2000. The mean technical efficiency score is 0.784, 0.806, 0.842 in 1980, 1990, and 2000 respectively. North America and Australasia are considered to be technically efficient continents. The weighted means of TFP change, technical change, and efficiency change of all countries throughout the study are 2.1%, 1.2%, and 0.9% respectively. Asia posted the highest TFP growth of 2.9% annually followed by North America, Australasia, Europe, Africa, and South America.

A Study by Luh, Chang, and Huang (2008) shows that domestic R&D is an important determinant of the growth in the agricultural sector for most East Asian economies. They highlight the importance of human capital in the production process in order to achieve “catching-up” or “frontier-shift” effects from neighbor’s innovation.

Rungsuriyawiboon and Wang (2009) used the Malmquist productivity index based on the SFA approach to measure agricultural TFP growth of 27 Asia countries with an emphasis on transition countries. They found that Southeast Asia countries experienced agricultural productivity progress during 1980-2004, mostly contributed from technical change effect. But the rate of growth in Southeast Asia countries (1% annually) is less than the average growth of overall Asia countries

(1.9% annually), and only superior to the western- and eastern-Asia. The relatively high rate of Asian agricultural TFP growth was mainly driven by technical improvement (2.02% per annum). TFP growth rate could have been higher if they did not experience downtrends in technical efficiency changes (-0.16% annually). In 2012, they conducted another study with more emphasis and coverage on a wide range of transition countries in Europe and Asia, 35 countries in total, over the period 1979-2004 (Rungsuriyawiboon & Wang, 2012). This time they applied the Malmquist productivity index based on the DEA approach to measure TFP growth. They found that transition economies had substantial improvement in agricultural productivity over two decades, with TFP growth of 3.65% per annum. Still, the aspect behind productivity progress in transition countries was the technology improvement or “frontier-shift” effect.

The results from all of these studies seem to imply that on average Asia agriculture sector experienced a regress in productivity from 1960 to the late 1970s then had a substantial growth after 2000. For Thailand, the results from many studies settled that Thailand, on average, experienced total factor productivity regress, i.e., negative growth, in agriculture for four decades; -1.4% annually during 1961-1993 (Arnade, 1994); -6.4% annually during 1961-1985 (Fulginiti & Perrin, 1997); -1.0% annually during 1965-1996 (Suhariyanto & Thirtle, 2001); -1.1% annually during 1961-1991 (Trueblood & Coggins, 2003); -0.5% annually during 1980-2000 (Coelli & Rao, 2005); -0.8% annually during 1961-2001 (Luh, Chang & Huang, 2008).

3.3.3 Total factor productivity of rice production in other countries

The total factor productivity measurement can apply not only in terms of the agriculture sector as a whole but can focus on more details of the activities such as rice production. This section provides the example of studies that investigate the total factor productivity of rice in other countries.

Coelli and Nhhiem (2002) investigated the TFP of rice production in Vietnam using panel data of eight agricultural regions over the period of 1976 to 1997. By applying the modified Malmquist productivity index, they found that the average TFP growth rate of rice production in Vietnam was between 3.3% to 3.5% per annum. Technical progress was the main aspect that contributes to the TFP growth whereas the catch-up effect had a little effect over the period of study. They also found that agricultural reform in 1981-which allow farmers to keep the surplus amount of rice they

produced, besides the amount that has to sell to the state by contracted price, for domestic consumption or for sale to the traders-have a significant role over the TFP growth by providing incentive for farmers to improve their production.

In Bangladesh, many studies try to measure the TFP growth of the agricultural sector included rice industry, which is one of their main staples. By applying the Fare-Primont index, Rahman and Salim (2013) investigated the TFP growth of the agricultural sector in 17 regions of Bangladesh. From 1948 to 2008, agricultural TFP grew about 0.57% per annum, on average, and was largely driven by technical progress. High-yielding varieties, representing green revolution technology, were found to be a significant determinant of technical change as well as scale-efficiency change but not significant in TFP growth. R&D investment was positively influenced technical changes, technical efficiency changes, and TFP growth. They also found that crop diversification is significantly positively influenced technical change and technical efficiency change. But, strangely, crop diversification had significant negative relations to TFP growth.

Focusing more on the rice sector, Hossain et al. (2012) applied Stochastic Frontier Approach and Data envelopment Analysis to measure the TFP of Bangladesh rice for 1989-2008. Three types of rice (Aus, Amam, and Baro) in Bangladesh have different TFP growth and are sensitive to the method used in measuring. On average, TFP growth of rice measured using Half normal-SFA (Truncated normal-SFA) is 5.2% (3.5%), 3.3% (-0.8%), and 3.2% (4.1%) annually for Aus, Aman, and Boro rice respectively. While TFP growth from DEA is 7.6%, 1.9%, and -0.6% per annum for Aus Aman and Boro rice respectively.

In Bangladesh, there is a joint crops system called “gher” in which freshwater prawn, crap, and High-yielding variety of Boro rice are circulating cultivated in the different seasons of a year. Applying the Fare-Primont index on 90 “gher” farms over the period 2002 to 2014 period, Rahman et al. (2020) found that TFP grew at the rate of 0.86% annually and was mainly driven by technical change at 0.54% per annum and mix-efficiency change at 0.06% per annum. However, they found that technical efficiency and scale efficiency changes were decline by 0.17% and 0.10% per annum, respectively. So the TFP growth of the agricultural sector and rice sector in Bangladesh mainly came from technical change, aka frontier-shift effects. In other words, the

improvement in Bangladesh's agriculture sector is mainly driven by adopting new technology.

There are studies that use aggregate data such as provincial rice production to investigate the TFP growth. This type of study allows researchers to investigate spatial and convergence features of the results. Liu (2015) study the TFP growth of 12 China's major Japonica rice-producing areas from 2001 to 2012. Lui found that only two out of twelve provinces experienced positive TFP growth. The average TFP growth of all areas is -2.3% per annum. This negative trend was mainly due to technical regress, on average, at -2.2% per annum; only provinces that have positive TFP growth experienced technical progress. Then Lui investigated the convergence of TFP of rice among these areas and found the sign of the sigma-convergence feature.

Kondo et al. (2017) investigated partial factor productivity and total factor productivity of rice production across 42 prefectures of Japan during 1996 to 2006. In terms of partial productivity, they found that while most prefectures experienced labour productivity progress at more than 1% annually, capital productivity, land productivity, and materials productivity are stagnated for most prefectures. The aggregate national growth rate of labour productivity, capital productivity, land productivity, and materials productivity was 2.52%, 0.394%, 0.007%, and 0.675% per annum respectively. TFP growth over 1996-2006 was 0.802% annually with technical progress at 1.271% per annum but drawback by technical efficiency regress at -0.466% per annum. In the second step, they tested for the convergence of TFP across prefectures using the panel unit root tests and found evidence for convergence in TFP across the prefectures of Japan.

In India, Pradhan (2018) measured the TFP of rice of 30 districts in Odisha by applying the Malmquist productivity index. From 2011 to 2013, TFP growth was 25.6% annually, with only one district experiencing negative TFP growth. All districts in Odisha have technical progress but for technical efficiency changes 14 districts were regressed, 13 districts were progressed, and 3 districts were no changes over the period of the study.

The summary of past studies about the efficiency and total productivity of rice and agricultural products across country is shown in Table 3.1.

Table 3.1

Studies on efficiency and total productivity of agriculture and rice production across country

Study	Topic of study	Method	Year	Country	Main finding
Arnade (1994)	TFP in agriculture	DEA MPI	1961-1987	77 countries	- Asian countries consider to be efficient over all the period of study except for North Korea, Cambodia, Vietnam, and Sri Lanka, however, many Asian countries experienced declining in agricultural productivity including Thailand. - Agricultural productivity gains were greatest in Northern European countries - Most advanced agricultural technology countries lie on the best-practice frontier for most years. - There was wide variation in the technology and productivity indices of middle-technology countries. - Except for Egypt, Honduras, Iraq, Sudan, and Zimbabwe, productivity declined for all low-technology countries
Fulginiti and Perrin (1997)	TFP in agriculture	DEA MPI	1961-1985	18 developing countries Less develop countries	- Less developing countries experienced a decline in agricultural productivity - The high tax rate on agricultural products is related to negative productivity growth.
Xu and Jeffrey (1998)	Efficiencies of rice production	SFA	1985-1986	China	- The average TE, EE, AE of hybrid rice production is lower than that of the conventional rice production - Hybrid rice production is more elastic with respect to chemical fertilizer and pesticides than conventional rice production - Land size is a positive factor in explaining the efficiencies of hybrid rice production in modern agricultural areas.
Suhariyanto and Thirtle (2001)	TFP in agriculture	MPI	1965-1996	18 Asia countries	- On average, Asia agricultural TFP grew at 0.31% per annum - Half the observations have experienced negative productivity growth due to losses in TE combined with stagnation in technological progress

Table 3.1

Studies on efficiency and total productivity of agriculture and rice production across country (Cont.)

Study	Topic of study	Method	Year	Country	Main finding
Coelli et al. (2002)	Efficiencies of rice production	DEA	1997	Bangladesh	• North Korea, Cambodia, Myanmar, Thailand, Vietnam, and all South Asian countries, except Sri Lanka, experienced declining TFP during 1965-1996 • Thai TFP growth is -1% due to TEC at -1.32% overcome TC at 0.33 • No evidence of convergence in agricultural productivity for countries in the study • The mean TE, AE, and CE of Boro rice season are higher than that of Aman rice season. • In labour intensive and Aman season, farmers who own land are more cost efficient . • Larger families are related to lower efficiencies in the less labour intensive Boro season • Old and experienced farmers have more knowledge about their land and familiar with traditional practices are less willing to adopt new technology • Poor infrastructure has negative effects on TE and AE • Larger farms are related to more allocative- and cost-efficient in the Aman season
Coelli and Nhhiem (2002)	TFP in agriculture	Tornquist index, MPI, The Three-Year-Window (TYW) DEA, The Full Cumulative (FC) DEA	1976-1997	Vietnam	• Rice productivity growth in Vietnam was higher after the two incentive reforms was introduced in 1981 and 1987 • TFP trends before and after the reform are significantly different. • The average annual TFP growth was 3.5% 3.3% and 3.1% from TYW, FC, and Törnqvist methods respectively • The vast majority of this TFP growth is due to technological change, while the average estimate of catch-up only contributes between 0.0% and 0.4% per year

Table 3.1

Studies on efficiency and total productivity of agriculture and rice production across country (Cont.)

Study	Topic of study	Method	Year	Country	Main finding
Trueblood and Coggins (2003)	TFP in agriculture	MPI	1961-1991	115 countries	- Global agricultural productivity declined during the 1960s and 1970s but rebounded in the 1980s - Agricultural productivity in the developing countries was declined - Developed countries exhibited positive productive growth - There were high growth in the North America and Western Europe while Asia and Sub-Sahara Africa showed negative growth.
Wadud (2003)	Efficiencies of rice production	DEA, SFA	1997	Bangladesh	- Mean TE, AE, and EE for SFA are 80%, 77%, and 61% respectively. - Mean technical, allocative, and economic efficiency for CRS-DEA is 86%, 91%, 78%, respectively, and 91%, 87%, 79% for VRS-DEA - Farmers with more education are having more allocative efficiency. - Farmers with greater plot size operated at a higher level of technical, allocative, and economic efficiency - Land degradation causes obstacles in applying technology and hinders the cost-minimizing input
Coelli and Rao (2005)	TFP in agriculture	MPI, DEA	1980-2000	93 countries	- Mean TE score of all countries is 78.4%, 80.6%, and 84.2% in 1980, 1990, and 2000 respectively - The average TFP growth of all countries was 1.1% annually with TEC at 0.5 % and TC at 0.6% per annum - Asia had the highest TFP growth at 2.9% annually - The average TFP growth of Thailand during 1980-2000 was -0.5% per annum due to TEC at -0.6%
Abedullah and Musgtaq (2007)	Technical efficiency of rice production	SFA	2005	Pakistan	- Mean TE score was 91% - An inappropriate combination of fertilizer has a negative impact on rice production.

Table 3.1

Studies on efficiency and total productivity of agriculture and rice production across country (Cont.)

Study	Topic of study	Method	Year	Country	Main finding
Balcombe et al. (2008)	Technical efficiency of rice production	DEA double bootstrap	2008	Bangladesh	• Means TE score was 91% • An inappropriate combination of fertilizer has a negative impact on rice production • Older farmers tend to be technically inefficient • Education and extension are positively related to technical efficient of the farm • Ownership, credit, and area variables are positively related to technical efficiency in both, yet statistically insignificant • Off-farm activity has a negative impact on TE
Luh, Chang, and Huang (2008)	TFP in agriculture	MPI	1961-2001	8 East Asian countries China, Indonesia, Japan, Korea, Malaysia, Philippines, Taiwan, and Thailand	• Agricultural productivity in Thailand, Philippines, and Indonesia economies has deteriorated due to the dominant effects of technical regress over the improvement in efficiency • Malaysia and Japan have improvements in productivity over time driven by consistent technical progress and improvement in efficiency. • Domestic R&D is an important determinant factor for the agricultural growth in most East Asian countries
Rungsuriyawiboon and Wang (2009)	TFP in agriculture	MPI, SFA	1980-2004	27 Asian countries	• The average annual growth rate of TFP across the Asian region was 1.857% • The growth rate of TFP in SEA was about half that of Asia as a whole. • TFP growth was trivial during 1980-1995 and was accelerated after that period. • TFP growth was mainly driven by technological progress and could have been higher if not pulled back by the decline in TEC

Table 3.1

Studies on efficiency and total productivity of agriculture and rice production across country (Cont.)

Study	Topic of study	Method	Year	Country	Main finding
Khai and Yabe (2011)	Technical efficiency of rice production	SFA	2006	Vietnam	• Vietnamese farmers were operating at increasing returns to scale • The average TE of Vietnamese rice farmers is 81.6% • Experience, high school education, and irrigation are related to a higher level of TE • Labor-land ratio is the biggest related variable related to more TE • Farmers who have a higher ability to improve their standard of living tend to be more technically efficient.
Hossain et al. (2012)	TFP, Technical efficiency of rice production	DEA, SFA	1989/90 and 2008/09	Bangladesh	• The average TE of rice production from 1989–1990 to 2008–2009 is 57.2% in SFA with truncated normal distribution, while the average technical efficiency is 63.9% in SFA with half-normal distribution. • Boro rice was the most efficient produced compared to Aus and Aman rice. • The annual average TFP growth is 3.90% and 2.30% for SFA with half-normal and truncated normal respectively and at 2.95% for DEA
Rungsuriyawiboon & Wang (2012)	TFP in agriculture	MPI, DEA	1979-2004	35 transition countries in Asia and Europe.	• The average TFP growth across all transition countries was 3.65% annually • Relatively high rate of TFP growth in these transition countries is mainly driven by technological progress; the adoption of new technologies • The annual growth rate of TFP across the Asian countries over the transition period was 4.73%
Rahman and Salim (2013)	TFP in agriculture	Färe-Primont index Generalised least squares	1948-2008	Bangladesh	• The annual average TFP growth was 0.57% in which largely driven by technological progress at 0.74% annually • TEC and SEC was at 0.01% per annum

Table 3.1

Studies on efficiency and total productivity of agriculture and rice production across country (Cont.)

Study	Topic of study	Method	Year	Country	Main finding
					• TFP growth went through a cycle of the Green revelation (GR) – The cycle of lower rates of TFP growth during the early stages of GR then rising during the post-GR period. • The GR technology is a significant determinant for both technical change and scale-efficiency change, but has no significant impact on TFP growth • TFP growth are positively influenced by farm size, R&D investment, and extension expenditure. • Crop diversification positively influenced technical change and technical-efficiency change but crop specialization positively related to TFP growth
Lui (2015)	TFP in agriculture	MPI	2001-2012	China	• The average annual TFP growth was -2.3% caused by technical regress at -2.2% • China's Japonica rice production had sigma convergence
Kondo et al. (2017)	PFP, TFP in agriculture	DEA, MPI	1996-2006	Japanese	• Annual PFP growth was 2.52% for labour 0.394% for capital 0.007% for land and 0.675% for materials • The average annual TFP growth was 0.802% with TEC at -0.466% and TC at 1.271% • There is evidence for convergence in TFP across prefectures of Japan
Pradhan (2018)	TFP, Technical efficiency of rice production	DEA, MPI	2011-2013	India	• The mean TE score is 79.1% • 43 percent of districts have made progress, 47 percent regressed and 10 percent remained unchanged
Rahman et al. (2020)	TFP in agriculture	Färe-Primont index, Tobit model	2002-2014	Bangladesh	• The average annual TFP grew at 0.86% which is mainly driven by technical change at 0.54% and mix-efficiency change at 0.06% while technical change and scale efficiency change declined at 0.17% and 0.10% respectively

Table 3.1

Studies on efficiency and total productivity of agriculture and rice production across country (Cont.)

Study	Topic of study	Method	Year	Country	Main finding
Sun and Li (2021)	Technical efficiency of chemical fertilizer used for rice production (TEFU)	SFA, Tobit model	1997-2018	China	• TFP growth rate of ‘Gher’ farming system was much higher than the long-term TFP growth rate of overall Bangladesh agriculture • In ‘Gher’ farming, TFP growth, technical change, and mix efficiency change are improved by farmer experience while it reduces technical efficiency change and scale efficiency • While Education, tenancy, and shared of family labor contribute to technical change and TFP growth, Education and shared of female labor have a negative effect on technical efficiency change • ‘Gher’ operation size related to higher technical efficiency and TFP growth • During 1997–2005, the average TEFU for early indica rice, intermediary indica rice, late indica rice, and japonica rice production had been fluctuated then rising during 2006–2018 • The government financial support to agriculture, agricultural labor productivity, agricultural mechanization, effective irrigation, have a significant positive impact on TEFU • Natural disasters and fertilizer prices had a significant negative impact on TEFU.

Note. Author’s summary

3.3.4 Efficiency and total factor productivity study of rice production in Thailand

Past studies in efficiency measurement of rice production in Thailand mostly used cross-sectional data of farm or household level of some provinces (Sriboonchitta and Wiboonpongse, 2001; Champhech, 2003; Krasachat, 2004; Chaovanapoonphol et al., 2005; Songsrirote & Singhapreecha, 2007; Kiatpathomchai, 2008; Rahman et al., 2009; Butso and Isvilanonda, 2010; Taraka et al., 2010; Sansri et al., 2014; Osti, 2016; Ebers et al., 2017; Panpluem et al., 2019; Jirarud & Suwanmaneepong, 2020). Only some study applies provincial level or aggregate level data to study the technical efficiency of rice production (Nunti et al., 2019; Ke Chung Peng, 2020).

The efficiency score of rice production is sensitive to the sample used in the study. Summary of the efficiency score of past studies is shown in Table 3.2. There are many factors that influence rice farming efficiency in Thailand, especially the characteristic of the farm.

Size of the farm found to have a negative effect on the efficiency level (Rahman et al., 2009; Taraka et al., 2010; Ebers et al., 2017; Panpluem et al., 2019; Jirarud & Suwanmaneepong, 2020). One explanation is that the farmers are operated at decreasing return to scale of production (Songsrirote & Singhapreecha, 2007; Butso & Isvilanonda, 2010; Sansri et al., 2014) in which an increase in output of rice is less than an increase of all input used. The farmers with more area of cultivation may find it hard to maintain good care on the farming over all their cultivated areas compared to the farmers with smaller farm size. However, Kiatpathomchai (2008) and Srisompun & Isvilanonda (2012) observed the opposite that the larger farm size is related to more efficiency.

Rice farming under irrigation areas tends to be more efficient (Butso & Isvilanonda, 2010; Srisompun & Isvilanonda, 2012). However, Kiatpathomchai (2008) found that in Songkhla and Phatthalung rain-fed farms were operated slightly more efficient than irrigated farms while some other studies are not found significant relation at all (Krasachat, 2003; Rahman et al., 2009).

The Organic farming practice also impacts the efficiency score in rice production. Some studies found that organic rice farmers are more technically efficient

compared to conventional rice farmers (Champhech, 2003; Songsrirote & Singhapreecha, 2007). This may be because the organic farmers are spending more attention to taking care of their farms and organic farms are also relatively in smaller size compared to conventional farms.

Lastly, unstable climate and pests impact the production of rice. Sriboonchitta and Wiboonpongse (2005) found the negative influence of neck blast disease and severe drought on the yield of rice and Osti (2016) also found the negative impact of drought on the technical efficiency level.

The difference in socio-economic and characteristics of the farmer household also has an impact on the efficiency level of rice production. Age of the head of household was found to be a significant negative influence on inefficiency score (Sriboonchitta & Wiboonpongse, 2001; Chaovanapoonphol, Battese, & Chang, 2005; Osti, 2016). Still, its close related aspect such as farming experience has a mixed effect on the efficiency level. The experience of the head of household in rice farming was found to have a negative influence on the inefficiency score (Chaovanapoonphol, Battese, & Chang, 2005; Taraka et al., 2012). This may be the result of having more knowledge of the practice and management of rice farming. However, more experience could lead to less efficiency. Taraka et al. (2010) found that farming experience has a negative influence on the efficiency level. They explained this as more experience farmers are less likely to adopt new technology, technique, and advice compared to the farmers with less experience.

Gender may play role in rice production. Sriboonchitta and Wiboonpongse (2001) found that the male-labour ratio has a significantly negative influence on the inefficiency score. Households with male as the head of household tend to be more technically efficient in rice farming (Taraka et al., 2012).

Education has the potential to enhance production efficiency through improving information management and decision making. Many studies found that more time that the head of household spends in education has a significantly negative influence on the inefficiency score (Sriboonchitta & Wiboonpongse, 2001; Chaovanapoonphol, Battese, & Chang, 2005; Ebers et al., 2017). However, well-educated farmers tend to be involved more in off-farm activities and are less active in farming which resulted in less efficiency in rice production. Osti (2016) and Jirarud &

Suwanmaneepong (2020) found that more educated farmers are less technical efficient and Panpluem et al. (2019) found that junior high school education has a negative impact on pure efficiency.

The income of the household also affects the efficiency of rice production. Panpluem et al. (2019) found that annual household income had a significant positive impact on pure efficiency. Nonetheless, the source of the income may also matter in the direction of the effect. Srisompun and Isvilanonda (2012) found that households with a higher ratio of farm income are more technically efficient while Ebers et al. (2017) found that more share of non-farm income and remittance from the government was associated with less efficiency.

Even there are dissent findings of the factor that impact the efficiency level of farmers and the direction of the effects, many studies still provided evidence for the difference in technical efficiency level across the observed areas, provinces, or regions (Krasachat, 2003; Kiatpathomchai, 2008; Butso & Isvilanonda, 2010; Sansri et al., 2014; Nunti et al., 2019). This indicates spatial influence on the production efficiency of rice farming.

Turning to the empirical research about total factor productivity. The productivity of rice in Thailand usually studies partial productivity, i.e., land productivity (yield) and labour productivity, but total factor productivity does not widely study and mainly focuses on the aggregate level of production.

In 2013, Suphannachart used the Solow-type growth accounting method to measure TFP of the main rice and the second rice of 4 regions of Thailand. The results show that TFP was the largest source of output growth for rice over the period 1995 to 2011. The northeastern has the highest rates of TFP growth, followed by the south. The TFP growth rate of the second rice was substantially higher than the TFP growth rate of the main rice. In investigating factors that affect the TFP of rice production, the author found that research budget and adoption of high-yielding rice varieties have a significantly positive impact on TFP. Irrigation and rainfall have an impact on the TFP of the second rice and main rice respectively, though the relation of rainfall and TFP of the main rice is negative. Lastly, the author found evidence of TFP differences in rice production among 4 regions of Thailand.

Ke Chung Peng (2020) calculated the TFP growth of wet season rice production of 18 provinces in the northern region of Thailand using the Malmquist productivity index. They found that the TFP growth of overall provinces is 0.3% annually which was mainly driven by technological progress at 0.5% per annum. Lampang, Mea Hong Son, Tak, Sukhothai, Nan, and Uttaradit experienced average negative TFP growth during the period of the study caused by technical efficiency regress.

Location and neighborhood area can influence the TFP growth of any individual province because the proximate areas may share some natural conditions, weather events, disasters, plant disease, or technological spillover. In this regard, Suphannachart (2018) investigate the spatial aspect of TFP of rice production in Thailand. Analyzing provincial data of 76 provinces covering 5 periods (2004, 2006, 2008, 2010, 2012) shows the evidence of spatial influence on TFP of rice among the provinces. Adopting high-yielding variety and area under irrigation were found to be significantly positive with TFP of rice while the amount of regional rainfall has negative relation.

The summary of past studies about the efficiency and total productivity of rice in Thailand is shown in Table 3.2. The past studies mentioned in this section indicate that there is a gap in the performance measurement and comparison in rice production among the provinces of Thailand. Thus, investigating production efficiency and TFP of rice production in terms of provincial level could help to fill the gap in this topic and could expand our understanding of spatial aspects of the TFP and efficiency in rice production.

Table 3.2

Studies on efficiency and total productivity of rice farming in Thailand

Study	Topic of study	Method	Years (Crop year)	Area of study (province)	Observation	Main finding
Champhech (2003)	Technical Efficiency	SFA	2001/02	Yasothon	81 farmers	Mean TE score of organic Jasmine rice farmers and normal Jasmine rice farmers was 65.91% and 62.39%, respectively.
Krasachat (2003)	Technical Efficiency	DEA	1999	Si Sa Ket, Surin, and Buri Ram	74 farmer households	- Mean TE score was 71% was is 96% and PTE was 74 - There is evidence that different provinces may have a difference in the efficiency level of rice farming. - Not found the effects of farm size and irrigation on the efficiency level.
Sriboonchitta and Wiboonpongse (2001)	Technical Efficiency	SFA	1999/2000	Chiang Mai Province, Phitsanulok Province, and Tung Gula Ronghai	489 farmers	- Mean TE score of jasmine rice and non-jasmine rice farmer was 67.56% and 71.61%, respectively. - Education, number of adults person in the household, and male-labor ratio were found to be a significantly negative influence on the inefficiency score for both rice whereas age has a significantly negative impact on inefficiency only for non-jasmine rice farmers.

Table 3.2

Studies on efficiency and total productivity of rice farming in Thailand (Cont.)

Study	Topic of study	Method	Years (Crop year)	Area of study (province)	Observation	Main finding
Sriboonchitta and Wiboonpongse (2005)	Technical Efficiency	SFA	1999/2000	Chiang Mai, Phitsanulok, and Tung Gula Ronghai	489 farmers	• Mean TE score of jasmine rice and non-jasmine rice farmer was 60.72% and 62.81%, respectively. • The neck blast disease and severe drought have a negative influence on the yield of rice.
Chaovanapoonphol, Battese, and Chang (2005)	Technical Efficiency	SFA	Data collected in 2004	Chiang Mai and Chiang Rai	656 rice farmers	• Mean TE score was 79.2%. • The amount of loans, experience, education, and age of the head of household have a negative influence on the inefficiency score.
Songsrirote and Singhapreecha (2007)	Technical Efficiency	SFA	2005/06	Yasothon	330 farms	• Mean TE score of organic jasmine rice farmer was 71.45% and 86.66% for input- and output-oriented, respectively. • Mean TE score of conventional jasmine rice farmer was 44.99% and 71.45% for input- and output-oriented respectively. • Farmers were operating in the decreasing return to scale of production.

Table 3.2

Studies on efficiency and total productivity of rice farming in Thailand (Cont.)

Study	Topic of study	Method	Years (Crop year)	Area of study (province)	Observation	Main finding
Kiatpathomchai (2008)	Technical Efficiency	DEA	2004/05	Songkhla and Phatthalung	247 farmer households	- Conventional farmers are prone to more illness than organic farmers. - Mean TE score was 86.6% and 85.9% depending on the model specification. - The rain-fed farm, on average, was operated slightly more efficient than irrigated farms. - Larger farm size is related to more efficiency but using the modern variety of rice and increasing in the number of paddy crops before new seed replacement have a negative impact on the efficiency level. - There is evidence the two provinces have different technical efficiency score.
Rahman et al. (2009)	Technical Efficiency	SFA	1999/2000	Chiang Mai, Phitsanulok, and Thung Kula Ronghai	348 farmers	- Mean TE score was 63%. - Larger farm tends to be relatively technically inefficient compares to smaller farm. - Not found significant relations between irrigation,

Table 3.2

Studies on efficiency and total productivity of rice farming in Thailand (Cont.)

Study	Topic of study	Method	Years (Crop year)	Area of study (province)	Observation	Main finding
Butso and Isvilanonda (2010)	Technical Efficiency	SFA	1987/88 and 2007/08	Suphan Buri and Khon Kaen	228 households	education, and located area on the efficiency score. • Mean TE score was 88.32% in crop year 1987/88 and was 72.63% in crop year 2007/08. • The difference in the environment (in terms of the located area) have an impact on the efficiency score. • The area under irrigation systems is more efficient than rain-fed area. • Farmers were operating in the decreasing return to scale of production.
Taraka et al. (2010)	Technical efficiency	DEA	2009/10 crop	Bangkok, Chainat, Nonthaburi, Pathumthani, Ayutthaya, Lopburi, Saraburi, Singburi, and Angthong	400 farmer households	• Mean TE score was 51.69% and 51.86% for CRS and VRS, respectively. • Farming experiences, family size, farm size, land tenure, and joining some agricultural extension programs have a significant negative influence on the efficiency level. • Using certified seed and direct access to the offices

Table 3.2

Studies on efficiency and total productivity of rice farming in Thailand (Cont.)

Study	Topic of study	Method	Years (Crop year)	Area of study (province)	Observation	Main finding
Srisompun and Isvilanonda (2012)	Technical Efficiency	SFA	1987/88 and 2007/08	Suphan Buri and Khon Kaen	228 households	have a positive impact on the efficiency level.
						• Mean TE score was 88.32% in crop year 1987/88 and 72.63% in crop year 2007/08. • Farmer in irrigated area has a higher technical efficiency score than other areas. • Larger rice farms and households with a higher farm income are more technically efficient.
Taraka et al. (2012)	Technical efficiency	SFA	2009/10	Bangkok, Chainat, Nonthaburi, Pathumthani, Ayutthaya, Lopburi, Saraburi, Singburi, and Angthong	384 farmer households	• Means TE score was 85.35%. • Households with male-head, good agricultural practices, and cropping intensity have a negative effect on technical inefficiency. • Farmers with good agricultural practices certificates and farmers who cultivate more than once a year tend to be more technical efficient.

Table 3.2

Studies on efficiency and total productivity of rice farming in Thailand (Cont.)

Study	Topic of study	Method	Years (Crop year)	Area of study (province)	Observation	Main finding
Suphannachart (2013)	Total Factor productivity	Solow-type growth accounting method	1995-2011	4 regions	Aggregate provincial data	• Largest source of rice output growth in most regions was due to the TFP. • The average annual rate of growth of TFP in the main rice was 0.34%, and was 4.95% in the second rice. Research budget and adoption of high-yielding rice varieties have a significantly positive impact on TFP. • Irrigation and rainfall have an impact on the TFP of the second rice and main rice respectively, though the relation of rainfall and TFP of the main rice is negative. • There is evidence of TFP differences in rice production among the 4 regions of Thailand.
Sansri et al. (2014)	Technical efficiency	SFA	2012/13	Roi-Et	80 farmer households	• Mean TE score was 77.17%. • Highlight the effect of soil group (type of soil in the area that cultivated rice) on the efficiency level.

Table 3.2

Studies on efficiency and total productivity of rice farming in Thailand (Cont.)

Study	Topic of study	Method	Years (Crop year)	Area of study (province)	Observation	Main finding
Osti (2016)	Technical efficiency	SFA	Data collected in 2012.	Nakhon Ratchasima	197 rice farmers	- Famers were operating in the decreasing return to scale of production. - Mean TE score was 41.21%. - Farmers with more age tend to be more efficient while more educated farmers are less efficient. - Found a negative impact of drought on the technical efficiency level.
Ebers et al. (2017)	Technical efficiency	SFA	Data collected in 2013.	Ubon Ratchathani	623 households in Thai and 407 households in Cambodia	- Mean TE score for Thai farmers was 72%. - The bigger farm size and more share of non-farm income were associated with less efficiency. - Education, having agricultural machines, and the value of agricultural assets have a negative impact on technical inefficiency. - Remittance shares of total income, the distance to the field, and the distance to town have a positive influence on technical inefficiency.

Table 3.2

Studies on efficiency and total productivity of rice farming in Thailand (Cont.)

Study	Topic of study	Method	Years (Crop year)	Area of study (province)	Observation	Main finding
Suphannachart (2018)	Total Factor productivity	Solow-type growth accounting method, Spatial model	2004, 2006, 2008, 2010, 2012	All provinces (76)	Aggregate provincial data	- Found evidence of spatial influence on TFP of rice among the provinces. - Adopting high-yielding variety and area under irrigation were significantly positive with TFP of rice while the amount of regional rainfall has a negative relation.
Nunti et al. (2019)	Technical efficiency	SFA	2009-2017	All provinces (76)	Aggregate provincial data	- Mean TE score of the northern, central, northeastern, and southern region was 86%, 81.9%, 76%, and 74%, respectively. - Mean TE score was 23% and 28% for CRS and VRS, respectively. - Pure efficiency was negatively influenced by junior high school education, farm size, water source, market accessibility, health symptoms, and labor but positively influenced by income
Panpluem et al. (2019)	Technical efficiency	DEA	Data collected in 2017-2018	Yasothon	328 farmers	

Table 3.2

Studies on efficiency and total productivity of rice farming in Thailand (Cont.)

Study	Topic of study	Method	Years (Crop year)	Area of study (province)	Observation	Main finding
Jirarud and Suwanmaneepong (2020)	Technical efficiency	SFA	Data collected in 2016	Chachoengsao	150 farmers	• Mean TE score was 82.9%. • The small-size farm was the most efficient but the difference in efficiency level is very small among all sizes of the farm. • Farmers with more education tend to be less efficient. Not found significant relationships with those of gender, age, number of active family members, or experience in farming.
Ke Chung Peng (2020)	Technical efficiency and Total Factor Productivity	DEA and Malmquist Index	2009/10-2018/19	Chiang Rai, Phayao, Lampang, Lamphun, Chiang Mai, Mae Hong Son, Tak, Kamphaeng Phet, Sukhothai, Phrae, Nan, Uttaradit, Phitsanulok, Pichit, Nakhon Sawan, Uthai Thani, and Phetchabun	Aggregate provincial data	• Mean TE score of all provinces was 89.1%. • Phetchabun, with a score of 100% throughout the period of study. • TFP growth of overall provinces is 0.3% annually with technological progress at 0.5% but efficiency regress at -0.3% annually.

Note. Author's summary

CHAPTER 4

RESEARCH METHODOLOGY

This chapter is divided into three parts. The first part covers the fundamental concepts and theories relating to the performance measurement of industrial economics, including the production function, productivity, production efficiency, and distance function. The approach employed in this study is described in full in the second part. The last section is the description of the data using in this study.

4.1 Theoretical framework

4.1.1 The production function

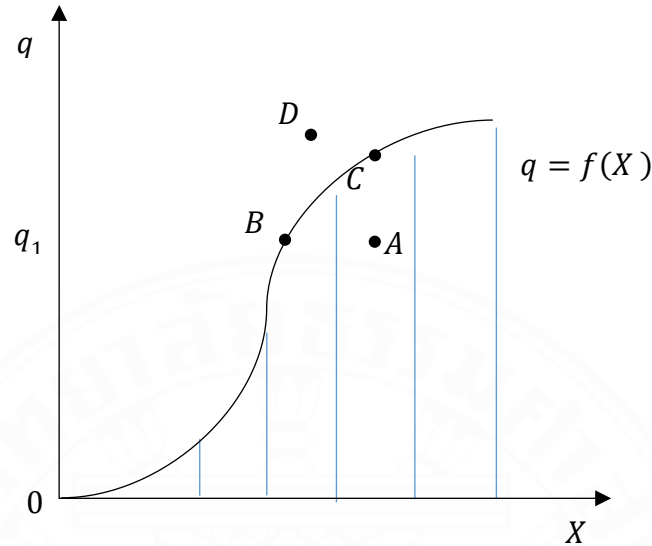
The production function is the fundamental concept of production in economic theory. It represents the production process of a firm using inputs (labor, land, fertilizer, etc.) to generate outputs (crops, livestock, etc.). The relationship that represents N inputs, $(x_1, x_2, \dots, x_N)$, to produce one output, q , can be mathematically shown as:

$$q = f(x_1, x_2, \dots, x_N) \quad (4.1)$$

All possible combination of inputs and output under an existing production technology is called feasible production set or production possibility set. Figure 4.1 shows the relationship of production that uses multiple inputs to produce one output, where X represents a vector of the combination of inputs and q represents an output. The S-curve line is called the production frontier. It represents the maximum output that can be produced at given any combination of inputs. The area under the production frontier is still possible production processes but not at its maximum output. Any combination on the production frontier and area under the line is the feasible production set given the existing production technology. In the case of Figure 4.1, A, B, and C are the combinations of the production process that is feasible where D is not.

Figure 4.1

Example of the production function



Note. Adapted from *An Introduction to Efficiency and Productivity Analysis 2nd ed.* (p 4) by Coelli et. al., 2005, Springer. Copyright 2005 by Springer Science+Business Media, Inc.

The common and most well-known form of production function is the Cobb-Douglas function proposed by Charles Cobb and Paul Douglas. The Cobb-Douglas function that represents the production process of producing one output by using N inputs can be shown as:

$$q = Ax_1^{\beta_1} x_2^{\beta_2} \dots x_N^{\beta_N} \quad (4.2)$$

With logarithm the function becomes:

$$\ln q = \ln A + \beta_1 \ln x_1 + \beta_2 \ln x_2 + \dots + \beta_N \ln x_N \quad (4.3)$$

A is the positive number that represents the total factor productivity. $\beta_1, \beta_2, \dots, \beta_N$ are constant and have values between 0 to 1. These constants represent output elasticities. The summation of β can indicate the returns to scale of the production. If the summation is less than, more than, or equal to unity, the production is decreasing, increasing, or constant returns to scale respectively.

Due to the limitation of the Cobb-Douglas function (constant input elasticity and fixed return to scale), there is another functional form that relaxes these restrictions so-called Trans-log production function. The Trans-log production function is a contraction of transcendental logarithmic function and is the generalization of Cobb-Douglas function to allows more flexibility. The Trans-log production function with one output and N inputs can be shown as:

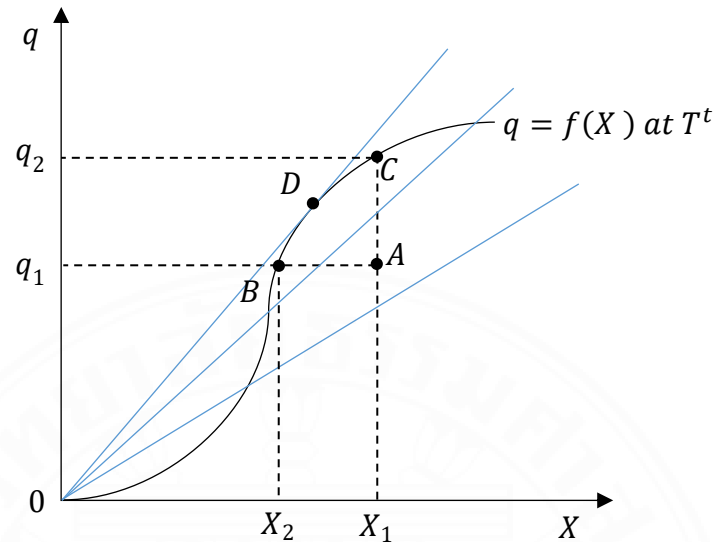
$$\ln q = \ln A + \sum_{i=1}^N \beta_i \ln x_i + \sum_{i=1}^N \sum_{j=1}^N \beta_{ij} \ln x_i \ln x_j \quad (4.4)$$

where i and j are $1, 2, 3, \dots, N$

4.1.2 Production efficiency

The production frontier defined in the previous section can be used to measure the performance of a firm. From Figure 4.2, $q = f(X)$ is the production frontier which represents the maximum output, q , that firm can produce for each input level, X , given production technology at period t (T^t). The possible combination of production is on and below the production frontier line. Firms that operate on the production frontier combination are called technically efficient and the others are called technically inefficient.

Figure 4.2

Production frontier

Note. Adapted from *An Introduction to Efficiency and Productivity Analysis 2nd ed.* (p 5) by Coelli et. al., 2005, Springer. Copyright 2005 by Springer Science+Business Media, Inc.

Point A represents a firm that uses input X_1 to produce output at q_1 , which is technically inefficient. This firm can be more technically efficient in two ways. The first is to reduce input from X_1 to X_2 while still producing output at q_1 , moving from point A to point B. Measuring how much the firm can reduce the input used in the production process while producing the same amount of output is called input-orientation of measuring technical efficiency. Another way is to increase output produced from q_1 to q_2 while still using the same amount of input, moving from point A to C. Measuring how much the firm can increase the output produced while using the same amount of input is called output-orientation of measuring technical efficiency

Even the production frontier can be employed for measuring technical efficiency, this approach is only appropriate when the production process has a single output. This leads to a drawback of this approach.

4.1.3 The distance function

In the reality, most production processes involve more than one input and/or produce more than one output, which the production frontier becomes

inadequate to assess the efficiency. In these cases, the distance function is employed to measure and explain the production process with multiple input and output technology.

Farrell (1957) is a pioneer to apply the concept of distance function, proposed by Malmquist (1953) and Shephard (1953), to efficiency measurement. In general, the distance function measures the distance between the observed input-output combination to the maximum input-output combinations on the efficiency frontier. Let the input vector with N inputs is $x = (x_1, x_1, \dots, x_N) \in \mathfrak{R}_+^N$ and the output vector with M outputs is $y = (y_1, y_2, \dots, y_M) \in \mathfrak{R}_+^M$. Output set of production technology is $P(x) = \{y : (y, x) \in T\}$ where $P(x)$ is the set of output on the interval $[0, y]$ that can produce given input x . Further, T is the production technology that represents any possible input-output vectors in the production process. The production process of a firm at period t can be defined as:

$$T^t = \{(x^t, y^t) : x^t \text{ can produce } y^t\} \quad (4.5)$$

The distance function can be measured either by focusing on input-oriented or output-oriented. The output distance function at t is:

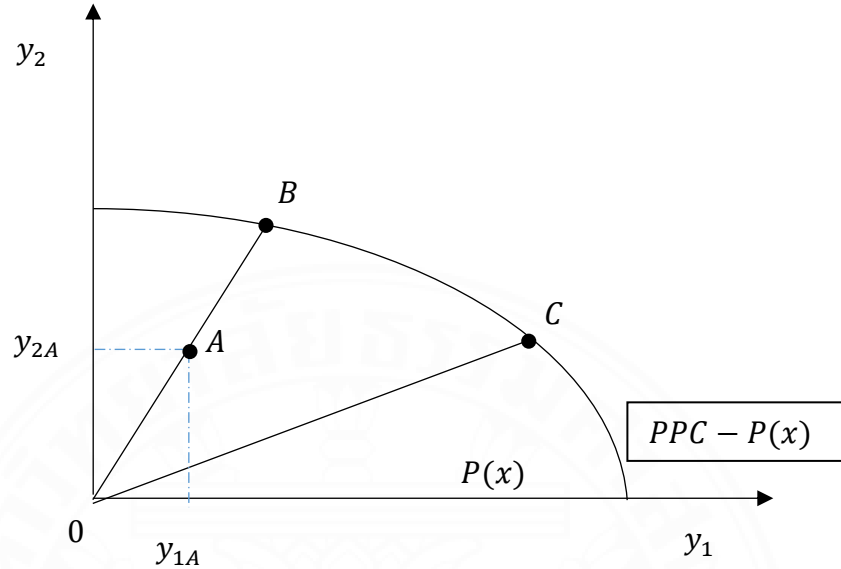
$$D_o^t(x^t, y^t) = \min \{\mu : (y^t/\mu) \in P(x^t)\} \quad (4.6)$$

The meaning of equation (4.6) is that we minimize μ where $\mu \leq 1$; so $y^t/\mu \geq 1$. In other words, we maximize the output given the input and still remain in the output set.

The concept of the output distance function can be illustrated in Figure 4.3. In this example, the production process uses an input vector, x , to produce two outputs, y_1 and y_2 . $P(x)$ is the boundary of input-output relation at given technology that firm can reach. $PPC - P(x)$ curve represents the production possibility frontier so any combination on the curve is the highest output combinations given a level of input. The value of the distance function for the firm at point A that using input level x to produce the outputs $(y_{1A}$ and $y_{2A})$ is equal to the ratio $\mu = OA/OB$. This μ reflects the output-oriented technical efficiency score.

Figure 4.3

Production boundary



Note. Adapted from *An Introduction to Efficiency and Productivity Analysis 2nd ed.* (p 48) by Coelli et. al., 2005, Springer. Copyright 2005 by Springer Science+Business Media, Inc.

4.1.4 Productivity

Another way to measure the performance of a firm is to use the concept of productivity. Productivity is defined as the ratio of the output to the input. This ratio is an approach to measuring the performance of firms. The greater value of productivity implies better performance of the firm in utilizing input in the production process. The productivity can be shown as follows:

$$Productivity = \frac{Output(s)}{Input(s)} \quad (4.7)$$

The production process can use more than one input and/or produces more than one output. If the productivity measures the ratio of one output and one input, the value of the measurement is called partial productivity. When measuring more than one output and/or more than one input, the productivity is referred as multifactor or total factor productivity (MFP or TFP). To calculate TFP, one can apply index number techniques to aggregate inputs and outputs into one number. The total factor productivity can be shown as follows:

$$\text{Total factor productivity} = \frac{\text{Output index}}{\text{Input index}} \quad (4.8)$$

Productivity change between two periods of productivity growth can be defined as:

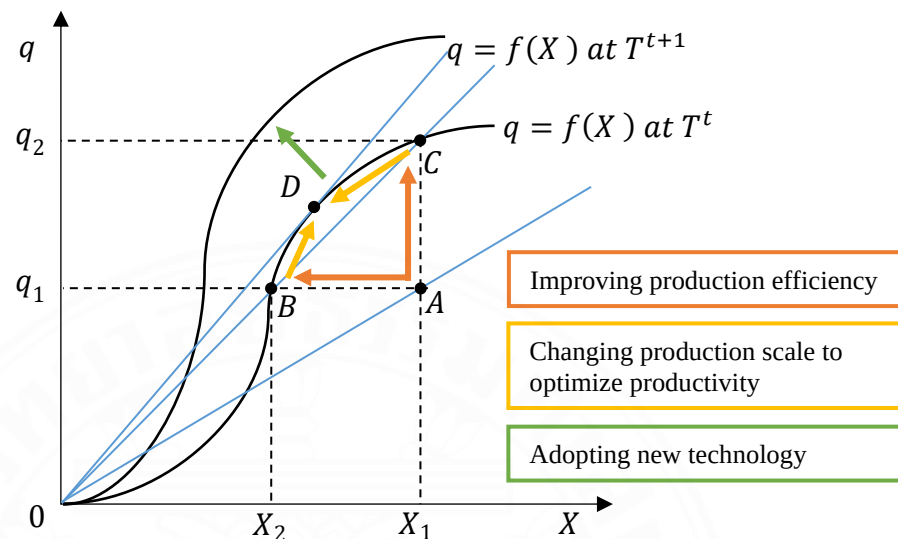
$$\begin{aligned} \text{Productivity}_{t,t+1} &= \frac{\text{Output}(s)_{t+1}/\text{Input}(s)_{t+1}}{\text{Output}(s)_t/\text{Input}(s)_t} \\ &= \frac{\text{Output}(s)_{t+1}/\text{Output}(s)_t}{\text{Input}(s)_{t+1}/\text{Input}(s)_t} \end{aligned} \quad (4.9)$$

Production efficiency and productivity are two different concepts for explaining performance. The difference is when we measure production efficiency, we are measuring and comparing the actual level and the potential level of utilization of the production technology. On the other hand, productivity is capturing the level of the output related to the input level (Sickles, R., & Zelenyuk, V., 2019).

The difference between production efficiency and productivity can be illustrated in Figure 4.4. Point A represents a firm that uses input level at X_1 to produce output at q_1 , which is technically inefficient. This firm can become technically efficient by moving to point B or C as we explained before. However, at points B or C, this firm is not achieving the optimal production combination yet. The straight lines that are drawn from the origin point to any combination of the production process are the ratio of the output to input, i.e., the productivity at that point. The maximum productivity, the highest slope of the line, that firm can reach given the production technology at period t is where the productivity line and production frontier are tangent at point D.

Figure 4.4

Production frontier with technology at different periods



Note. Adapted from *An Introduction to Efficiency and Productivity Analysis 2nd ed.* (p 71) by Coelli et. al., 2005, Springer. Copyright 2005 by Springer Science+Business Media, Inc.

In this respect, we can consider production efficiency as a subset of productivity. When firms improve production efficiency, they also enhance productivity. When firms reach the frontier of production, the maximum feasible output given the technology at that period, the firms can further increase their productivity by adjusting their production scale.

The production processes in different periods may operate under different technologies. When new technology of production emerges after time passed, firms can improve productivity by adopting new technology and shifting their frontier. In Figure 4.4, the production frontier at T^{t+1} represents new feasible output levels caused by the new technology of production given the same input level. By this illustration, we can conclude that the sources that contribute to productivity growth are technical efficiency change (improving production efficiency), technical change (adopting new technology), and scale efficiency change (changing production scale to optimize productivity).

The approaches to measuring the TFP growth can be classified into the frontier and non-frontier approaches. The difference is that frontier approaches

estimate the best obtainable positions based on the estimation of a maximum bounding of production while non-frontier approaches estimate the index or an average function line that best fits the sample data. Another difference is the frontier approaches consider the role of the technical efficiency in the performance of observation while non-frontier assume that they are technically efficient (Dhehibi et al., 2015). These approaches can further divide into parametric and non-parametric approaches. Parametric approaches require assumptions of the functional form to represent the production process while non-parametric approaches do not assume the functional form. This allows non-parametric approaches to be less restrictive in assumption at the drawback that it cannot statistically test on its results.

The non-frontier approaches to TFP measurement include Divisia index, Törnqvist index, and the Hicks-Moorsteen productivity index which are non-parametric techniques and the growth accounting equation which is a parametric technique.

Divisia index is a weighted sum of the growth rate of the component's shares in total value. Divisia index can be based on price and quantity data. However, the Divisia index is a theoretical construct in the continuous-time data form (Jorgenson & Griliches, 1971). One approach to measure the TFP growth of discrete data is to use the Törnqvist index as an approximation to the Divisia index (Dhehibi et al., 2015). Törnqvist quantity index is defined as the ratio of all goods weighted by the average value shared in two periods. The TFP change in the Törnqvist index is the ratio of the Törnqvist output index to the Törnqvist input index. Törnqvist index is an index number technique that is most commonly employed in measuring TFP, compared to other index numbers like the Laspeyres index, the Paasche index, or the Fisher index.

However, using index numbers to measure TFP where the data of prices are not market prices or firm's behavior is not optimal may result in incorrect measurement and the interpretation may not in accordance with the economical meaning of the index numbers (Coelli et al., 2005).

Hicks-Moonsteen TFP index (HMPI), attributed to Hicks (1961) and Moorsteen (1961), also represents productivity by the ratio of output index to the input index. Hence, the productivity change is the geometric mean of the two HMPIs. The advantage of HMPI is the interpretation of TFP is directly corresponds to the notion of

the total factor productivity, aggregate output divided by aggregate input. However, the drawback is that it requires unreal and unobserved combinations of input and output in the calculation. This may result incorrectly in TFP when the changes are large (Sickles & Zelenyuk, 2019).

For the parametric non-frontier approach, the growth accounting equation, proposed by Robert Solow in 1957, measures TFP from the residual of an aggregate production function. The growth rate of the output can be represented as the weighted average of the growth rate of each input. The TFP growth is then the result of the growth rate of output subtracted by the growth rate of all inputs; the part that cannot explain by input growths (Solow, 1957). The growth accounting approach is widely employed for measuring TFP growth in macro-economic data, such as GDP of country, industry, or state level. However, this approach has limitations due to its assumptions (Sickles & Zelenyuk, 2019). Firstly, all observations are assumed to be efficient while the observations in this study may have a variation in the efficiency level. Secondly, the assumption of the Hicks-neutral-type technological change property, which, means the combination of input mix will not change given input's prices are constant over time. Lastly, the Solow's growth accounting approach needs to know the partial scale elasticity of each input for the production function. This information has to be estimated or taken from other studies or even specifically assumed in the model.

Turning to the frontier approaches, they are also divided into parametric and non-parametric approaches. Parametric frontier approaches employ econometric models to estimate the frontier for measuring productivity. A parametric frontier approach that is widely employed to measure TFP is the stochastic frontier analysis proposed by Aigner, Lovell, and Schmidt (1977). The advantage of the parametric method is it accommodates random error and noise of the observations and it can do statistical tests for the results (Coelli et al., 2005). Still, the parametric approaches are required prior specify functional form of production before the estimation.

Lastly, the Malmquist productivity index (MPI), employed in this study, is a non-parametric frontier approach. This approach employs the distance function to calculate TFP. The TFP changes for MPI are the geometric mean of two MPIs, the same ways as TFP change of the HMPI. The advantages of MPI are 1) it does

not require researchers to prior specify functional form 2) it does not need information of prices and 3) it allows researcher to investigate further into the aspects that drive TFP growth, namely technical efficiency change, technical change, and scale efficiency change.

An important issue to be noted is that under non-constant returns to scale of the production, the Malmquist productivity index may not accurately measure TFP change (Grifell-Tatjé & Lovell, 1995). Nevertheless, the data used in this study is the aggregate data of inputs and output at the provincial level so the collective data of various farms size could result in the constant returns to scale property. For this reason, this study assumed the constant returns to scale (CRS) technology in measuring efficiency score by the DEA and in measuring TFP growth by the Malmquist productivity index. Under constant return to scale assumption, there is no scale of production to be adjusted and the main components that contribute to TFP growth are technical efficiency change and technical change. To use the illustration in Figure 4.4, production frontier under constant return to scale technology will become straight lines despite s-curve line as for variable returns to scale technology.

4.1.5 Spatial effects

In regional science and many modern social sciences, data are obtained in which the observations can be characterized by the location in space and time. Spatial econometrics is a subfield of econometrics that develop the handle with this type of data. Anselin (1998) consider the field of spatial econometrics as a study that focuses on location and spatial interaction and use method and techniques to represent the spatial effects. The two aspects of spatial effects that are common in this field are spatial dependence and spatial heterogeneity.

The spatial dependence or spatial autocorrelation is present when there is a correlation across cross-sectional units with the pattern that follows a certain spatial ordering. This means the value of the question is influenced by the relative location. The second effect, spatial heterogeneity, is a special case of observed and unobserved heterogeneity (Anselin, Gallo, & Jayet, 2008). This heterogeneity is structurally related to the relative location and other spatial variables. The spatial heterogeneity can be in the form of non-constant error variances or in the form of varying coefficients of the regression model depending on the location.

The spatial dependence can be captured by incorporating the spatial weight matrix into the model.

4.2 Research Methodology

The methodology employed in this study can divide into two parts. The first is methods for performance measurement, including the Data Envelopment Analysis and the Malmquist Productivity index. The second part is the method for investigating the spatial influence of the total factor productivity growth of rice between provinces. This sub-section gives some details about these methods.

4.2.1 Performance measurement

4.2.1.1 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a non-parametric approach for measures efficiency. By using the linear programming method to build a non-parametric piecewise linear envelopment frontier overall data of the decision-making units (DMUs), we can compare the performance of each DMU. The efficiency score measured by DEA can be either input-oriented or output-oriented. For input-oriented, the DEA method defines the frontier by minimizing the input used given constant output levels. For output-oriented, the DEA method tries to maximize the output given the same levels of input.

Both input- and output-oriented are employed in the literature of rice efficiency measurement. This study employs the output-oriented DEA because, in the characteristic of rice farming, some inputs are fixed or cannot adjust freely. Hence, it is more intuitive to consider how to improve the output produced given the same resources. The output-oriented DEA measures efficiency score by using the output distance function and solving the linear programming for each DMU. Following Charnes, Cooper, and Rhodes (1978), the linear programming to solve for i^{th} DMU (or province in this study) problem in an output-oriented DEA model with the constant return to scale technology given K inputs and M outputs on each of N province at time t are as follows (Coelli et al., 2005):

$$\max_{\theta, \lambda} \theta_i^t,$$

Subject to

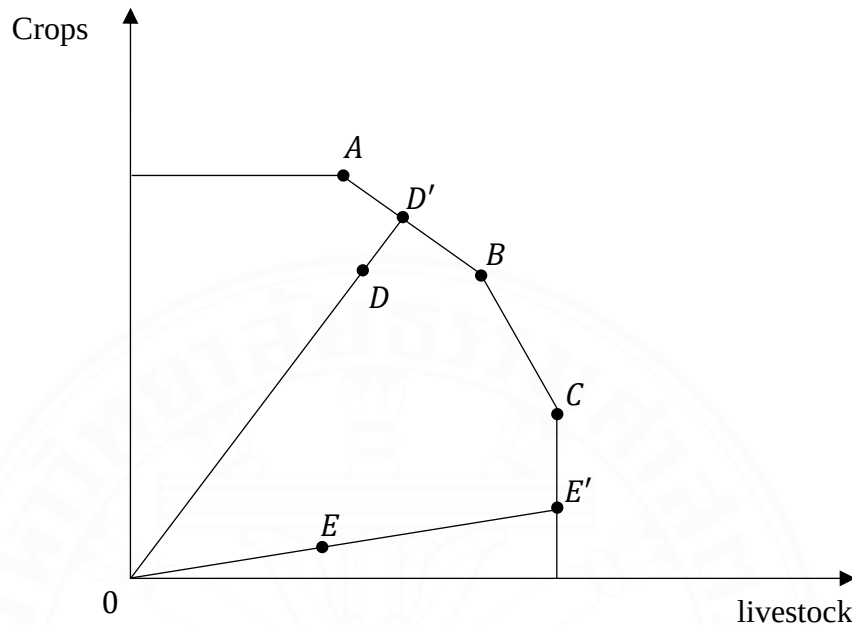
$$\begin{aligned} \theta y_i^t &\leq Y^t \lambda^t, \\ X^t \lambda^t &\leq x_i^t, \\ \lambda^t &\geq 0 \end{aligned} \tag{4.10}$$

where x_i^t and y_i^t are the input and output vectors for the province i^{th} . X^t is the $K \times N$ input matrix of all provinces and Y^t is the $M \times N$ output matrix of all provinces. λ^t is a $N \times 1$ vector of the intensity variables which represent the weights of all provinces involved in construct the frontier for the province i^{th} . Then, $Y^t \lambda^t$ and $X^t \lambda^t$ is the boundary of the output set and input set, respectively. θ^t is a scalar in which $1 \leq \theta^t \leq \infty$. The inverse of θ^t is defines a TE score and also equals to the output distant function of the province i^{th} ($0 \leq 1/\theta_i^t = TE_{i,o}^t = D_{i,o}^t(x, y) \leq 1$). The interpretation is that if $TE_{i,o}^t \neq 1$, the province i^{th} is technically inefficient at period t . This province has to increase the amount of output produced by $(1 - TE_o^t) \times 100$ percent while using the same amount use of inputs in order to become technical efficient, where $TE_o^t = 1$.

Technical efficiency scores are computed based on the radial distance of every DMUs from the frontier. For the output-oriented DEA, the frontier is constructed from the output set. An example of the DEA method can be illustrated in Figure 4.5.

Figure 4.5

Example of the output-oriented of the DEA approach



Note. Adapted from *An Introduction to Efficiency and Productivity Analysis 2nd ed.* (p 181) by Coelli et. al., 2005, Springer. Copyright 2005 by Springer Science+Business Media, Inc.

Consider five provinces produce two aggregate outputs, i.e., crops and livestock, and have the same input vectors in production. Provinces A, B, and C are technically efficient because they define the frontier, while provinces D and E are technically inefficient. For province D the output-oriented technical efficiency score is equal to

$$TE_D = OD/OD' \quad (4.11)$$

The projected point, D' , lies on a line joining points of points A and B. Therefore, province A and province B are referred as the peers of province D and province D have non-zero λ weights associated with province A and B. The output-oriented technical efficiency score of province D is, approximately, 90% ($TE_D = 0.9$). This means province D should be able to increase outputs by 10% given a constant proportion of inputs. The technical efficiency score of province E is equal to

$$TE_E = OE/OE' \quad (4.12)$$

Province E has only province C as its peer which means province E has non-zero λ weight associated with province C. The output-oriented technical efficiency score of farmer E is 40% ($TE_E = 0.4$) which means that this province should be able to increase outputs by 60% given a constant proportion of inputs. However, projected point E' lies on the part of the frontier which is parallel to the crops axis. Thus point E' is not the efficient production process for province E because it can increase crops output while still used the same inputs. To obtain technically efficient, province E has to increase both outputs by 60% and then further increase crops output so that province E will have the same production process as province C. Consider provinces A, B, and C lying on the frontier, they would have the technical efficiency score equal to 100% ($TE_{A,B,C} = 1$) and each province is its peer.

There are several programs for computing the equation 4.10. For instance, Data Envelopment Analysis (Computer) Program (DEAP), Efficiency Measurement System (EMS), 'Benchmarking' or 'rDEA' packages in R software, and pre-coding of ado files in STATA.

4.2.1.2 The Malmquist Productivity Index

Malmquist productivity index can be measured using either output distant function (output orientated) or input distant function (input orientated). This study adopts the output-orientated MPI approach so the explanation will be based on the output-orientated term. The Malmquist productivity index given the technology at period t is defined as

$$M_t^o(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{D_t^o(x_{t+1}, y_{t+1})}{D_t^o(x_t, y_t)} \quad (4.13)$$

where D_t^o is the output distance function measures based on production technology at period t given observed input and output data at period t and $t + 1$. The Malmquist productivity index given the technology at period $t + 1$ is defined as

$$M_{t+1}^o(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{D_{t+1}^o(x_{t+1}, y_{t+1})}{D_{t+1}^o(x_t, y_t)} \quad (4.14)$$

The Malmquist TFP change index defines the change in productivity as the geometric average of two indices based on two periods of technology. The Malmquist TFP change index can be shown as

$$\begin{aligned} M_{t,t+1}^o(x_t, y_t, x_{t+1}, y_{t+1}) &= [M_t^o(x_t, y_t, x_{t+1}, y_{t+1}) M_{t+1}^o(x_t, y_t, x_{t+1}, y_{t+1})]^{1/2} \quad (4.15) \\ &= \left[\frac{D_t^o(x_{t+1}, y_{t+1})}{D_t^o(x_t, y_t)} \times \frac{D_{t+1}^o(x_{t+1}, y_{t+1})}{D_{t+1}^o(x_t, y_t)} \right]^{1/2} \end{aligned}$$

where $M_{t,t+1}^o$ is the changes of TFP or TFP growth (TFPC) from period t to $t + 1$

There are three factors that attributed to TFP growth; 1) Technical efficiency change (TEC) is the ability of DMU to improve their technical efficiency over time 2) Scale efficiency change (SEC) is the ability of DMU to adjust their size to optimal scale over time and 3) Technical change (TC) is the ability of the farmer to adopts new technology to improve their output set of production (Färe et al, 1994). Under constant return to scale assumption, SEC is equal to unity and the Malmquist TFP change index can be decomposed into two components that attributed the TFP growth as follows:

$$M_{t,t+1}^o(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{D_{t+1}^o(x_{t+1}, y_{t+1})}{D_t^o(x_t, y_t)} \left[\frac{D_t^o(x_{t+1}, y_{t+1})}{D_{t+1}^o(x_{t+1}, y_{t+1})} \times \frac{D_t^o(x_t, y_t)}{D_{t+1}^o(x_t, y_t)} \right]^{1/2} \quad (4.16)$$

or

$$TFPC = TEC \times TC \times (SEC = 1) \quad (4.17)$$

where:

$$\left(\frac{D_{t+1}^o(x_{t+1}, y_{t+1})}{D_t^o(x_t, y_t)} \right) \text{ is technical efficiency change}$$

$$\left(\left[\frac{D_t^o(x_{t+1}, y_{t+1})}{D_{t+1}^o(x_{t+1}, y_{t+1})} \times \frac{D_t^o(x_t, y_t)}{D_{t+1}^o(x_t, y_t)} \right]^{1/2} \right) \text{ is technical change.}$$

The interpretation for the Malmquist TFP change index is that the total factor productivity is increased (or decreased if TFPC is less than one) by $(TFPC - 1) \times 100$ percent. The decomposition to the technical efficiency change and the technical change are interpreted as progress, no change, and regress when their values are greater than, equal to, or less than unity, respectively.

In the context of rice farming, technical efficiency progress represents the more efficient ways of using input in farming or using it at the more adequate level under the same technology. For example, adjusting the soil surface to be even level so the seed can receive even nutrients and grow evenly or applying fertilizer at a more adequate amount. Technical progress represents the adoption of new technologies in rice farming. For example, adopting new varieties of rice that are more high-yielding, high pest resistance, or the varieties that are more suitable for the land condition so it improves the yield of rice. It can also represent the adoption of new machines in agriculture to reduce human labor, save time, and improve productivity such as the combined harvester to reduce output losses or drone to apply fertilizer and pesticide more evenly across the rice field.

With these two components, we can separate the effect and get more precise information about what aspect that contributes to the TFP growth of rice in each province. This information allows policymakers to design adequate policies about rice based on the issue's area of the province and the region.

To calculate equations 4.15 and 4.16 is to calculate four-component distance functions by solving the following four LP problems for each DMU i^{th} given I DMU (Coelli et al., 2005):

$$1) \quad [D_o^t(x^t, y^t)]^{-1} = \max_{\phi, \lambda} \phi,$$

Subject to

$$\begin{aligned} -\phi y_i^t + Y^t \lambda &\geq 0, \\ x_i^t - X^t \lambda &\geq 0, \end{aligned} \tag{4.18}$$

$$\lambda \geq 0$$

$$2) \quad [D_o^{t+1}(x^{t+1}, y^{t+1})]^{-1} = \max_{\phi, \lambda} \phi,$$

Subject to

$$-\phi y_i^{t+1} + Y^{t+1} \lambda \geq 0, \quad (4.19)$$

$$x_i^{t+1} - X^{t+1} \lambda \geq 0,$$

$$\lambda \geq 0$$

$$3) \quad [D_o^t(x^{t+1}, y^{t+1})]^{-1} = \max_{\phi, \lambda} \phi,$$

Subject to

$$-\phi y_i^{t+1} + Y^t \lambda \geq 0, \quad (4.20)$$

$$x_i^{t+1} - X^t \lambda \geq 0,$$

$$\lambda \geq 0$$

$$4) \quad [D_o^{t+1}(x^t, y^t)]^{-1} = \max_{\phi, \lambda} \phi,$$

Subject to

$$-\phi y_i^t + Y^{t+1} \lambda \geq 0, \quad (4.21)$$

$$x_i^t - X^{t+1} \lambda \geq 0,$$

$$\lambda \geq 0$$

Where: λ is a $I \times 1$ vector of constants

X^t is input matrix ($N \times I$) of all DMU with technology at period t

X^{t+1} is input matrix ($N \times I$) of all DMU with technology at period $t + 1$

Y^t is output matrix ($M \times I$) of all DMU with technology at period t

Y^{t+1} is output matrix ($M \times I$) of all DMU with technology at period $t + 1$

ϕ is a parameter with is not greater than unity

This study uses the ‘Benchmarking’ package in R software to calculate technical efficiency score by the DEA approach and TFP growth as well as its components by the MPI approach.

4.2.2 Total factor productivity growth determinant model for spatial analysis

4.2.2.1 Basic model

Total factor productivity growth is the improvement in output that cannot be explained by the growth of its inputs. The potential determinants of the TFP growth, then, include the variables that could affect the growth. This study uses irrigation (*Irrig*), gross provincial product (*GPP*), high-yielding rice varieties adoption (*HYS*), average surface temperature (*skinT*), total precipitation over the area (*Tpre*), and the damaged planted area as the proxy of the extreme conditions that can cause loss to the farming (*NF*) as the explanatory variable for the change in TFP of rice production in Thailand.

The most simple method to investigate the determinant of any dependent variables is to employ Ordinary Least Squares regression using the pooled data. The model could be shown as:

$$TFP\ growth_{it} = Irrig_{it} + GPP_{it} + HYS_{it} + skinT_{it} + Tpre_{it} + NF_{it} + \varepsilon_{it} \quad (4.22)$$

However, the model in 4.22 does not use the panel data, that I have in this study, at its full potential and ignores the difference of each individual. This heterogeneity of individuals could lead to biased coefficients. There are many treatments for the heterogeneity problem and the most common are the fixed effects and the random effects. A model that incorporates the individual effects can be shown as:

$$TFP\ growth_{it} = Irrig_{it} + GPP_{it} + HYS_{it} + skinT_{it} + Tpre_{it} + NF_{it} + \mu_i + \varepsilon_i \quad (4.23)$$

μ_i represent the individual effects, provinces in this study, that do not vary over time. The fixed effect model assumes that each individual has its own effect and intercept in the model that could vary from the others. These individual

effects can be captured by using dummy variables. The Random effects model, however, assumes that these individual effects are part of the random term and are expected to not differ from zero.

4.2.2.2 Spatial model

(1) Spatial weight matrix

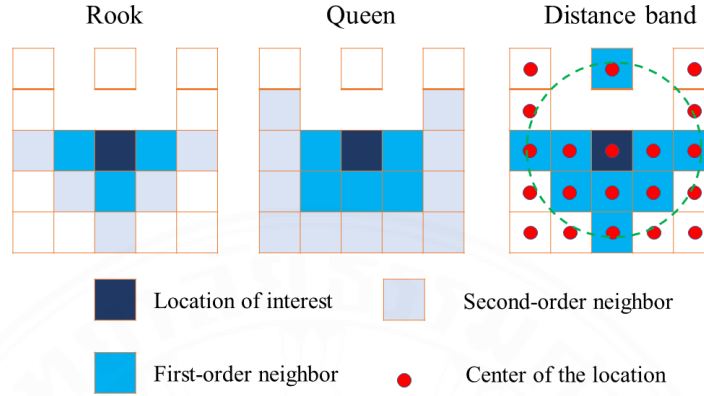
The relative location or the neighbor relation is expressed in the spatial model via the spatial weight matrix. A spatial matrix is a non-negative matrix that represents the adjacent location of each individual in the cross-sectional space. The spatial weight matrix is mostly created by “Rook”, “Queen”, or “Distance band” contiguity criterion.

The neighbor’s location under the Rook contiguity criterion is the adjacent locations that share the same boundary line, excluding the location of the corner area. For the Queen contiguity criterion, the neighbor is every area that shares the common boundary line. However, these two criteria may face the problem of the island area, the location that has no common boundary line with any other location and has no neighbor, which could cause problems when implementing spatial analysis. One way to avoid this island area problem is to use the distance band criterion. This last criterion uses the distance of the center of a location polygon to determine a neighbor area. If the linear distance between the center of the location is less than the assigned threshold, these locations, then, is the neighbor of each other. Figure 4.6 illustrates the neighbor location created under each criterion.

Rows and columns in the spatial weight matrix correspond to the space of the observations. Under the Rook and Queen criterion, the value of w_{ij} equals to one if the location i and j are neighbors and equal to zero if they are not. For the distance band criterion, each element of the spatial weight matrix w_{ij} is computed by the inverse distance function with the parameter that defines the decay effect. The Rook contiguity criterion is employed in this study, except for Phuket, which is an isolated province, that is manually imposed to be the neighbor of Phang Nga province and vice versa.

Figure 4.6

Spatial neighbor based on the rook, queen, and distance band criterion



Note: Reprinted from *The effect of human capital on income in Thailand: A Spatial effect analysis* [Master's thesis, Thammasat University] (p 33), by Chitdecha, M. J., 2016, Thammasat University Digital Collections, Copyright 2016 by Thammasat University.

Conventionally, a location is not neighbor to itself, the diagonal elements $w_{ii} = 0$. The weight in each row is usually standardized by the summation of its row such that the element in each row sum to unity, $w_{ij}^s = w_{ij} / \sum_j w_{ij}$ (Anselin, Gallo, & Jayet, 2008). The extension of the spatial weight matrix from cross-sectional to the panel data can be shown in equation 4.24.

$$W_{NT} = I_T \otimes W_N \quad (4.24)$$

W_N is the weight matrix of cross-sectional observation with N locations and dimensions of $N \times N$. I_T is the identity matrix with the dimension of total time period T . The Kronecker product, $\otimes$, means we multiply the whole of the latter vector or matrix to each element of the former vector or matrix in the equation. The result is the spatial weight matrix with the dimension of $NT \times NT$.

(2) Spatial Lag Model

The spatial lag model is the formal specification for the equilibrium outcome of a spatial or social interaction process of the cross-section

observations. The dependent variable of any observation in the model is jointly determined by its neighbor observations. Following Anselin, Gallo, and Jayet (2008), the pooled spatial lag model expressed in stacked form can be shown as:

$$\mathbf{y} = \rho(\mathbf{I}_T \otimes \mathbf{W}_N)\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad (4.25)$$

$\mathbf{y}$ is the $NT \times 1$ vector of the dependent variable with the cross-sectional agent of N and the total period of T . $\mathbf{X}$ is the matrix of the explanatory variable with dimension of $NT \times K$, where K is the number of the explanatory variable of the equation; there are six explanatory variables for the TFP growth of rice in this study. $\boldsymbol{\varepsilon}$ is a vector of error term with dimension of $NT \times 1$ with $E[\boldsymbol{\varepsilon}\boldsymbol{\varepsilon}'] = \sigma_\varepsilon^2 \mathbf{I}_{NT}$. $\boldsymbol{\beta}$ is the vector of explanatory coefficient with dimension of $K \times 1$. ρ is the spatial autoregressive parameter.

We can also extend the spatial lag model to the panel data which can account for the individual effects. Fixed effects spatial lag model can be shown as:

$$\mathbf{y} = \rho(\mathbf{I}_T \otimes \mathbf{W}_N)\mathbf{y} + (\iota_T \otimes \boldsymbol{\alpha}) + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad (4.26)$$

where ι_T is a $T \times 1$ vector of one. $\boldsymbol{\alpha}$ is a $N \times 1$ vector of individual fixed effects, with a constraint that $\boldsymbol{\alpha}'\iota_N = 0$. And the Random effects spatial lag model can be shown as:

$$\begin{aligned} \mathbf{y} &= \rho(\mathbf{I}_T \otimes \mathbf{W}_N)\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \\ \boldsymbol{\varepsilon} &= (\iota_T \otimes \mathbf{I}_N)\boldsymbol{\mu} + \mathbf{u} \end{aligned} \quad (4.27)$$

where $\boldsymbol{\mu}$ is a $N \times 1$ vector of cross-sectional random components.

(3) Spatial Error Model

The spatial error model is used for capturing spatial dependence in the error terms. The spatial error specification does not require a theoretical model for spatial/social interaction as it does for the spatial lag model. The spatial correlation of locations in the error term can be captured by adding the spatial

autocorrelation part in the error. Following Anselin, Gallo, & Jayet (2008), pooled spatial error model can be shown as:

$$\begin{aligned} \mathbf{y} &= \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \\ \boldsymbol{\varepsilon} &= \lambda(\mathbf{I}_T \otimes \mathbf{W}_N)\boldsymbol{\varepsilon} + \mathbf{u} \end{aligned} \quad (4.28)$$

where $\mathbf{u}$ is a $NT \times 1$ idiosyncratic error vector with variance $\sigma_u^2 \mathbf{I}_{NT}$. λ is the spatial auto-regressive parameter, and other terms are the same as mentioned before.

For the panel data, the fixed effects spatial error model and random effects spatial error model can be shown as equations 4.29 and 4.30 respectively.

$$\begin{aligned} \mathbf{y} &= \mathbf{X}\boldsymbol{\beta} + (\iota_T \otimes \boldsymbol{\alpha}) + \boldsymbol{\varepsilon}, \\ \boldsymbol{\varepsilon} &= \lambda(\mathbf{I}_T \otimes \mathbf{W}_N)\boldsymbol{\varepsilon} + \mathbf{u} \end{aligned} \quad (4.29)$$

$$\begin{aligned} \mathbf{y} &= \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \\ \boldsymbol{\varepsilon} &= (\iota_T \otimes \mathbf{I}_N)\boldsymbol{\mu} + (\mathbf{I}_T \otimes \mathbf{B}_N^{-1})\mathbf{u} \end{aligned} \quad (4.30)$$

where $\mathbf{B}_N = \mathbf{I}_N - \lambda \mathbf{W}_N$. $\mathbf{u} \sim IID(0, \sigma_u^2 \mathbf{I}_{NT})$ is a $NT \times 1$ vector of idiosyncratic errors.

4.2.3 Testing and selecting the spatial model

4.2.3.1 Moran's I test

Moran's I, developed by Moran (1948), is a statistical test for the spatial autocorrelation in the residuals of the model. The null hypothesis of this test is that there is no spatial autocorrelation in the residuals. If the null hypothesis is rejected, then, the spatial lag model and spatial error model should be applied instead of the OLS model. The Moran's I test can be mathematically shown as follows:

$$I = \frac{N}{W} \frac{\sum_{i=1}^N \sum_{j=1}^N w_{ij} (A_i - \bar{A})(A_j - \bar{A})}{\sum_{i=1}^N (A_i - \bar{A})^2} \quad (4.31)$$

where w_{ij} is the element of the spatial matrix corresponding to area i and j . W is the sum of w_{ij} . N is the number of the area in the study. A_i and A_j are the value of the interest area.

4.2.3.2 Lagrange Multiplier test

Lagrange Multiplier test is the test for the significant effects of spatial dependence and chooses model specification accordingly. The tests are discussed in more detail in Anselin (1988). Null hypothesis of the test is that there is no significant spatial dependence in the lagged term ($\rho = 0$) or in the error term ($\lambda = 0$). If the null hypothesis is rejected the spatial lag mode and spatial error model should be applied for each case. The robust version of the tests, proposed by Anselin et al. (1996), are also applied for determine the model specification for the pooled spatial model.

4.2.3.3 Testing for spatial effects in panel data

Baltagi et al. (2003) proposed five Lagrange multiplier (LM) tests for the panel data regression model. The hypotheses under each test are as follows:

- (a) $H_0^a: \lambda = \sigma_\mu^2 = 0$, and the alternative H_1^a is that at least one component is not zero.
- (b) $H_0^b: \sigma_\mu^2 = 0$ (assuming no spatial correlation, i.e., $\lambda = 0$), and the one-sided alternative H_1^b is that $\sigma_\mu^2 > 0$.
- (c) $H_0^c: \lambda = 0$ (assuming no random effects, i.e., $\sigma_\mu^2 = 0$), and the two-sided alternative is $H_1^c: \lambda \neq 0$.
- (d) $H_0^d: \lambda = 0$ (assuming the possible existence of random effects, i.e., $\sigma_\mu^2 \geq 0$), and the two-sided alternative is $H_1^d: \lambda \neq 0$.
- (e) $H_0^e: \sigma_\mu^2 = 0$ (assuming the possible existence of spatial correlation, i.e., λ may be zero or different from zero), and the one-sided alternatives is $H_1^e: \sigma_\mu^2 > 0$.

Test (a) is a joint LM test for simultaneously testing for the existence of spatial error correlation and the random region effects at the same time. The next two tests are the standardized of the marginal test that used in Test (a), one is testing for random regional effect assuming no spatial correlation (b) and another is testing for spatial correlation with an assumption of no random effects (c). However,

these tests may lead to misinference due to their assumption of no spatial correlation or no random effect when testing each other effects. Therefore tests (d), and (e) are derived to account for this problem.

The log-likelihood function, LM test statistic, and more details are discussed in Baltagi et al. (2003).

4.2.3.4 Spatial Hausman test

The Hausman test, proposed by Hausman in 1978, is used to identify whether the fixed effects or random effects model is more suitable for the panel data. Mutl and Pfaffermayr (2011) extend the test to apply to the spatial panel model. The Hausman test statistic form is as follows:

$$H = NT(\hat{\theta}_{FGLS} - \hat{\theta}_W)^T (\hat{\Sigma}_W - \hat{\Sigma}_{FGLS})^{-1} (\hat{\theta}_{FGLS} - \hat{\theta}_W) \quad (4.32)$$

where $\hat{\theta}_{FGLS}$ is the spatial generalized least squares estimator. $\hat{\theta}_W$ is the spatial within estimators. $\hat{\Sigma}_{FGLS}$ and $\hat{\Sigma}_W$ are corresponding estimates of the coefficient variance covariance matrices. H is asymptotically distributed χ^2 with k degree of freedom which is the number of regressors in the model. The null hypothesis of the test is that $E[\mu] = 0$ or the expected value of the individual effects equal to zero. If the null hypothesis cannot be rejected, it means that the spatial random effects model is more appropriate. If the null hypothesis is rejected, the spatial fixed effects model is more suitable.

4.3 Data descriptions

4.3.1 Data and variables

Provincial data of inputs and output of rice production are secondary data obtained from the Office of Agricultural Economics (OAE) and cover the period from 1997 to 2018. The inputs of rice production consist of 1) household of rice farmer 2) seed used 3) chemical fertilizer used and 4) cultivation area. Thus, the only output in performance measurement is paddy rice. The characteristic of the data is not a full-balanced panel due to establishment of a new province, Bueng Kan, in 2011. The data

for second rice is less completed in terms of the province number because some provinces lack a well-irrigation system and are suitable to cultivate rice only once a year. Hence, there is no second rice data in these provinces.

Data of labor used in measuring the efficiency of rice farming can be different in detail. When the analysis is at farm-level data, the labor data is usually collected as man-hours (Sriboonchitta & Wiboonpongse, 2001; Sriboonchitta & Wiboonpongse, 2005; Chaovanapoonphol, Battese, & Chang, 2005; Abedullah & Musgtaq, 2007; Songsrirote & Singhapreecha, 2007; Khai & Yabe, 2011; Ebers et al., 2017; Jirarud & Suwanmaneepong, 2020) or man-days (Coelli et al., 2002; Champhech, 2003; Krasachat, 2003; Wadud, 2003; Balcombe et al., 2008; Rahman et al., 2009; Butso & Isvilanonda, 2010; Srisompun and Isvilanonda, 2012; Sansri et al., 2014; Osti, 2016; Rahman et al., 2020). However, data used at the provincial level analysis is less detailed as it is collected as the number of rice farmer households (Suphannachart, 2013; Suphannachart, 2018, Nunti et al., 2019).

Other variables are standard input that used in performance measurement include seed of rice, chemical fertilizer, and cultivation area (Xu & Jeffrey, 1998; Sriboonchitta & Wiboonpongse, 2001; Coelli et al., 2002; Coelli & Nhhiem, 2002; Champhech, 2003; Krasachat, 2003; Wadud, 2003; Sriboonchitta & Wiboonpongse, 2005; Chaovanapoonphol, Battese, & Chang, 2005; Abedullah & Musgtaq, 2007; Songsrirote & Singhapreecha, 2007; Balcombe et al., 2008; Rahman et al., 2009; Butso & Isvilanonda, 2010; Taraka et al., 2010; Khai & Yabe, 2011; Hossain et al., 2012; Srisompun and Isvilanonda, 2012; Taraka et al., 2012; Sansri et al., 2014; Osti, 2016; Ebers et al., 2017; Pradhan, 2018; Nunti et al., 2019; Panpluem et al., 2019; Jirarud & Suwanmaneepong, 2020; Ke Chung Peng, 2020; Rahman et al., 2020).

The possible explanatory variables for the TFP growth determinant model are also secondary data and are obtained from various sources.

Firstly, irrigation data was obtained from the Royal Irrigation Department. It is the accumulation of big-, medium-, and small-irrigation projects in each province. Increasing in irrigation area can be considered as an improvement of the infrastructure for rice farming. The irrigation system allows farmers to grow more crops of rice in a year, adopting new varieties of rice that needed consistent water, and could reduce negative impacts from some weather shocks.

Second is the high-yield variety of rice adoption. This variable is measured as the ratio of the planted area of rice variety that is attributed as the high yield variety, by the Rice Department, to the total planted area of rice. It represents the adoption of seed technology which would play an important role in improving the productivity of rice. Third is a natural factor. It is measured as a ratio of the damaged area (non-harvested area) to the total planted area of rice. The natural factor is the proxy of natural and weather shocks that could impact the production of rice, such as drought, flood, or pest epidemics. The natural factors and the High-yielding rice varieties adoption are calculated by using data from the Office of Agricultural Economics.

These first three variables are used in the TFP determinant model by Jin et al. (2002), Suphannachart (2013), and Suphannachart (2018).

The next two factors, surface temperature and total precipitation, are remote sensing data from the ERA5-Land dataset obtained via the Google Earth Engine. These variables represent the climate change factor that could affect the productivity of rice. Many studies try to investigate and project the impact of climate change on the yield of rice (Amien et al., 1996; Yao et al., 2007; Sarker et al., 2012; Kim et al., 2013; Boonwichai, 2018; Chen et al., 2020; Pakeechay et al., 2020), TFP of rice (Kunimitsu et al., 2014; Kunimitsu et al., 2016), and TFP of agriculture products (Zhong et al., 2019; Rahman et al., 2022).

Lastly, the gross domestic product may affect the TFP of rice. A study by Liu et al. (2020) found that GDP per capita had a negative relationship with agricultural TFP growth for countries in South and Southeast Asia. To capture the effect at the provincial level, this study uses the gross provincial product of each province, as the chain value measures provided by the Office of the National Economic and Social Development Council.

Definitions and sources of data used in this study are summarized in Table 4.1.

Table 4.1

Summary of the data used in TFP and efficiency score measurement.

Variables	Definitions	Unit	Source
Data for the performance measurement analysis*			
Paddy rice	Amount of paddy rice produced	ton	OAE
Household	Number of rice farmer household	household	OAE
Seed	Amount of seed used in rice production	ton	OAE
Fertilizer	Amount of chemical fertilizer used in rice production	ton	OAE
Land	cultivation area of rice	rai	OAE
Data for the spatial analysis			
TFP growth	Total factor productivity of rice calculated in the first-step of the analysis	percentage	Calculated by author
Irrigation	Accumulated irrigation area including small-, medium, large-scale irrigation projects then divided by the planted area of each province	Ratio (rai/rai)	RID
GPP	Gross provincial product as the chain value measurement	billion baht	NESDC
High-yielding rice varieties adoption	Planted area of rice varieties as share of total planted area	percentage	OAE
Skin temperature	Yearly temperature average of the surface of the earth.	Celsius	ERA5-Land monthly averaged data
Total precipitation	Accumulated liquid and liquid and frozen water, including rain and snow, that falls to the Earth's surface but exclude fog, dew or the precipitation that evaporates in the atmosphere before it lands at the surface of the Earth	Depth in meters of water if it spread evenly over the province	ERA5-Land monthly averaged data
Natural factor	The damaged area that cannot be harvested is measure as one subtracted by the ratio of harvested area to the total rice planted area then multiplied by a hundred	percentage	OAE

Note. Author's summary.

* All variables used in performance measurement analysis are further divided into the input and output of the main rice and the second rice.

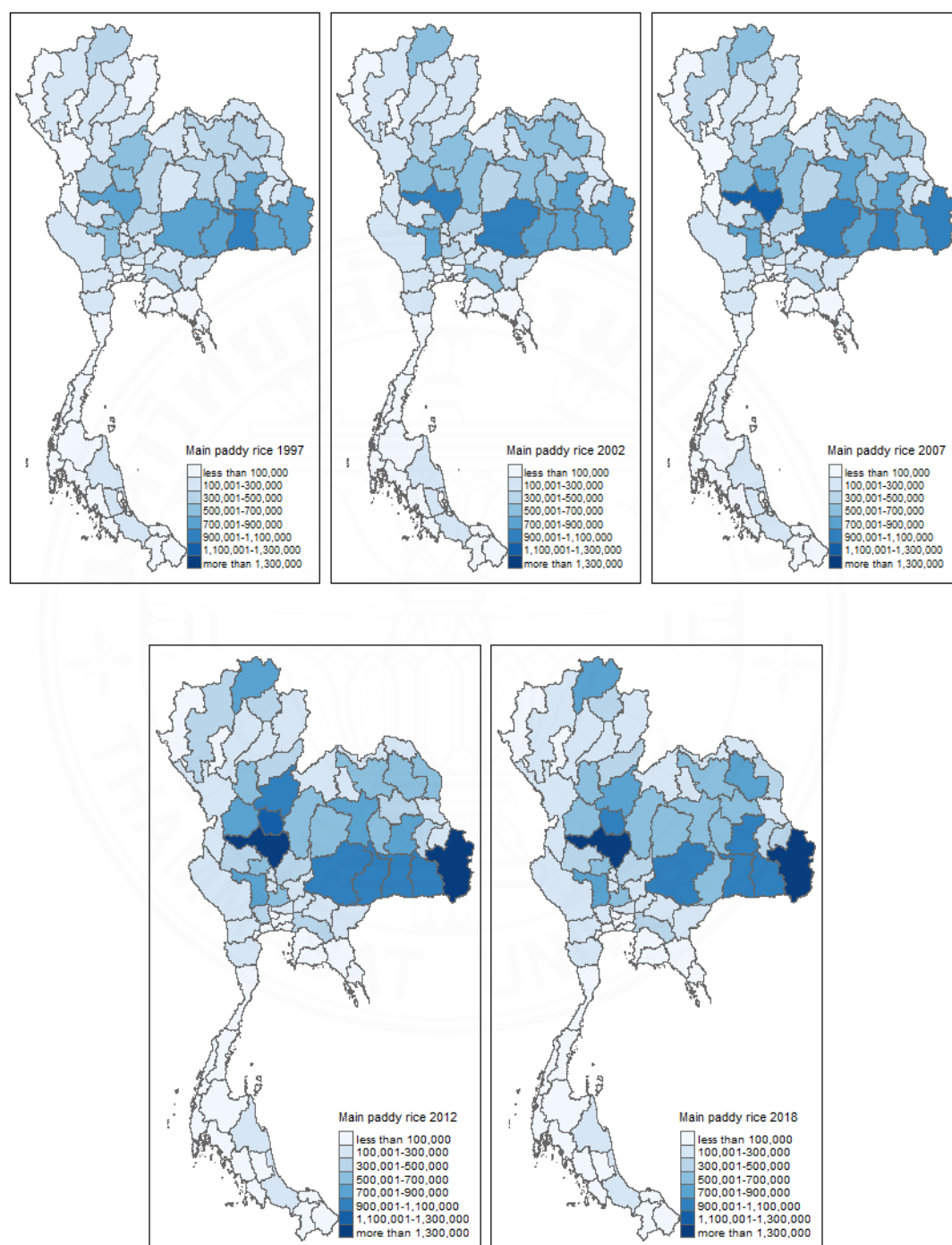
4.3.1.1 Data for the performance measurement

(1) Main rice

Paddy of the main rice is mostly produced in the northeastern region of Thailand, followed by the northern and central. In 1997, the top five provinces that produced the highest amount of the main rice were Surin (901,210 tons), Nakhon Ratchasima (885,008 tons), Si Sa Ket (780,191 tons), Roi Et (749,614 tons), and Ubon Ratchathani (746,471 tons). The five lowest produced provinces are Phuket, Samut Songkhram, Ranong, Phang-nga, and Rayong with 395, 2,092, 6,460, 7,174, and 10,441 tons respectively.

Rank of the main rice producer province in 2018 are mostly the same as in 1997. Top five producer provinces were Nakhon Sawan (1,425,335 tons), Ubon Ratchathani (1,382,578 tons), Phichit (1,041,351 tons), Si Sa Ket (1,034,863 tons), and Nakhon Ratchasima (1,008,611 tons). While the five lowest producer provinces were Phuket (32 tons), Ranong (245 tons), Phang-nga (1,041 tons), Chumphon (1,190 tons), and Krabi (1,403 tons).

Figure 4.7

Main rice produced (ton)

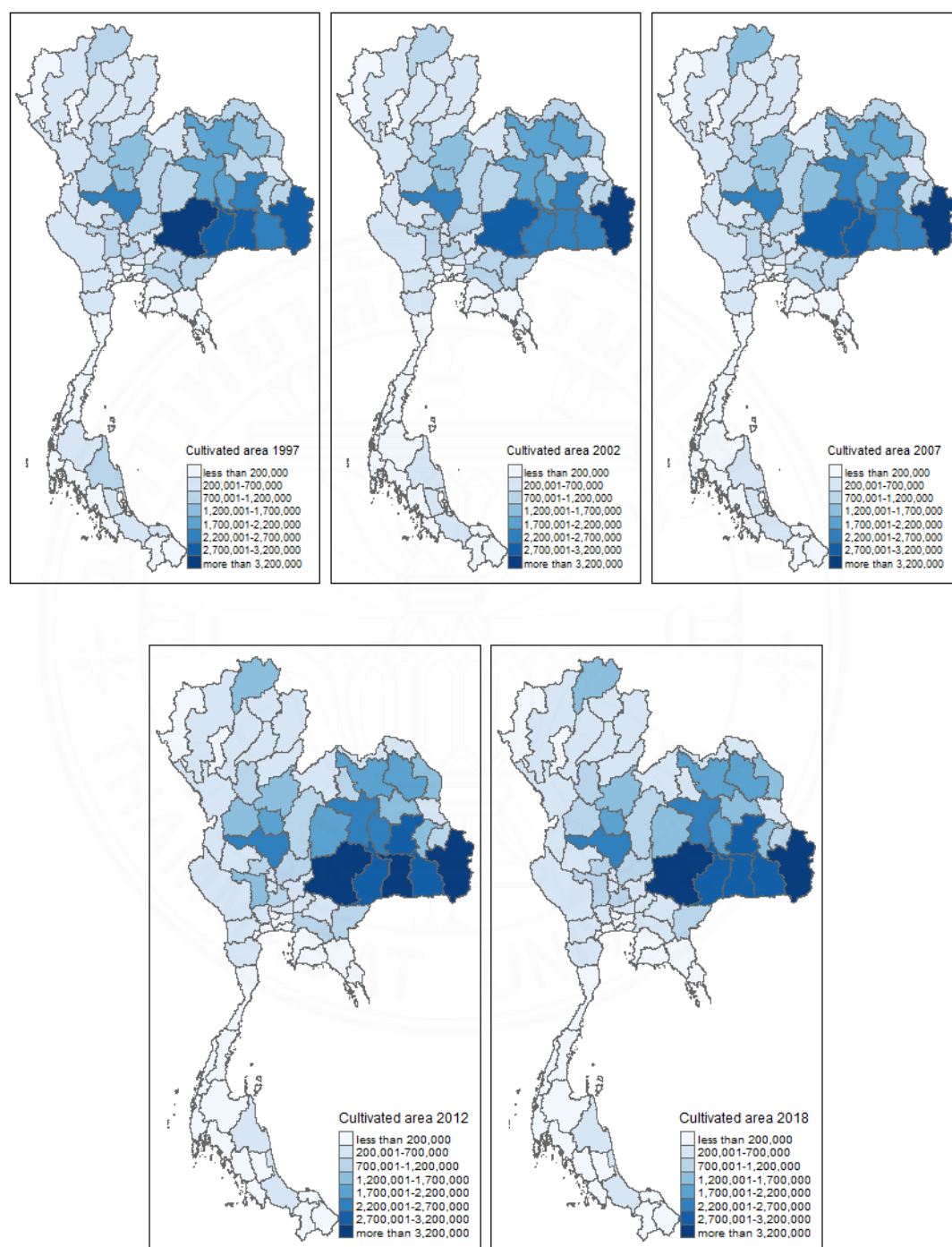
Note. Author's visualization based on OAE data.

The northeastern region also has the biggest rice planted area. In 1997, five provinces that have the most planted area of the main rice were Nakhon Ratchasima (3,256,870 rai), Ubon Ratchathani (2,979,330 rai), Surin (2,917,629 rai), Buri Ram (2,853,337 rai), and Roi Et (2,641,536 rai). On the other hand, the five lowest provinces were Phuket (825 rai), Samut Songkhram (4,270 rai), Phang-nga (21,242 rai), Ranong (24,848 rai), and Rayong (38,619 rai).

In 2018, the province that had the greatest planted area of the main rice was Ubon Ratchathani (3,924,596 rai) followed by Nakhon Ratchasima (3,461,389 rai), Roi Et (3,059,709 rai), Surin (3,042,244 rai), and Si Sa Ket (3,006,706 rai). In addition, five provinces that have the lowest cultivated area were Phuket (64 rai), Ranong (666 rai), Samut Songkhram (2,210 rai), Chumphon (3,075 rai), and Phang-nga (3,134 rai).



Figure 4.8

Main rice planted area (rai)

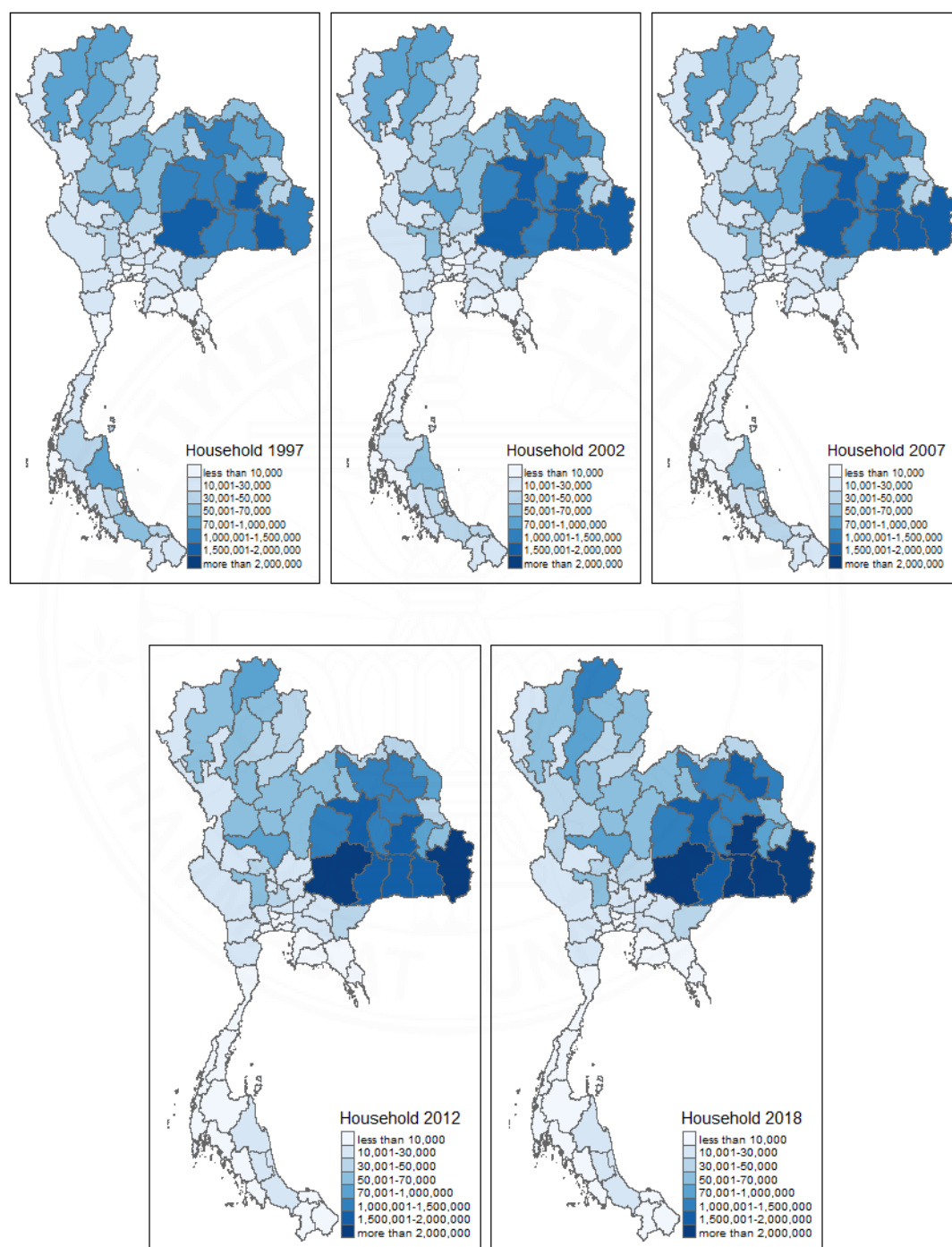
Note. Author's visualization based on OAE data.

In 1997, the provinces that have the greatest number of the main rice farmer household were Nakhon Ratchasima, Roi Et, Si Sa Ket, Ubon Ratchathani, and Buri Ram with 177,693, 153,090, 150,872, 149,450, and 146,677 households respectively. On the other hand, the lowest five provinces were Samut Songkhram, Phuket, Samut Sakhon, Samut Prakan, and Ranong with 241, 330, 1,762, 2,412, and 2,753 households respectively.

In 2018, farmer households of the main rice still concentrated in the northeastern region. The top five provinces that have the most main rice household in 2018 were Ubon Ratchathani, Nakhon Ratchasima, Si Sa Ket, Roi Et, and Surin with 280,390, 237,094, 236,383, 229,129, and 215,558 households respectively. In addition, the lowest provinces were Phuket, Ranong, Samut Songkhram, Samut Sakhon, and Phang-nga with 8, 109, 144, 221, and 454 households respectively.



Figure 4.9

Main rice farmer household

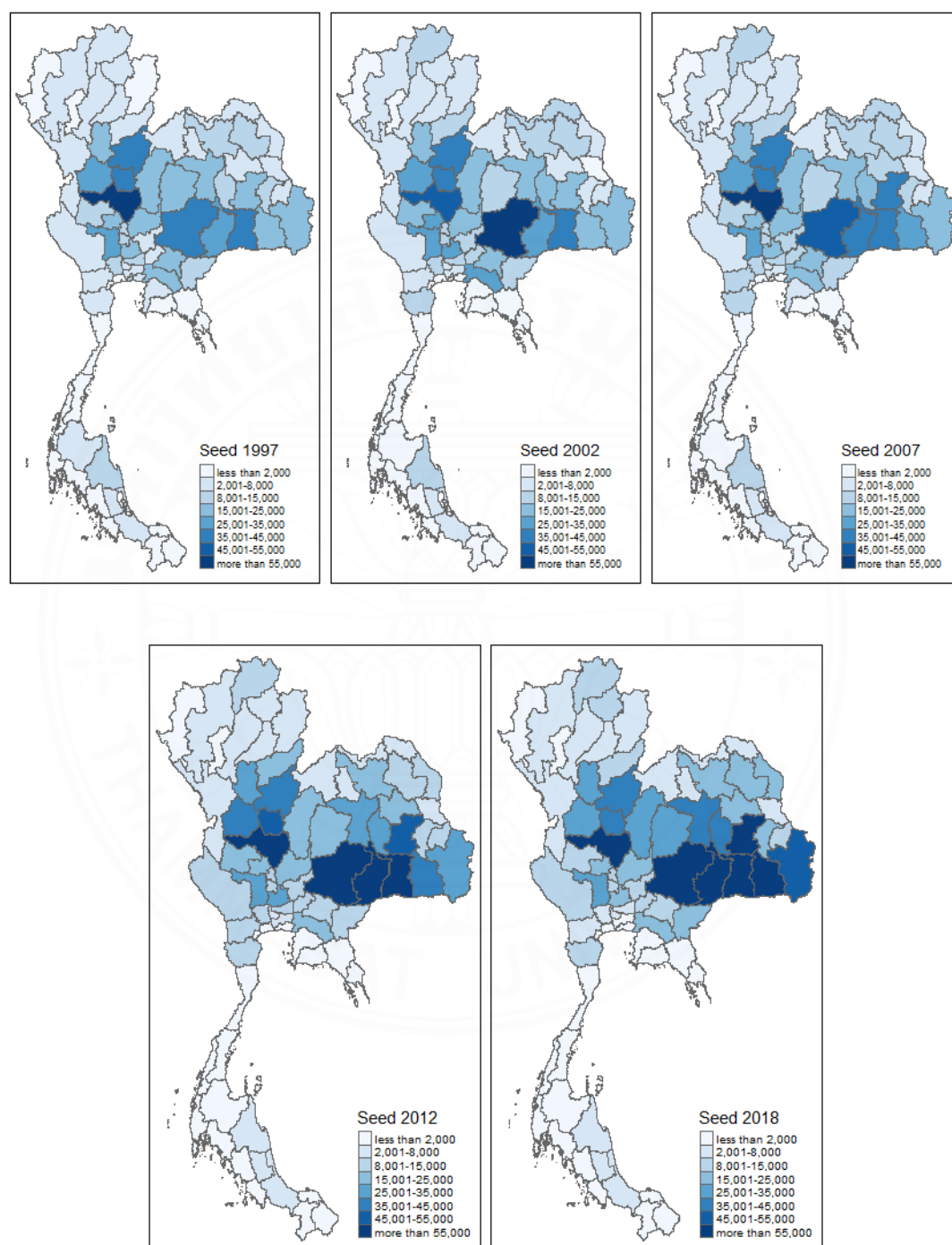
Note. Author's visualization based on OAE data.

The top five provinces that used the most amount of seed in the main rice farming in 1997 were Nakhon Sawan, Nakhon Ratchasima, Surin, Phichit, and Phitsanulok with 57,544, 43,518, 36,499, 35,723, and 35,069 tons respectively. On the other hand, the five lowest were Phuket, Samut Songkhram, Ranong, Phang-nga, and Krabi with 6, 92, 125, 204, and 320 tons respectively.

In 2018, Nakhon Ratchasima used the most seed in the main rice farming followed by Surin, Roi Et, Buri Ram, and Nakhon Sawan with 85,294, 79,314, 71,627, 68,771, and 65,095 tons respectively. In addition, the five lowest provinces were Phuket, Ranong, Krabi, Phang-nga, and Chumphon with 0.5, 3, 22, 29, and 55 tons respectively.



Figure 4.10

Main rice seed used (ton)

Note. Author's visualization based on OAE data.

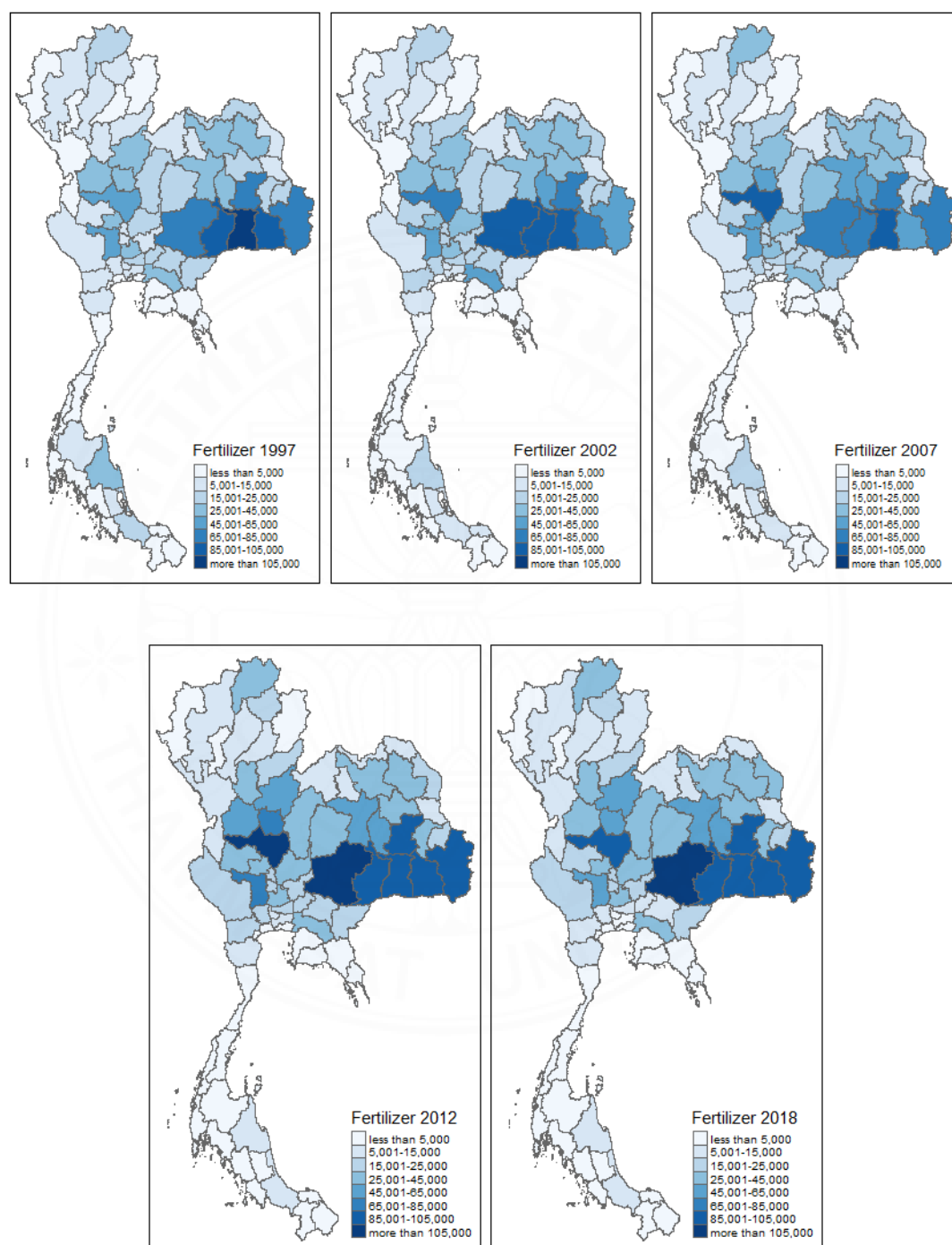
The top five provinces that used the most fertilizer in the main rice farming in 1997 were Surin (116,180 tons), Si Sa Ket (90,458 tons), Buri Ram (89,417 tons), Nakhon Ratchasima (79,939 tons), and Roi Et (73,756 tons). And the lowest five provinces were Phuket (30 tons), Samut Songkhram (134 tons), Ranong (180 tons), Phang-nga (517 tons), and Mae Hong Son (599 tons).

In 2018, five provinces that used the most chemical fertilizer were Nakhon Ratchasima (105,398 tons), Ubon Ratchathani (104,228 tons), Nakhon Sawan (102,872 tons), Surin (102,183 tons), and Si Sa Ket (96,777 tons). While the five lowest provinces were Phuket (2 tons), Ranong (7 tons), Krabi (69 tons), Phang-nga (83 tons), and Samut Songkhram (90 tons).

In summary, the main rice is mostly cultivated and produced in the northeastern region of Thailand, followed by northern, central, and southern. The amount of input used is according to the size of production. The statistical summary of the variables of the main rice is shown in Table 4.2.

Figure 4.11

Main rice fertilizer used (ton)



Note. Author's visualization based on OAE data.

Table 4.2

Variables summary of the main rice

	1997	2002	% Change	2007	% Change	2012	% Change	2018	% Change
Main Paddy Rice (ton)									
Whole country	18,788,788	21,819,932	16.1%	23,582,596	8.1%	27,233,903	15.5%	25,177,856	-7.5%
Northern	4,887,740	6,189,642	26.6%	6,687,982	8.1%	8,744,836	30.8%	7,847,727	-10.3%
Northeastern	8,633,595	9,569,963	10.8%	10,499,821	9.7%	12,303,561	17.2%	11,706,257	-4.9%
Central	4,342,743	5,261,932	21.2%	5,580,092	6.0%	5,751,115	3.1%	5,250,274	-8.7%
Southern	924,710	798,395	-13.7%	814,701	2.0%	434,391	-46.7%	373,598	-14.0%
Min	395	533		459		34		32	
Max	901,210	1,065,499		1,258,301		1,432,101		1,425,335	
Median	182,253	227,469		233,339		230,754		208,135	
Mean	247,221	287,104		310,297		353,687		326,985	
Std. dev	231,936	268,802		295,955		364,823		344,179	
Cultivated Area (rai)									
Whole country	56,958,032	56,907,578	-0.1%	57,385,921	0.8%	64,950,593	13.2%	59,980,731	-7.7%
Northern	12,363,686	12,598,802	1.9%	12,779,212	1.4%	14,927,584	16.8%	13,814,978	-7.5%
Northeastern	32,144,320	32,410,958	0.8%	32,773,544	1.1%	39,487,220	20.5%	36,878,181	-6.6%
Central	9,683,472	9,782,036	1.0%	9,814,339	0.3%	9,553,265	-2.7%	8,507,059	-11.0%
Southern	2,766,554	2,115,782	-23.5%	2,018,826	-4.6%	982,524	-51.3%	780,513	-20.6%
Min	825	1,693		1,308		69		64	
Max	3,256,870	3,224,240		3,201,999		4,314,831		3,924,596	
Median	427,730	414,555		426,961		445,262		381,015	
Mean	749,448	748,784		755,078		843,514		778,971	
Std. dev	808,446	804,348		815,771		1,002,044		937,982	
Farmer Household									
Whole country	3,707,043	3,725,794	0.5%	3,700,529	-0.7%	3,728,544	0.8%	4,288,092	15.0%

Table 4.2

Variables summary of the main rice (Cont.)

	1997	2002	% Change	2007	% Change	2012	% Change	2018	% Change
Northern	919,193	918,533	-0.1%	921,442	0.3%	887,169	-3.7%	944,139	6.4%
Northeastern	1,980,166	2,092,989	5.7%	2,093,251	0.0%	2,363,100	12.9%	2,858,641	21.0%
Central	467,052	436,755	-6.5%	448,418	2.7%	396,512	-11.6%	398,293	0.4%
Southern	340,632	277,517	-18.5%	237,418	-14.4%	81,763	-65.6%	87,019	6.4%
Min	241	186		146		16		8	
Max	177,693	198,755		186,009		220,499		280,390	
Median	34,248	33,169		33,722		26,931		28,694	
Mean	48,777	49,024		48,691		48,423		55,690	
Std. dev	43,954	47,226		47,052		55,259		67,969	
Seed Used (ton)									
Whole country	768,736	869,612	13.1%	922,143	6.0%	1,107,033	20.1%	1,197,265	8.2%
Northern	238,115	250,005	5.0%	273,544	9.4%	338,775	23.8%	313,386	-7.5%
Northeastern	266,721	330,141	23.8%	358,043	8.5%	504,305	40.9%	649,210	28.7%
Central	232,296	261,895	12.7%	258,032	-1.5%	248,177	-3.8%	220,178	-11.3%
Southern	31,604	27,570	-12.8%	32,524	18.0%	15,776	-51.5%	14,491	-8.1%
Min	6	11		8		1		0	
Max	57,544	82,720		68,501		73,942		85,294	
Median	5,986	6,970		8,330		8,513		7,928	
Mean	10,115	11,442		12,133		14,377		15,549	
Std. dev	11,611	14,080		13,672		17,774		20,242	
Chemical Fertilizer Used (ton)									
Whole country	1,519,560	1,583,813	4.2%	1,643,871	3.8%	1,955,635	19.0%	1,869,274	-4.4%
Northern	275,199	328,095	19.2%	380,092	15.8%	514,041	35.2%	472,497	-8.1%
Northeastern	801,636	761,367	-5.0%	776,581	2.0%	980,683	26.3%	998,164	1.8%

Table 4.2

Variables summary of the main rice (Cont.)

	1997	2002	% Change	2007	% Change	2012	% Change	2018	% Change
Central	360,135	427,538	18.7%	423,934	-0.8%	427,963	1.0%	372,251	-13.0%
Southern	82,590	66,813	-19.1%	63,264	-5.3%	32,948	-47.9%	26,362	-20.0%
Min	30	51		36		2		2	
Max	116,180	91,815		86,946		112,045		105,398	
Median	12,550	15,417		16,213		15,935		13,801	
Mean	19,994	20,840		21,630		25,398		24,276	
Std. dev	23,854	22,685		22,654		29,428		29,229	

Note. Author's summary.

(2) Second rice

Turning to the production of the second rice, most of the second rice is produced in the central and lower-northern regions of Thailand. The top five provinces that produced the most second rice in 1997 were Suphan Buri (633,921 tons), Phichit (387,732 tons), Chai Nat (367,154 tons), Phitsanulok (349,012 tons), and Nakhon Sawan (284,992 tons). However, the five lowest produced provinces were Chon Buri (79 tons), Mukdahan (126 tons), Lamphun (168 tons), Phayao (247 tons), and Yala (248 tons).

In 2018 the biggest producer province was Suphan Buri (650,768 tons), followed by Phitsanulok (558,955 tons), Nakhon Sawan (530,502 tons), Phra Nakhon Si Ayutthaya (513,950 tons), and Phichit (475,533 tons). In addition, the lowest five produced provinces were Mae Hong Son (53 tons), Satun (58 tons), Narathiwat (91 tons), Yala (149 tons), and Mukdahan (226 tons).

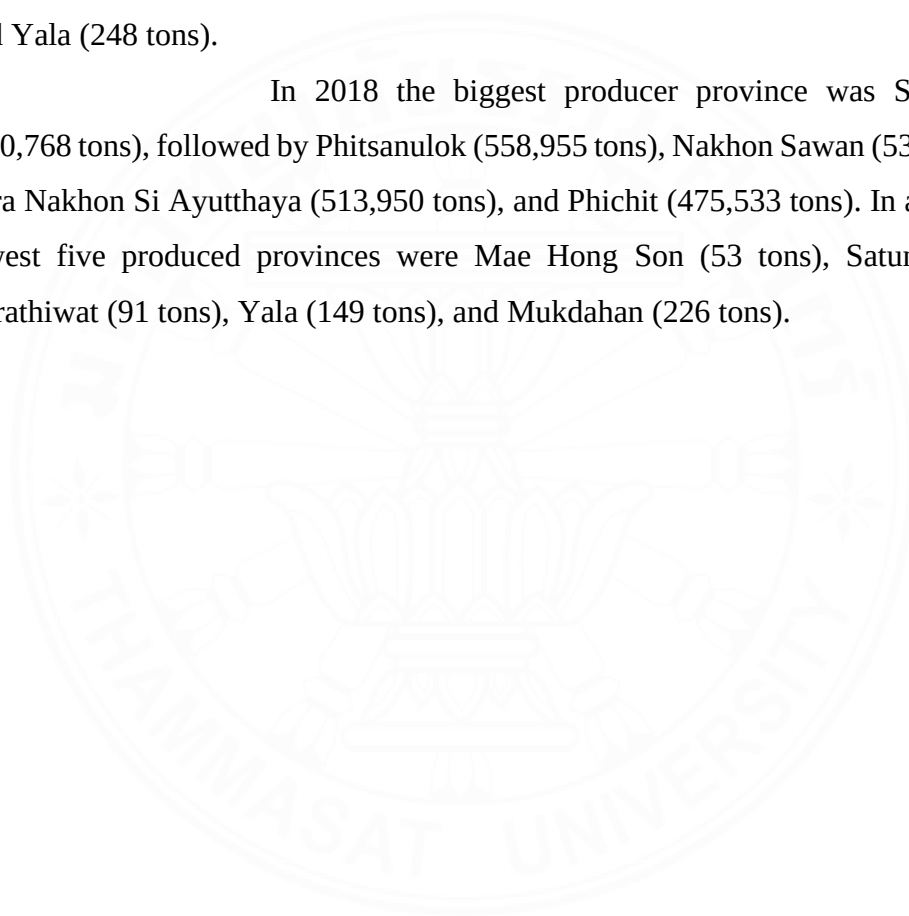
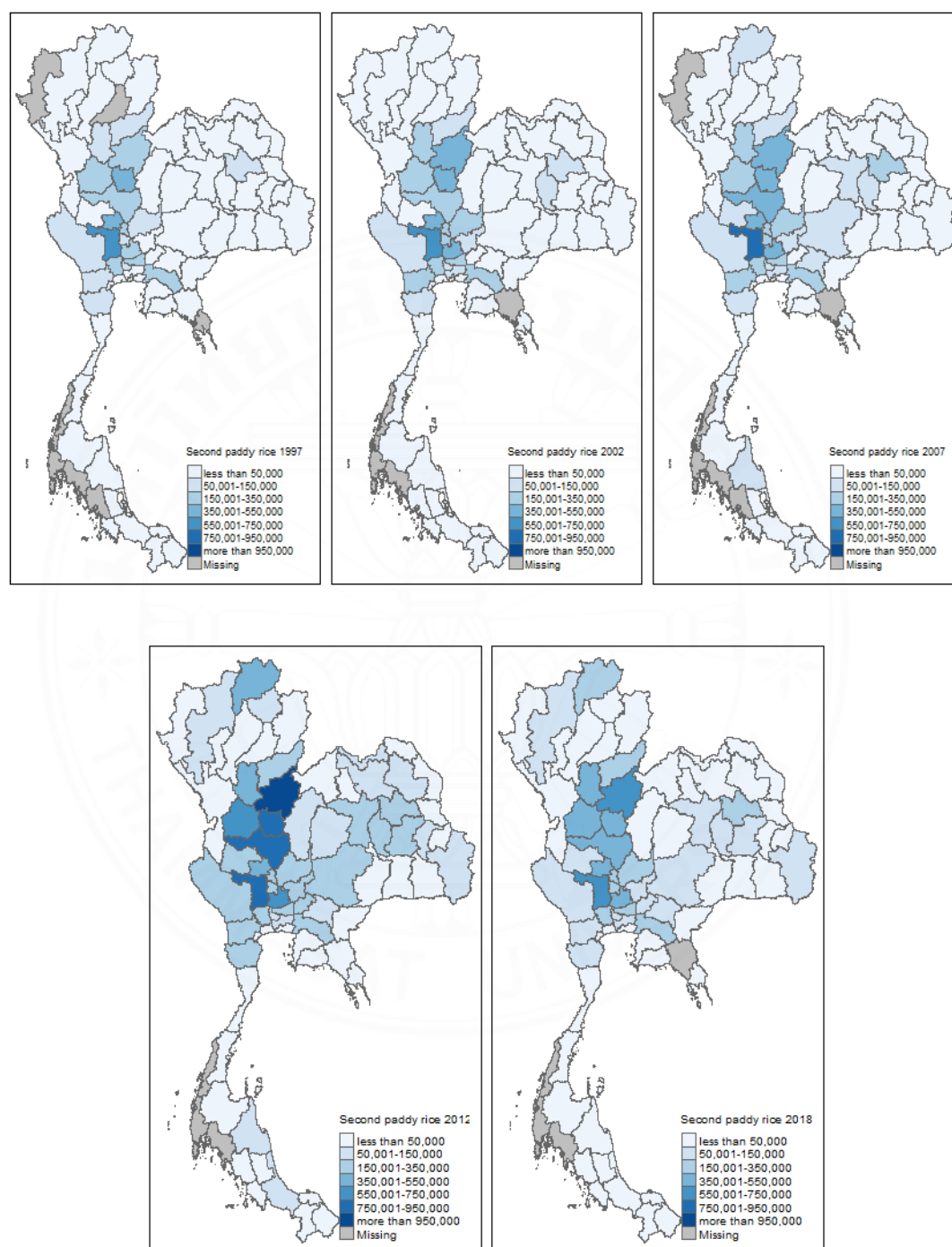


Figure 4.12

Second rice produced (ton)

Note. Author's visualization based on OAE data.

The top five provinces that have the most planted area of the second rice in 1997 were Suphan Buri (819,898 rai), Phichit (522,337 rai), Chai Nat (501,894 rai), Phitsanulok (470,994 rai), and Nakhon Sawan (420,398 rai). However, the provinces that have the lowermost cultivated area were Chon Buri (230 rai), Mukdahan (251 rai), Lamphun (260 rai), Phayao (450 rai), and Chanthaburi (500 rai).

Suphan Buri still had the biggest planted area of the second rice in 2018 with 906,036 rai, followed by Phitsanulok (844,203 rai), Nakhon Sawan (813,679 rai), Phichit (746,553 rai), and Phra Nakhon Si Ayutthaya (723,939 rai). And the provinces that have the least second rice planted area in 2018 were Mae Hong Son (91 rai), Satun (185 rai), Narathiwat (225 rai), Yala (340 rai), and Mukdahan (493 rai).

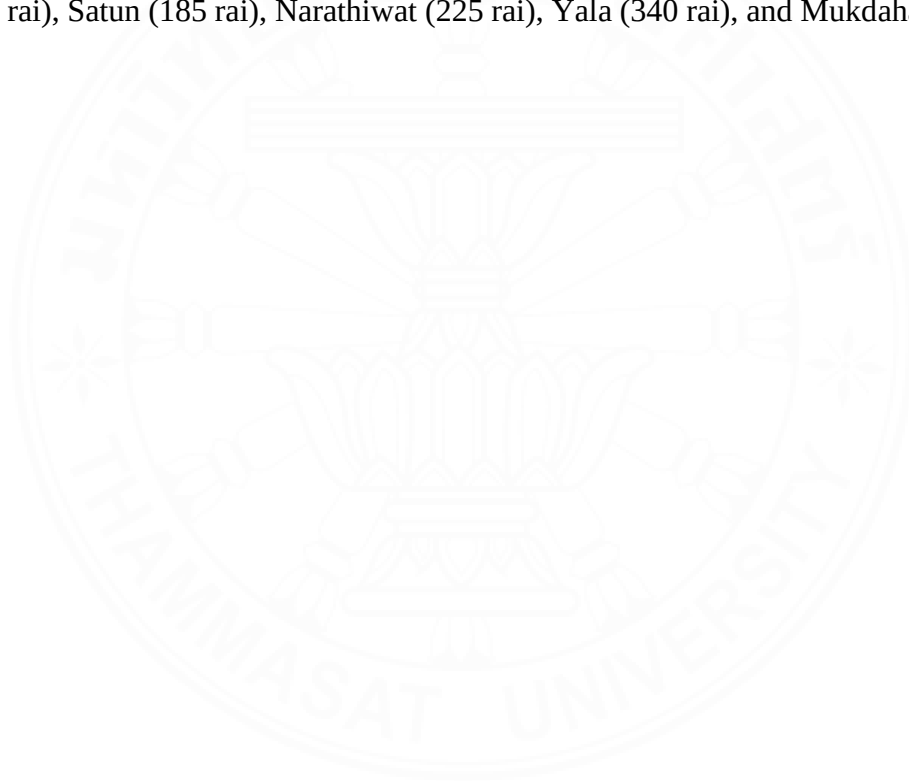
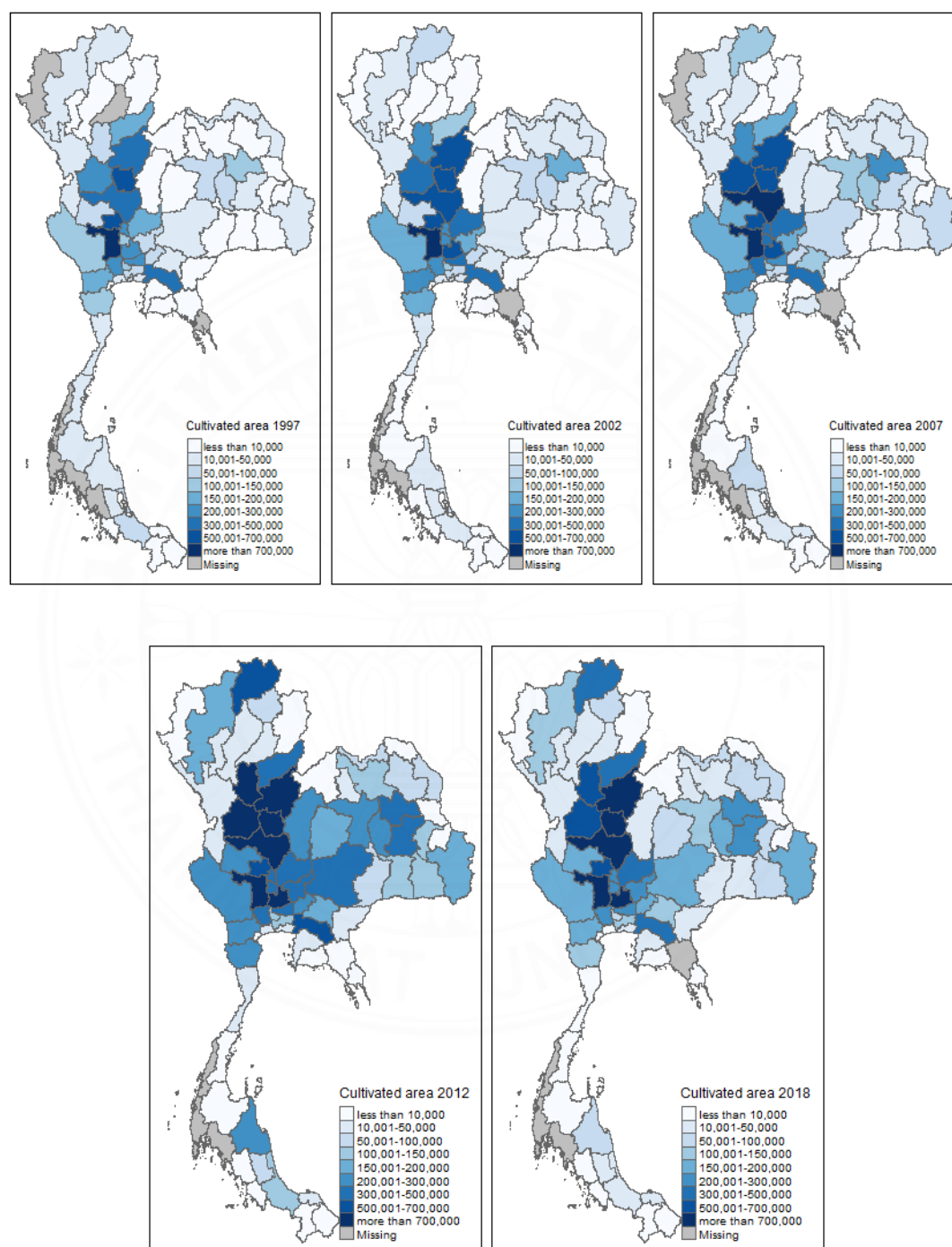


Figure 4.13

Second rice planted area (rai)

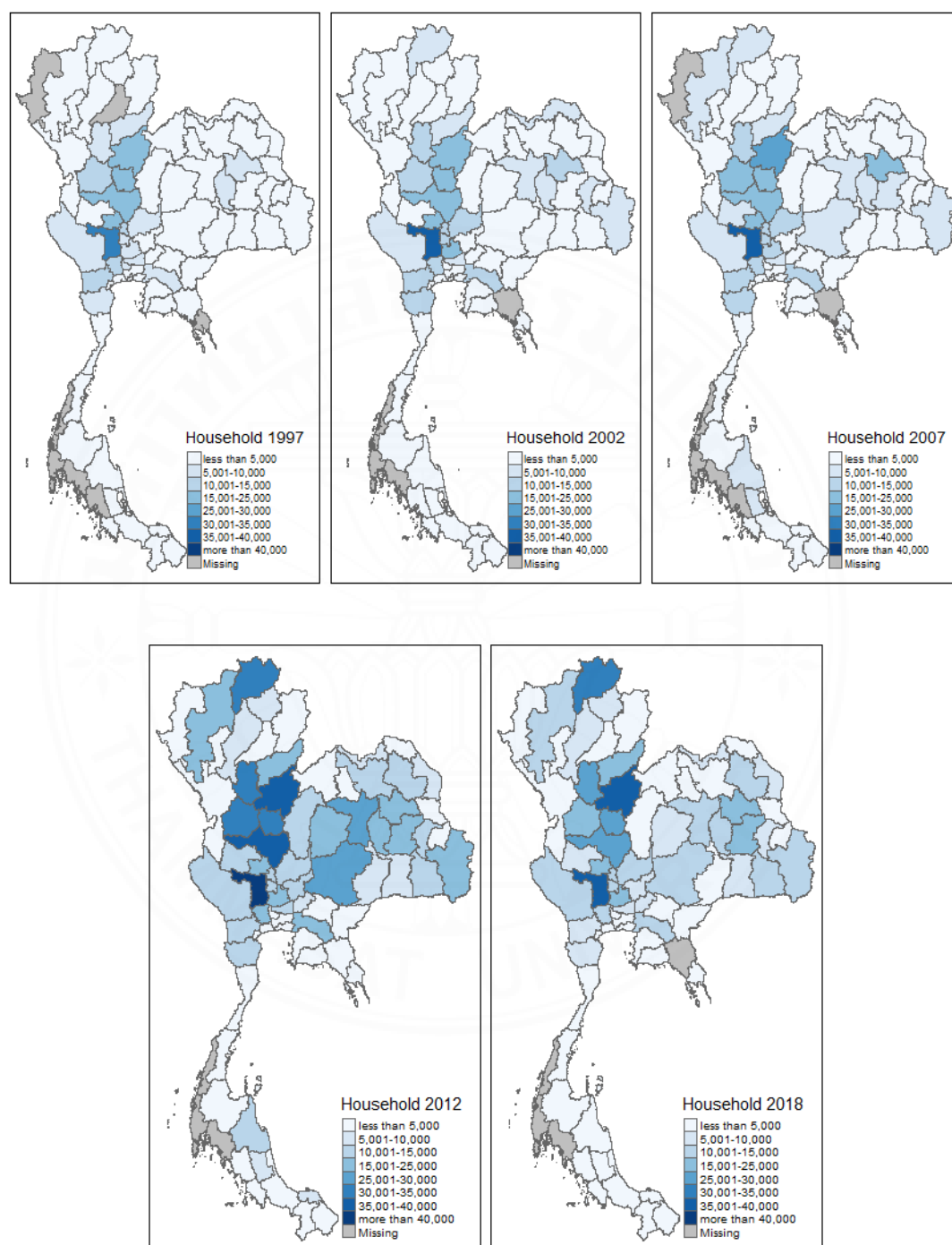
Note. Author's visualization based on OAE data.

In 1997, the provinces where the most of second rice farmers are located were Suphan Buri, Phitsanulok, Phichit, Chai Nat, and Nakhon Sawan with 34,421, 22,206, 22,049, 21,898, and 18,471 households respectively. In addition, the provinces that have the least second rice farmer household located were Mukdahan, Satun, Lamphun, Sa Kaeo, and Chanthaburi with 68, 69, 114, 133, and 135 households respectively.

In 2018, provinces that have the most second rice household were Suphan Buri, Phitsanulok, Chiang Rai, Sukhothai, and Phichit with 36,868, 35,684, 33,115, 27,926, and 27,369 households respectively. While provinces that have the least second rice farmer household were Mae Hong Son, Satun, Narathiwat, Chumphon, and Yala with 21, 31, 48, 69, and 97 households respectively.



Figure 4.14

Second rice farmer household

Note. Author's visualization based on OAE data.

The province that use the most seed in second rice farming in 1997 were Suphan Buri (26,458 tons) followed by Phichit (18,329 tons), Phitsanulok (15,920 tons), Chai Nat (13,616 tons), and Nakhon Sawan (13,091 tons). Provinces that used the least seed were Satun (2 tons), Lamphun (2 tons), Phayao (6 tons), Chon Buri (6 tons), and Yala (8 tons).

In 2018, the top five provinces that used the most seed in second rice farming were Phitsanulok (26,834 tons), Suphan Buri (25,737), Nakhon Sawan (22,985 tons), Phichit (22,062 tons), and Phra Nakhon Si Ayutthaya (19,166 tons). However, the least seed used provinces were Trang (2 tons), Narathiwat (3 tons), Satun (4 tons), Yala (4 tons), and Mukdahan (7 tons).

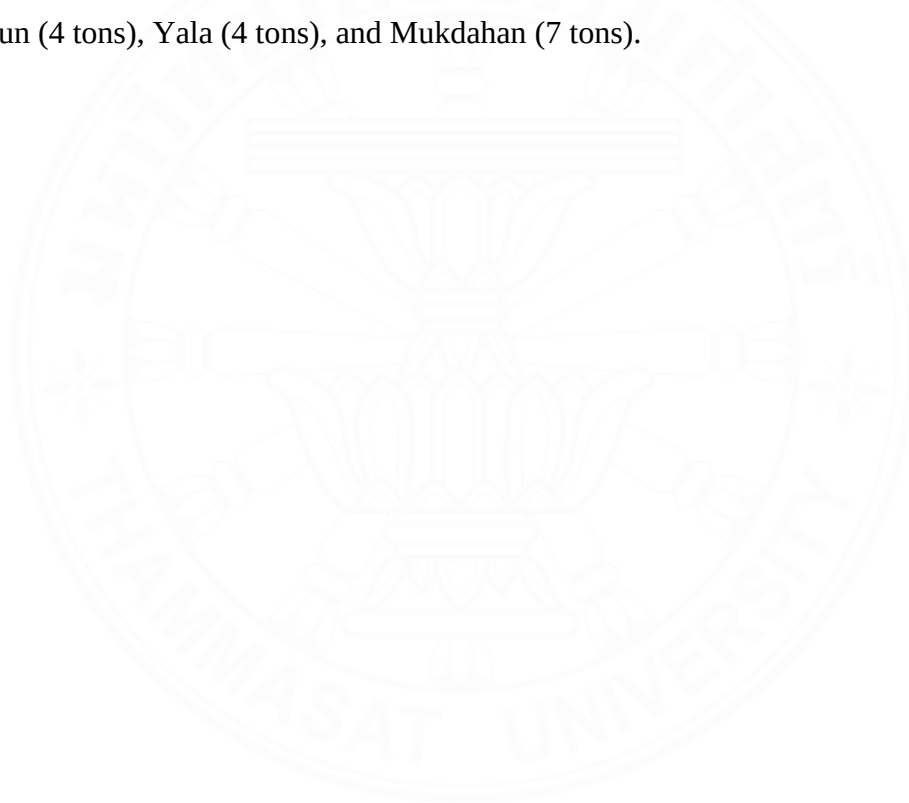
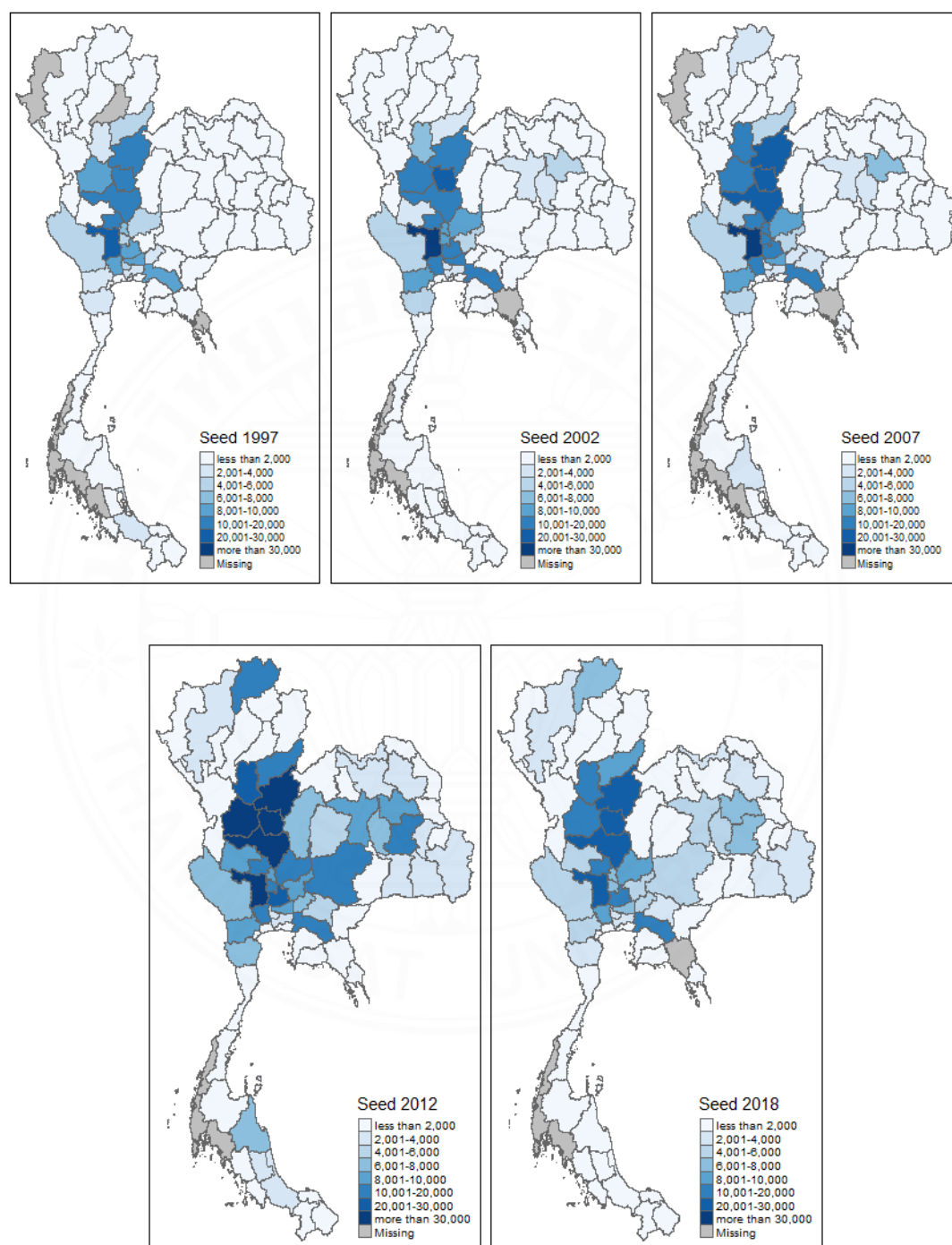


Figure 4.15

Second rice seed used (ton)

Note. Author's visualization based on OAE data.

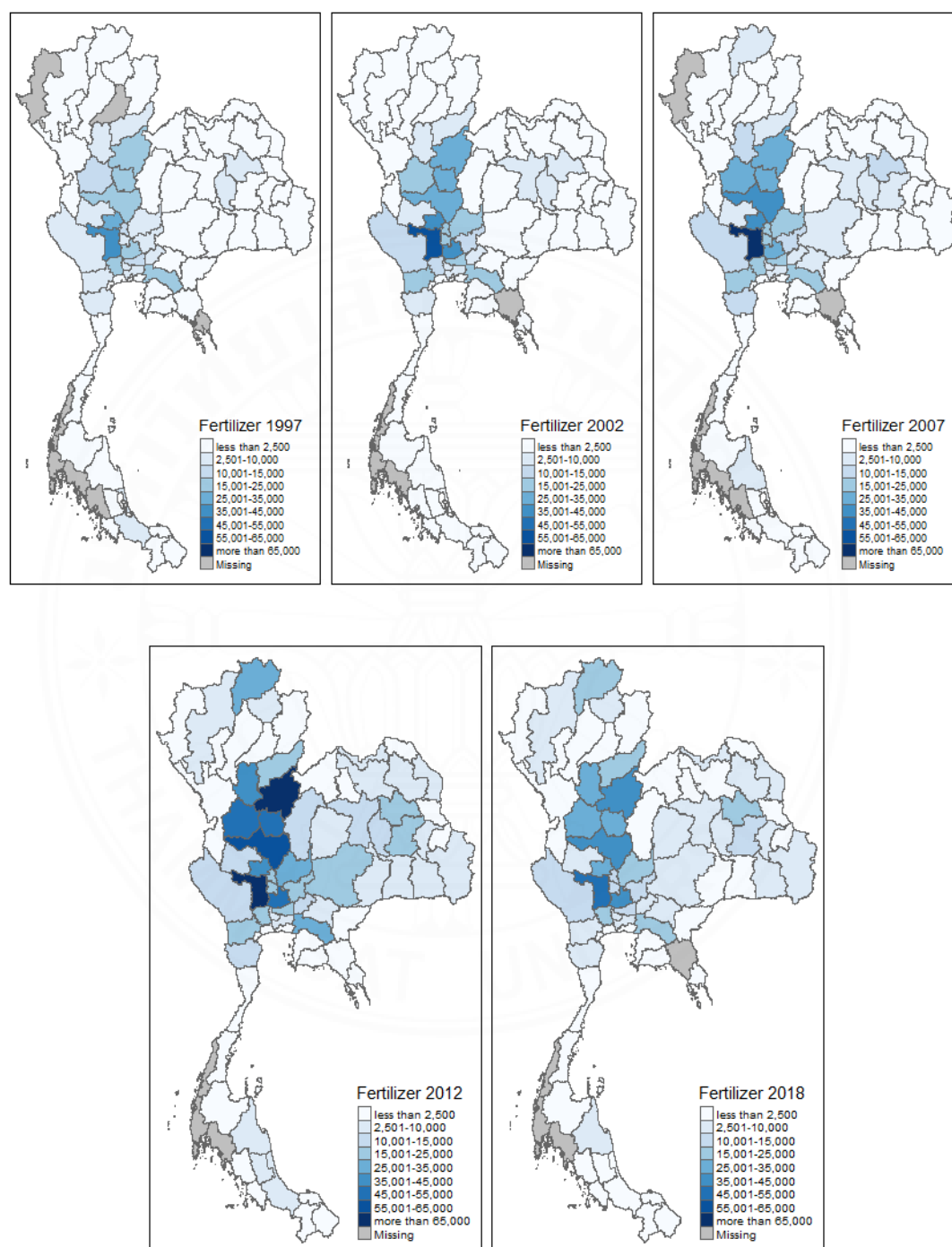
The top five provinces that used the most chemical fertilizer for second rice farming in 1997 were Suphan Buri, Chai Nat, Phitsanulok, Phichit, and Chachoengsao with 38,761, 28,224, 21,846, 21,809, and 20,549 tons respectively. The lowest chemical fertilizer used provinces were Chon Buri, Mukdahan, Lamphun, Loei, and Phayao with 8, 12, 15, 17, and 18 tons respectively.

In 2018, the top five chemical fertilizer used provinces were Suphan Buri, Phitsanulok, Nakhon Sawan, Phra Nakhon Si Ayutthaya, and Phichit with 45,943, 39,612, 37,241, 36,516, and 34,693 tons respectively. In addition, the lowest five provinces were Mae Hong Son, Satun, Narathiwat, Yala, and Mukdahan that used 3, 5, 6, 11, and 22 tons of fertilizer, respectively.

In summary, the second rice is mainly cultivated and produced in the central and northern regions of Thailand, in contrast to that of the main rice. A reason behind this difference may come from the difference in irrigation development. Big- and medium-irrigation projects are mostly located in the central and northern regions of Thailand (Table 2.3). The irrigation system can supply water to the rice field and allows farmers in these regions to cultivate rice outside the rainy season. But the limitation of irrigation development also limits the area and amount of second rice that is cultivated and produced. So, the total production of the second rice, in terms of the planted area, is only one fifth of the main rice.

The statistical summary of the variables of the main rice is shown in Table 4.3.

Figure 4.16

Main rice fertilizer used (ton)

Note. Author's visualization based on OAE data.

Table 4.3

Variables summary of the second rice

	1997	2002	% Change	2007	% Change	2012	% Change	2018	% Change
Second Paddy Rice (ton)									
Whole country	4,549,755	5,690,375	25.1%	6,882,201	20.9%	12,235,347	77.8%	7,964,554	-34.9%
Northern	1,474,665	1,752,684	18.9%	2,338,297	33.4%	5,198,586	122.3%	3,139,976	-39.6%
Northeastern	189,727	290,619	53.2%	484,041	66.6%	1,638,381	238.5%	1,016,166	-38.0%
Central	2,803,744	3,590,912	28.1%	3,955,717	10.2%	5,164,330	30.6%	3,717,454	-28.0%
Southern	81,619	56,160	-31.2%	104,146	85.4%	234,050	124.7%	90,958	-61.1%
Min	60	28		58		95		28	
Max	633,921	694,071		819,277		1,001,796		650,768	
Median	11,316	13,850		21,215		67,962		38,295	
Mean	66,908	80,146		99,742		167,607		110,619	
Std. dev	117,591	135,164		157,360		236,988		153,514	
Cultivated Area (rai)									
Whole country	6,436,596	8,434,067	31.0%	10,074,148	19.4%	18,101,239	79.7%	12,066,980	-33.3%
Northern	2,074,991	2,593,866	25.0%	3,477,315	34.1%	7,615,783	119.0%	4,819,308	-36.7%
Northeastern	401,394	628,516	56.6%	900,130	43.2%	2,946,744	227.4%	1,766,573	-40.1%
Central	3,782,316	5,093,134	34.7%	5,485,903	7.7%	7,095,692	29.3%	5,311,948	-25.1%
Southern	177,895	118,551	-33.4%	210,800	77.8%	443,020	110.2%	169,151	-61.8%
Min	200	80		140		202		60	
Max	819,898	969,829		1,100,375		1,436,319		906,036	
Median	26,481	27,650		40,609		111,536		65,320	
Mean	94,656	118,790		146,002		247,962		167,597	
Std. dev	155,733	190,697		218,951		333,217		225,971	
Farmer Household									
Whole country	336,026	387,869	15.4%	425,630	9.7%	804,786	89.1%	618,997	-23.1%

Table 4.3

Variables summary of the second rice (Cont.)

	1997	2002	% Change	2007	% Change	2012	% Change	2018	% Change
Northern	103,301	115,624	11.9%	139,566	20.7%	289,703	107.6%	232,698	-19.7%
Northeastern	42,373	67,001	58.1%	74,152	10.7%	234,682	216.5%	160,354	-31.7%
Central	172,046	187,556	9.0%	190,711	1.7%	252,288	32.3%	214,251	-15.1%
Southern	18,306	17,688	-3.4%	21,201	19.9%	28,113	32.6%	11,694	-58.4%
Min	62	20	-67.7%	25	25.0%	19	-24.0%	15	
Max	34,421	35,802	4.0%	38,664	8.0%	45,293	17.1%	36,868	
Median	2,490	3,197	28.4%	3,216	0.6%	8,465	163.2%	5,285	
Mean	4,942	5,461	10.5%	6,169	13.0%	11,024	78.7%	8,597	
Std. dev	6,574	6,741	2.5%	7,259	7.7%	10,973	51.2%	9,310	
Seed Used (ton)									
Whole country	193,558	266,677	37.8%	312,464	17.2%	532,966	70.6%	327,611	-38.5%
Northern	66,167	86,800	31.2%	113,280	30.5%	232,845	105.5%	134,532	-42.2%
Northeastern	5,887	14,208	141.3%	20,365	43.3%	77,179	279.0%	46,396	-39.9%
Central	116,877	162,176	38.8%	172,851	6.6%	210,846	22.0%	142,667	-32.3%
Southern	4,627	3,494	-24.5%	5,968	70.8%	12,096	102.7%	4,015	-66.8%
Min	2	1		1		4		1	
Max	26,458	32,837		37,050		47,788		26,834	
Median	485	725		834		3,078		1,792	
Mean	2,846	3,756		4,528		7,301		4,550	
Std. dev	5,035	6,401		7,302		10,589		6,505	
Chemical Fertilizer Used (ton)									
Whole country	327,469	462,364	41.2%	543,337	17.5%	891,056	64.0%	589,327	-33.9%
Northern	93,569	121,631	30.0%	169,047	39.0%	353,977	109.4%	229,908	-35.1%
Northeastern	16,637	24,754	48.8%	40,577	63.9%	129,150	218.3%	82,432	-36.2%

Table 4.3

Variables summary of the second rice (Cont.)

	1997	2002	% Change	2007	% Change	2012	% Change	2018	% Change
Central	208,999	310,525	48.6%	324,427	4.5%	387,972	19.6%	269,245	-30.6%
Southern	8,264	5,454	-34.0%	9,286	70.3%	19,957	114.9%	7,742	-61.2%
Min	6	2		4		7	75.0%	2	
Max	38,761	59,169		73,729		71,500	-3.0%	45,943	
Median	775	1,341		1,483		5,511	271.6%	3,259	
Mean	4,816	6,512		7,874		12,206	55.0%	8,185	
Std. dev	7,823	11,079		12,820		16,692	30.2%	11,027	

Note. Author's summary.

4.3.1.2 Data for the spatial regression

There are some issues to be noted and correct before employing spatial analysis. First is the problem of the varying spatial matrix. Bueng Kan province was established in 2011 by separating from Nong Khai. This causes the difference in the spatial matrix between the period before and after 2011. The software and package used in this study, package `spml` in R software, is not coded to deal with this issue. So, the author decided to reduce observations in the spatial analysis from 77 provinces to 76 provinces, by adding each variable of Bueng Kan back to Nong Khai. The satellite data are also collected based on the 76 provinces.

High-yielding varieties shared data is lacked for the main rice season before the year 2002. Therefore, the total observation of the main rice for spatial analysis is 1,292 (76 provinces $\times$ 17 periods).

Data for the first step of the analysis of the second rice contained more missing values than the main rice. This also caused missing value (NA) in the TFP growth results. The software and package used in this study only allowed balanced panel data for the analysis. As a result, the author drops 16 provinces that contained missing value. The total observation of the second rice for spatial analysis is 1,260 (60 provinces $\times$ 21 periods). Details of the dropped provinces and the spatial map are shown in appendix B.

Accumulated irrigation area of all sizes projects is greatest in the central region followed by northern, northeastern, and southern. High-yielding variety adoption is relatively higher for the Central and Northern regions. The rate of shared is also higher for the second rice compared to the main rice. The average surface temperature is higher in the Central and Northeastern compared to other regions for both rice seasons. And the average surface temperature is slightly higher in the main rice season for all regions. Total precipitation is very different for each rice season but less varies across the region within the same season. The damaged area, that captures the natural shocks, is relatively higher in the Northeastern region for both rice seasons. The summary of data used in the spatial analysis is shown in Table 4.4.

Table 4.4

Variables summary for the spatial analysis

	1997	2002	2007	2012	2018	1997-2018
Accumulated irrigation area (rai)						
Whole country	24,590,979	27,659,792	28,858,023	30,585,690	33,446,314	
Northern	6,892,452	7,472,100	7,923,721	8,751,173	9,787,516	
Northeastern	5,058,302	6,210,253	6,443,105	6,927,576	7,851,078	
Central	10,448,682	11,449,107	11,744,315	11,941,819	12,639,020	
Southern	2,191,543	2,528,331	2,746,882	2,965,122	3,168,700	
Min	0	0	0	0	0	0
Max	2,108,068	2,120,598	2,230,918	2,235,418	2,286,008	2,286,008
Median	249,657	311,663	328,193	344,054	386,366	329,022
Mean	323,566	363,945	379,711	397,217	434,368	383,489
Std. dev	353,950	359,275	366,877	372,870	385,474	367,179
High-yield varieties shared of main rice (%)						
Whole country		44.73	49.28	45.71	40.01	
Northern		48.70	61.06	58.93	46.55	
Northeastern		42.99	42.55	38.44	35.02	
Central		51.71	60.56	56.22	50.94	
Southern		15.47	29.17	34.53	40.63	
Min		0.00	0.00	0.00	0.18	0.00
Max		99.64	100.00	100.00	84.90	100.00
Median		49.26	57.14	57.63	49.40	54.02
Mean		44.30	49.33	50.54	47.21	48.08
Std. dev		26.36	26.71	24.05	22.27	24.49
High-yield varieties shared of second rice (%)						
Whole country	79.04	82.23	71.37	64.64	58.55	
Northern	88.10	81.50	68.22	62.53	60.21	
Northeastern	57.89	67.40	41.29	47.57	47.45	
Central	77.10	84.31	78.93	74.40	60.83	
Southern	62.28	87.72	54.87	58.04	55.10	
Min	0.00	0.00	0.00	22.26	17.91	0.00
Max	100.00	100.00	100.00	86.56	90.10	100.00
Median	51.98	79.35	58.48	59.86	55.77	61.17
Mean	56.80	67.86	56.67	59.12	55.90	60.97
Std. dev	28.91	30.70	23.82	15.85	13.77	23.78
Average surface temperature in MAY-OCT (°C)						
Whole country	27.01	26.42	26.38	26.52	26.59	
Northern	26.01	25.01	25.20	25.52	25.39	
Northeastern	27.06	26.56	26.87	26.79	27.02	
Central	28.08	27.15	27.10	27.26	27.22	
Southern	26.18	26.60	25.79	25.97	26.27	
Min	23.25	22.59	22.72	22.87	22.89	22.35
Max	29.72	28.59	28.44	28.70	28.48	29.98
Median	26.94	26.50	26.54	26.60	26.85	26.69

Table 4.4

Variables summary for the spatial analysis (Cont.)

	1997	2002	2007	2012	2018	1997-2018
Mean	27.01	26.42	26.38	26.52	26.59	26.65
Std. dev	1.46	1.33	1.24	1.24	1.23	1.37
Average surface temperature in NOV-APR (°C)						
Whole country	26.43	26.75	26.58	26.43	26.25	
Northern	24.68	24.94	25.00	24.90	24.66	
Northeastern	26.10	26.74	26.45	26.45	26.27	
Central	28.09	28.15	28.05	27.68	27.40	
Southern	25.91	26.36	25.93	25.93	26.00	
Min	21.11	21.47	21.21	21.62	21.49	20.35
Max	29.64	29.64	29.55	29.18	28.74	30.63
Median	26.16	26.66	26.44	26.27	26.25	26.45
Mean	26.43	26.75	26.58	26.43	26.25	26.44
Std. dev	1.91	1.78	1.81	1.65	1.55	1.85
Total precipitation in MAY-OCT (millimeter)						
Whole country	40.14	46.17	48.07	44.69	44.07	
Northern	42.08	53.79	51.97	46.85	49.01	
Northeastern	41.04	53.66	47.71	45.61	43.63	
Central	37.02	41.44	42.27	44.57	41.48	
Southern	42.31	35.01	54.62	40.98	43.49	
Min	20.79	26.56	30.10	28.65	29.94	20.78
Max	88.09	90.95	76.90	82.06	90.26	90.35
Median	37.93	44.94	47.62	42.25	42.31	42.28
Mean	40.14	46.17	48.07	44.69	44.07	43.55
Std. dev	11.06	12.97	9.32	9.25	11.47	10.32
Total precipitation in NOV-APR (millimeter)						
Whole country	8.79	9.83	9.80	10.93	13.50	
Northern	4.51	6.68	4.08	6.36	8.54	
Northeastern	6.73	5.56	4.83	5.32	6.40	
Central	6.43	9.33	8.22	8.27	14.11	
Southern	21.31	20.70	26.79	29.47	28.53	
Min	2.14	3.81	2.76	3.99	4.86	1.21
Max	34.14	26.66	43.13	46.56	34.51	63.86
Median	5.97	7.82	6.77	6.68	10.65	7.75
Mean	8.79	9.83	9.80	10.93	13.50	11.50
Std. dev	6.66	5.75	8.81	9.65	8.17	9.92
Damaged area of main rice (%)						
Whole country	3.66	10.64	6.09	9.52	7.26	
Northern	1.89	14.17	6.26	1.70	1.58	
Northeastern	3.99	10.68	6.30	14.27	10.87	
Central	4.06	7.89	5.15	2.75	1.47	
Southern	6.31	1.75	6.16	3.24	0.25	
Min	0.00	0.00	0.83	0.00	0.00	0.00

Table 4.4

Variables summary for the spatial analysis (Cont.)

	1997	2002	2007	2012	2018	1997-2018
Max	27.68	35.83	9.72	29.39	28.04	51.23
Median	1.83	5.58	4.39	1.83	1.01	2.73
Mean	3.67	7.75	4.90	5.33	3.43	4.66
Std. dev	5.45	8.77	2.40	7.24	5.40	5.60
Damaged area of second rice (%)						
Whole country	1.45	0.96	0.42	0.69	0.26	
Northern	1.83	1.35	0.83	0.38	0.25	
Northeastern	2.56	1.91	0.62	0.61	0.51	
Central	0.96	0.65	0.13	1.04	0.18	
Southern	5.03	0.83	0.22	0.92	0.64	
Min	0.00	0.00	0.00	0.00	0.00	0.00
Max	9.06	18.50	7.45	36.29	8.41	36.29
Median	0.21	0.38	0.35	0.40	0.26	0.30
Mean	1.52	1.82	0.66	1.35	0.48	1.33
Std. dev	2.39	3.89	1.05	4.45	1.04	3.42

Note. Author's summary.

CHAPTER 5

RESULTS AND DISCUSSION

There are two steps of analysis in this study. First is the performance measurement of rice production. The second is the spatial regression analysis for the TFP determinant model. Each part will be further divided into the results of the main rice and of the second rice. This chapter will present the results in this order.

5.1 Performance of rice production in Thailand

5.1.1 Main rice

5.1.1.1 Technical efficiency score

The average technical efficiency of every province over the study period is 75.53%. Northern and central provinces, on average, are more efficient than the provinces in the south and northeastern. There are three provinces that are the most efficient provinces thorough the period of the study which are Samut Prakan, Chiang Mai, and Chiang Rai. The most efficient rice producer provinces of the central region are Samut Prakan, Pathum Thani, Nonthaburi, Bangkok, and Nakhon Pathom while less efficient provinces are Chanthaburi, Prachin Buri, Sa Kaeo, Rayong, and Prachuap Khiri Khan. The most efficient provinces in the northeastern region are Ubon Ratchathani, Amnat Charoen, Udon Thani, and Sakon Nakhon but the score is still not greater than 84%. Nakhon Ratchasima is, on average, the less efficient rice producer in the northeastern followed by Surin, Chaiyaphum, Roi Et, and Buriram. Besides Chiang Mai and Chiang Rai, Mae Hong Son, Phetchabun, and Lamphun have the highest technical efficiency score in the north, with the score greater than 97%. The less efficient in the northern region are Nakhon Sawan, Sukhothai, Kamphaeng Phet, and Phitsanulok, but the scores are still greater than 70% for these provinces. For the southern region, the highest efficiency score provinces are Ranong, Krabi, Narathiwat, and Yala. And the provinces with the lowest score are Nakhon Si Thammarat, Chumphon, Surat Thani, and Phang-nga.

The reason that central and northern regions are more technically efficient main rice producers than other regions may come from that big irrigation projects are mostly located in these regions. Farmers in these regions may be benefited from irrigation when there is a variance in the rainfall, which helps them to still do farming with a more adequate level of water compared to those in other areas. Another reason that makes central and northern regions more technical efficient may come from the quality of the soil. Data about the level of appropriateness for rice farming area from the Land Development Department shows that rice farming areas in the central, northern, and southern regions are considered to be more appropriate areas to cultivating rice, sum of the high- and medium-appropriate levels areas of these region are more than 80% of total rice farming area (more detail of appropriateness for rice farming area are shown in appendix C Table C.1). However, provinces in the South may face more flood problems than other regions which cause losses in production and reduce farm efficiency in the South.

Full results on the technical efficiency score of main rice are shown in appendix A, Table A.1 and A.5.

Figure 5.1

Average technical efficiency score of the main rice on map

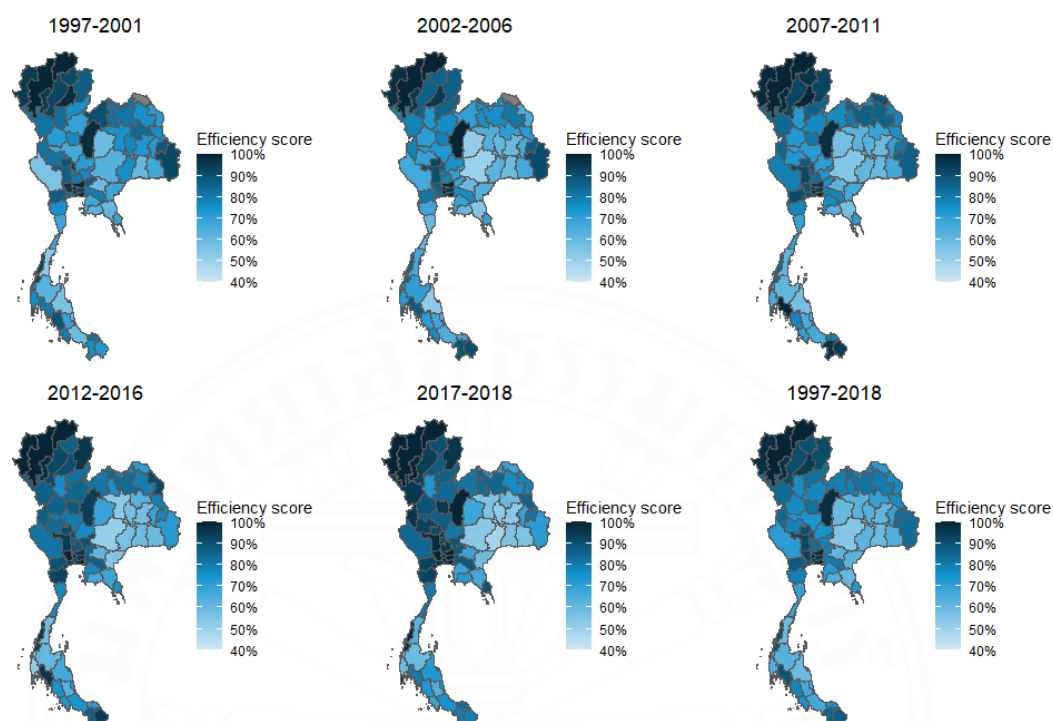


Table 5.1

Average technical efficiency score of the main rice by region weighted by shared paddy rice produced

Province	Efficiency score of Main rice						
	1997-2001	2002-2006	2007-2011	2012-2016	2017	2018	1997-2018
Central	0.8183	0.8003	0.8288	0.8667	0.8907	0.9049	0.8343
Northeastern	0.7467	0.6639	0.6820	0.6417	0.6424	0.6081	0.6771
Northern	0.8196	0.8226	0.8364	0.8741	0.8944	0.9203	0.8440
Southern	0.6490	0.6431	0.6719	0.7063	0.6967	0.7578	0.6723
Whole country	0.7788	0.7368	0.7547	0.7512	0.7577	0.7542	0.7553

Note. Author's calculation

Because the technical efficiency score is truncated (value between 0 to 1), this study cannot employ spatial regression to investigate this score further. Nevertheless, a simple linear correlation between the technical efficiency score

and other variables can be described by using the Pearson correlation coefficient (Table 5.2).

Input and output variables have a negative correlation to the technical efficiency score of the main rice, with a mediocre magnitude. This may indicate that the production of main rice farming is already in the phase of decreasing returns to scale of production. Expanding more rice farming areas may lead to decreasing in yield and technical efficiency score due to excessive workload and cost of managing the farm.

The interesting part is that the irrigation area has a different correlation to the technical efficiency score, in terms of direction and magnitude. The irrigation area of big project has a positive correlation, but with little strength, while irrigation area of small- and medium projects have a negative correlation to the technical efficiency score of the main rice. The reason behind these results for the main rice, which is cultivated during the rainy season, is that only the big irrigation project could adequately help in managing the supply of water for rice farming purposes. While small irrigation projects usually launch in arid areas for general and utility purposes. So increasing in irrigation area of the small project in one province may not help in improving the farming efficiency of rice, but indicate that that province is lacked the water for general purpose in the first place, putting aside the water for rice farming.

Table 5.2

Pearson correlation coefficient for the main rice

	TE score	Paddy rice	Land	Household	Seed	Fertilizer	Small irrigation	Medium irrigation	Large irrigation	All irrigation
TE score	1									
Paddy rice	-0.1911	1								
Land	-0.3479	0.9377	1							
Household	-0.3413	0.8325	0.9400	1						
Seed	-0.3162	0.9138	0.8505	0.7151	1					
Fertilizer	-0.3174	0.9622	0.9388	0.8249	0.9451	1				
Small irrigation	-0.2691	0.6093	0.6719	0.7538	0.5636	0.6123	1			
Medium irrigation	-0.1976	0.3628	0.2724	0.2429	0.3609	0.3083	0.3581	1		
Large irrigation	0.1019	0.2939	0.1326	0.0176	0.3176	0.2964	-0.0116	-0.0117	1	
All irrigation	-0.0097	0.4973	0.3451	0.2525	0.5076	0.4901	0.3090	0.2678	0.9310	1

Note. Author's calculation

5.1.1.2 Total factor productivity change

From 1998 to 2018, the average TFP change or TFP growth is -0.53% annually. There are improvements during 1998 to 2002 after that TFP was regressed up to 2018. On average, central provinces have the highest TFP progress while northeastern is the only region where average TFP growth is negative. Phra Nakhon Si Ayutthaya has the highest average TFP growth of rice production in the central region, and of the whole country, at 3.12% annually, followed by Kanchanaburi (2.34%), Phetchaburi (2.04), and Rayong (1.52%). Sa Kaeo is the only province that has negative TFP change over the period of study, at -0.69% annually.

In the northern region, Kamphaeng Phet, Nakhon Sawan, Uthai Thani, and Phichit have the highest average TFP growth, with more than 1% annually, and Mae Hong Son, Phrae, Chiang Mai, and Nan are the most TFP regress province.

Songkhla, Ranong, and Nakhon Si Thammarat have the highest average TFP growth in the south while the least are Surat Thani, Trang, Satun, Phuket.

Mukdahan, Chaiyaphum, Yasothon, and Nakhon Phanom are the only four provinces in the northeastern region that have average TFP progress during 1998 to 2018, with the annual growth of 0.99%, 0.77%, 0.65%, and 0.04% respectively. And the most TFP regress provinces in the northeast are Bueng Kan (-5.33%), Kalasin (-2.27), Buri Ram (-2.21%), and Maha Sarakham (-2.1%). In general, province in northeastern region have low TFP progress, if it is positive at all, and have the highest TFP regress compared to other regions. A reason that may cause northeastern to be the only region with the average TFP regress is during the period of the study northeastern region faced many natural disasters in which have a detrimental effect on TFP growth. To further investigate sources that attribute to TFP change, the Malmquist productivity index can be decomposed into technical efficiency change and technical change. This will give more information about which source contributes to the TFP change of each province or region.

Full results on TFP change of main rice are shown in appendix A, Table A.2 and A.6.

Figure 5.2

Average TFP change of the main rice on map

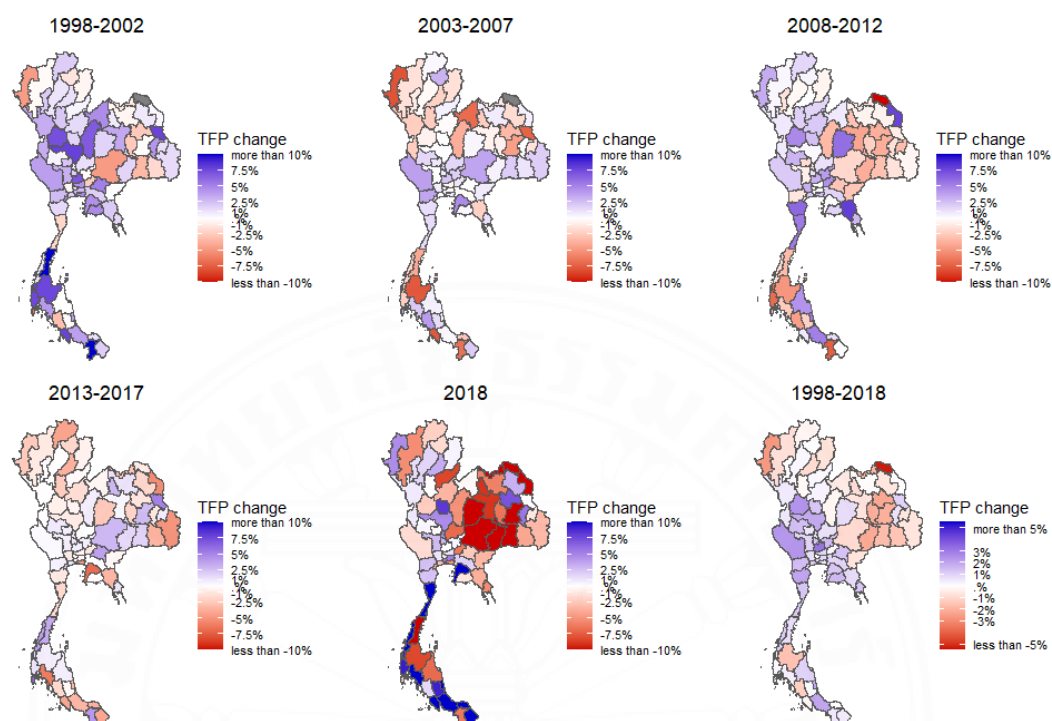


Table 5.3

Average TFP change of the main rice by region weighted by shared paddy rice produced in based year

Province	TFP change rate of Main rice (%)					
	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Central	2.02	0.83	0.07	0.15	0.16	0.74
Northeastern	-0.72	-0.24	-1.92	-0.75	-10.93	-1.41
Northern	2.36	-0.70	0.78	-1.34	0.04	0.25
Southern	1.69	-0.45	1.61	-1.75	5.94	0.53
Whole country	0.71	-0.13	-0.85	-0.85	-5.39	-0.53

Note. Author's calculation

5.1.1.3 Technical efficiency change

Technical efficiency change of the main rice is, on average, at -0.81% per annum. In terms of region, northeastern has average technical efficiency regress while other regions have a progression. Phra Nakhon Si Ayutthaya,

Phetchaburi, Chon Buri, and Rayong have the highest average technical efficiency change in the central region, with the annual rate of 1.58%, 1.46%, 1.32%, and 1.32% respectively. Provinces that face technical efficiency regress in the central area are Sa Kaeo, Nakhon Nayok, Nonthaburi, Chai Nat, and Lopburi, but the rate is not less than -1% per annum.

Kamphaeng Phet, Nakhon Sawan, and Uthai Thani have the highest average technical efficiency growth in the northern region with the rate of 1.56%, 1.41%, and 0.87% annually. However, Sukhothai, Uttaradit, Phrae, Phayao, and Lampang are faces average technical efficiency regress in the period of study, but not less than 0.8% per annum.

For the northeastern region, the highest technical efficiency progress province, Mukdahan, is still not greater than 1% per annum. While more than half of the province in the northeastern area faces technical efficiency regress, with Bueng Kan (-4.4%), Buri Ram (-2.7%), Roi Et (-2.47%) and Kalasin (-2.21%) faced the greatest regression. We can see that technical efficiency regress is the main source that pulled TFP growth in this region to be negative rate. With relatively fewer areas of big- and medium-irrigation projects, farmers in this region may find it hard to mitigate the effects of natural shocks, e.g., drought and flood. This problem can be more severe with climate change which results in changes in the weather patterns and increase the likelihood of extreme weather.

A reason that may causes the northeast to be the only region with the average technical efficiency regress is during the period of the study northeastern region faced many natural disasters which have detrimental effects on technical efficiency growth.

Full results on technical efficiency change of main rice are shown in appendix A, Table A.3 and A.7.

Figure 5.3

Average technical efficiency change of the main rice on map

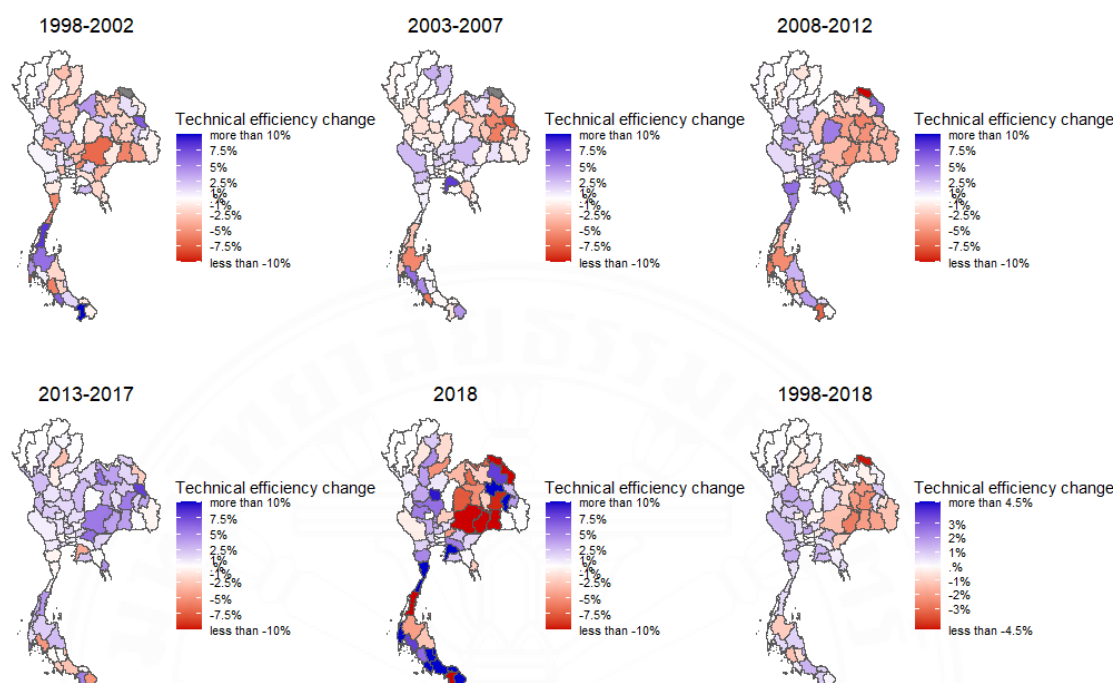


Table 5.4

Average technical efficiency change of the main rice by region weighted by shared paddy rice produced in based year

Province	Technical efficiency change rate of Main rice (%)					
	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Central	-1.17	0.52	-0.32	0.95	1.69	0.07
Northeastern	-2.52	-1.39	-3.40	2.28	-7.40	-1.58
Northern	-1.13	-0.49	0.55	0.77	2.88	0.06
Southern	-0.38	-0.17	0.72	-0.49	8.75	0.32
Whole country	-1.87	-0.64	-1.78	1.41	-2.45	-0.81

Note. Author's calculation

5.1.1.4 Technical change

Overall technical change of the main rice production is 0.28% annually. This means technical change is the main source that drives the TFP growth of main rice in many regions. However, there is an average technical regress for all

regions during 2013-2018. The central region has the highest technical progress per year at the rate of 0.67%. Phra Nakhon Si Ayutthaya is the most progress province, 1.51% per annum, followed by Kanchanaburi (1.1%), Saraburi (0.99%), and Pathum Thani (0.91%). The only province that faces technical regress in the central region is Chon Buri.

The annual average technical change in the southern region is 0.20% per annual. The most technical progress provinces are Ranong (1.06%), Phatthalung (0.78%), Songkhla (0.62%), and Phang-nga (0.24%). And the most province in terms of technical regress are Pattani (-0.86%), Satun (-0.63%), Surat Thani (-0.52%), and Yala (-0.34%).

Annual average technical change in the northern region is slightly less than the southern region, at the rate of 0.19% annually. Uttaradit, Kamphaeng Phet, Phichit, and Sukhothai are the most progress in terms of technical improvement, at the annual rate of 0.87%, 0.83%, 0.69%, and 0.58%, respectively. While Mae Hong Son, Chiang Mai, Nan, and Phrae face the worst regression with the annual rate of -2.67%, -0.82%, -0.76%, and 0.42%, respectively.

Lastly, the annual average technical change in the northeastern region is 0.17%. The highest technical progress provinces are Ubon Ratchathani (0.59%), Buriram (0.51%), Roi Et (0.4%), and Si Sa Ket (0.39%). And the lowest technical change province are Bueng Kan, Loei, Nong Khai, and Sakon Nakhon with the rate of -0.98%, -0.89%, -0.61%, and -0.35% per annum, respectively.

Full results on technical change of main rice are shown in appendix A, Table A.4 and A.8.

Figure 5.4

Average technical change of the main rice on map

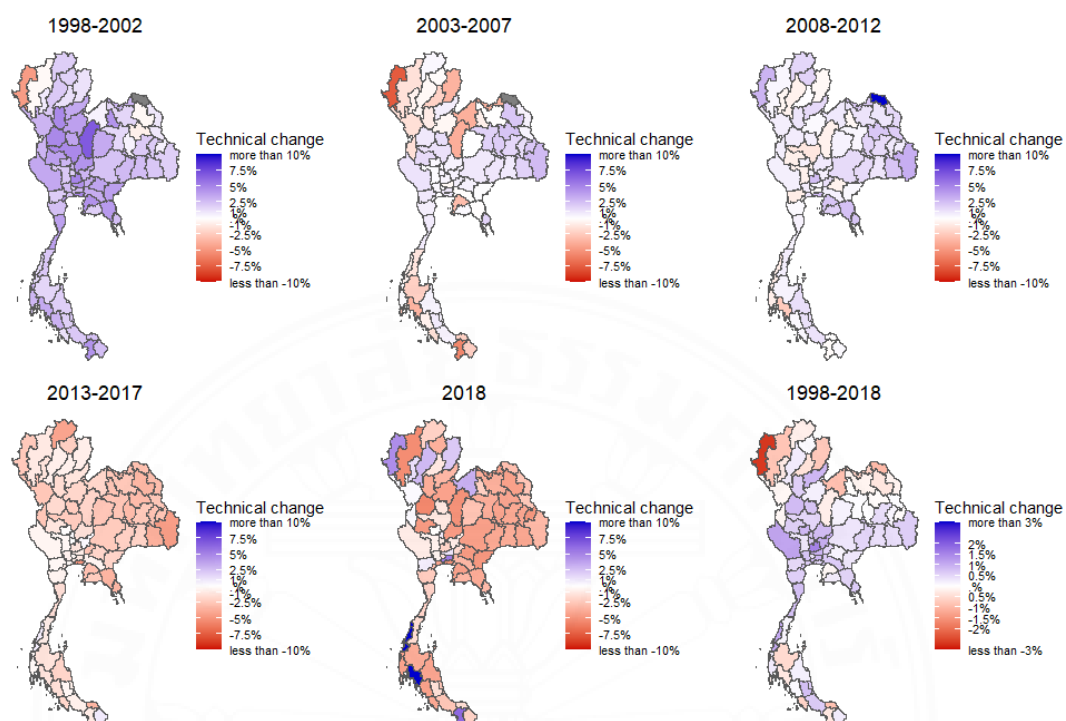


Table 5.5

Average technical change of the main rice by region weighted by shared paddy rice produced in based year

Province	Technical change rate of Main rice (%)					
	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Central	3.23	0.31	0.39	-0.79	-1.50	0.67
Northeastern	1.84	1.17	1.52	-2.96	-3.81	0.17
Northern	3.52	-0.21	0.23	-2.10	-2.76	0.19
Southern	2.08	-0.28	0.88	-1.27	-2.59	0.20
Whole country	2.62	0.51	0.95	-2.23	-3.01	0.28

Note. Author's calculation

5.1.2 Second rice

5.1.2.1 Technical efficiency score

From 1997 to 2018, the average technical efficiency of the second rice of every province of Thailand is 89.75%. Provinces in the northern region

and central regions are still, on average, more technically efficient than that in the northeastern and southern. And the reasons behind the difference in technical efficiency level may be due to the differences in the irrigation development and shared of rice farming in more appropriate areas as in the main rice.

The most efficient provinces for second rice farming in the central region are Samut Prakan (100%), Nakhon Pathom (98.58%), Phra Nakhon Si Ayutthaya (96.67%), and Chai Nat (96.36%). The least efficient provinces in the central region are Trat (58.59%), Prachuap Khiri Khan (66.19%), Rayong (67.03%), and Sa Kaeo (68.12%).

The top three efficient provinces in the northern region, Chiang Rai, Lamphun, Chiang Mai, have technical efficiency score over 99%. And the least efficient is Phetchabun (70.11%) followed by Phrae (79.66%) and Mae Hong Son (81.99%).

Loei, Bueng Kan, Nong Bua Lam Phu, and Nakhon Ratchasima are the most efficient province in the northeastern region, with the score of 88.78%, 81.01%, 78.51%, and 78.13% respectively. The least efficient provinces in northeastern region are Surin, Buri Ram, Si Sa Ket, and Sakon Nakhon with the score of 57.72%, 58.16%, 60.82%, and 62.18% respectively

In the South, Pattani and Satun are the only two provinces that have technical efficiency scores above 80% while the least three efficient provinces are Phatthalung (68.1%), Songkhla (69.78%), and Surat Thani (70.69%).

Full results on technical efficiency score of second rice are shown in appendix A, Table A.9 and A.13.

Figure 5.5

Average technical efficiency score of the second rice on map

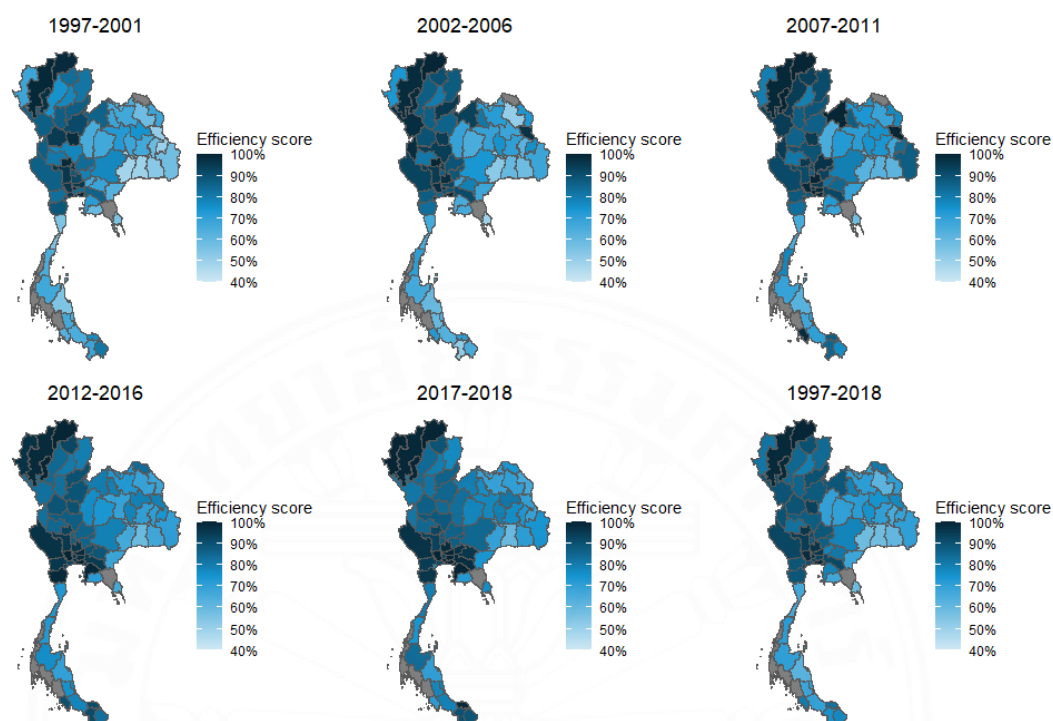


Table 5.6

Average technical efficiency score of the second rice by region weighted by shared paddy rice produced

Province	Efficiency score of Second rice						
	1997-2001	2002-2006	2007-2011	2012-2016	2017	2018	1997-2018
Central	0.9254	0.9363	0.9338	0.9474	0.9414	0.9506	0.9366
Northeastern	0.7076	0.6981	0.7475	0.7326	0.7406	0.7860	0.7249
Northern	0.9082	0.9124	0.8971	0.8965	0.8463	0.8977	0.9006
Southern	0.6358	0.6127	0.6786	0.7483	0.7573	0.7677	0.6751
Whole country	0.8998	0.9077	0.8917	0.8948	0.8713	0.9049	0.8975

Note. Author's calculation

The Pearson correlation coefficient suggests that the second rice may have a different stage of production compared to the main rice. The correlation coefficients of the input and output variables are positively correlated to the technical efficiency score, still with the mediocre magnitude, indicating increasing returns to

scale of production for the second rice. The irrigation area of the big project also has a positive correlation to the efficiency score like it does in the main rice, but with more strength, which is intuitive because the second rice is relying more on the irrigated water for farming. While the strength of the negative correlation of small and medium irrigation projects is less for the second rice.



Table 5.7

Pearson correlation coefficient for the second rice

	TE score	Paddy rice	Land	Household	Seed	Fertilizer	Small irrigation	Medium irrigation	Large irrigation	All irrigation
TE score	1									
Paddy rice	0.3881	1								
Land	0.3561	0.9943	1							
Household	0.2876	0.9111	0.9261	1						
Seed	0.3444	0.9887	0.9932	0.8990	1					
Fertilizer	0.3700	0.9927	0.9907	0.9105	0.9842	1				
Small irrigation	-0.1873	-0.0185	0.0150	0.1922	-0.0113	-0.0274	1			
Medium irrigation	-0.0889	0.2030	0.2379	0.2895	0.2266	0.1806	0.3515	1		
Large irrigation	0.2824	0.6111	0.6061	0.5505	0.5962	0.6271	-0.0526	-0.0332	1	
All irrigation	0.2059	0.6150	0.6251	0.6259	0.6069	0.6240	0.2643	0.2399	0.9337	1

Note. Author's calculation

5.1.2.2 Total factor productivity change

Second rice production in Thailand faces the TFP regress over the period of the study at the rate of -0.59% per annum. The most regress region is the northeast (-1.09%) followed by the central (-0.53%) and north (-0.51%) while the South is the only region that has some progress, at 0.98% per annum. Looking at the decomposition of the TFP change (Table 5.9 and 5.10), we can see that both technical efficiency regress and technical regress contribute to the negative rate of TFP for the central, northern, and northeastern regions.

In the central, provinces that have TFP of second rice improved the most are Chon Buri, Sa Kaeo, and Prachuap Khiri Khan with the annual growth rate of 3.88%, 2.48%, and 1.57% respectively. Provinces that face the highest rate of TFP regression per year in the central region are Nonthaburi (-0.88%), Suphan Buri (-0.74%), and Nakhon Pathom (-0.47%).

Udon Thani has the most average TFP growth in the northeastern region, at the rate of 2.06%, followed by Roi Et (0.78%), Nakhon Ratchasima (0.74%), and Maha Sarakham (0.69%). On the other side, the province that faced the most TFP regress in the northeastern region are Mukdahan, Loei, Bueng Kan, and Nakhon Phanom at the rate of -3.33%, -3.16%, -3.1%, and -2.93% per annum, respectively.

The only four provinces that face the TFP progress of second rice in the northern region are Mae Hong Son, Nakhon Sawan, Nan, and Uthai Thani, with the annual growth of 1.93%, 0.25%, 0.18%, and 0.06% respectively. And the top TFP regress provinces are Lampang, Lamphun, Phetchabun, and Phrae at the annual rate of -1.66%, -1.2%, -0.97%, and 0.94% respectively.

In the south, the top TFP progress per year are Pattani (1.6%), Nakhon Si Thammarat (1.43%), and Phatthalung (1.35%) while Satun, Narathiwat, and Chumphon are the only three provinces that faced negative growth, at the rate of -2.41%, -1.95%, and -0.26% per annum, respectively.

Full results on TFP change of second rice are shown in appendix A, Table A.10 and A.14.

Figure 5.6

Average TFP change of the second rice on map

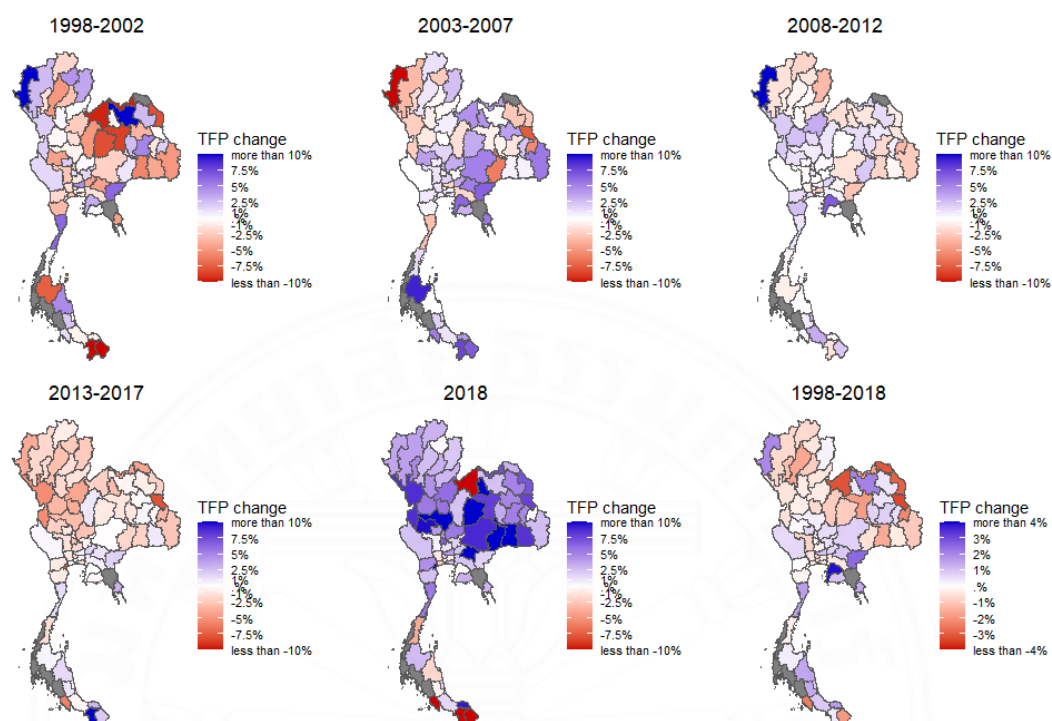


Table 5.8

Average TFP change of the second rice by region weighted by shared paddy rice produced in based year

Province	TFP change rate of Second rice (%)					
	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Central	-1.48	0.61	-0.37	-1.45	2.49	-0.53
Northeastern	-5.55	1.75	-0.17	-1.54	5.75	-1.09
Northern	-1.59	0.29	0.92	-2.90	6.10	-0.51
Southern	0.35	1.87	1.09	0.83	-0.19	0.98
Whole country	-1.72	0.54	0.04	-2.14	4.33	-0.59

Note. Author's calculation

5.1.2.3 Technical efficiency change

Average technical efficiency change of the second rice is negative rate. Only provinces in the southern region have the regional progress over the period of study. During 1998-2002 and 2013-2017 are the periods that central, northern,

and northeastern regions faced technical efficiency regress together. A reason for the technical efficiency regressing in these periods may come from extreme and prolonged drought during 1997-1999 and 2013-2016. The magnitude of the negative impact during 1998-2002 is more profound in the northeast which has fewer big- and medium-irrigation projects compared to the central and northern regions. However, during 2013-2017 provinces in the northern region faced the most impact followed by the northeastern and central regions. Nevertheless, provinces in the south may have faced less impact because the regions tend to have more rainfall compared to other regions.

In central, Chon Buri, Sa Kaeo, Prachuap Khiri Khan, and Trat are the most technical efficiency progress provinces, with the annual rate of 3.51%, 2.05%, 2.01%, and 1.67% respectively. While the most annual technical efficiency regress are Sing Buri (-0.5%), Chai Nat (-0.36%), Samut Sakhon (-0.3%), and Nonthaburi (-0.25%).

Udon Thani, Sakon Nakhon, Yasothon, and Roi Et are the provinces that have the most technical efficiency progress for second rice in the northeastern region with the rate of 2.38%, 1.32%, 0.93%, and 0.91% per annum, respectively. In terms of annual technical efficiency regress, Bueng Kan (-2.76%), Nakhon Phanom (-1.75%), Loei (-1.61%), and Nong Khai (-1.25%) are the most regress province.

For the northern region, Mae Hong Son, Nan, Nakhon Sawan, and Tak have the highest technical efficiency change per year for second rice, at the rate of 3.55%, 0.97%, 0.42%, and 0.41% respectively. While the greatest regress provinces are Phrae (-1.06%), Phichit (-0.46%), Phetchabun (-0.43%), and Uttaradit (-0.34%)

Pattani, Nakhon Si Thammarat, Phatthalung, and Yala are the provinces that have the most technical efficiency progress, at the rate of 2.89%, 1.63%, 1.53%, and 1.44% per year, respectively, while Satun (-1.38%) and Narathiwat (-0.2%) are the only two provinces that face the negative average change.

Full results of the technical efficiency change of the second rice are shown in appendix A, Table A.11 and A.15.

Figure 5.7

Average technical efficiency change of the second rice on map

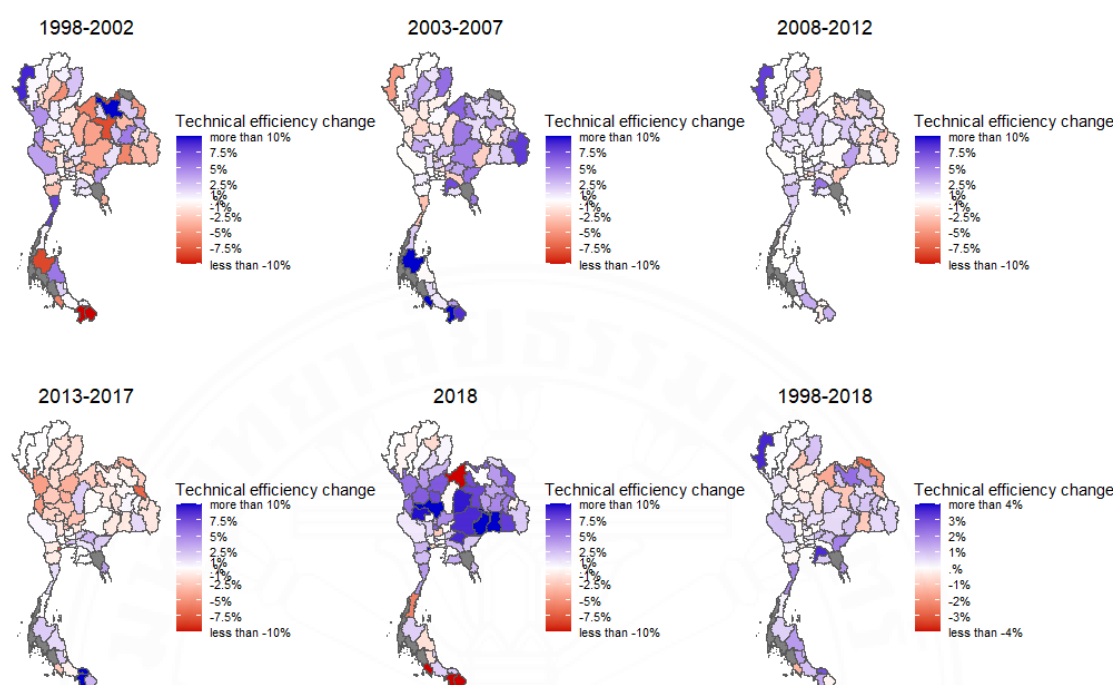


Table 5.9

Average technical efficiency change of the second rice by region weighted by shared paddy rice produced in based year

Province	Technical efficiency change rate of Second rice (%)					
	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Central	-0.87	0.42	-0.16	-0.94	1.40	-0.30
Northeastern	-5.57	2.52	0.12	-1.11	5.15	-0.77
Northern	-0.37	-0.37	0.84	-2.34	6.06	-0.26
Southern	0.98	1.81	1.28	1.51	-0.49	1.31
Whole country	-0.93	0.27	0.20	-1.59	3.74	-0.32

Note. Author's calculation

5.1.2.4 Technical change

For the technical change of the second rice, the average of the whole country is -0.27% per year. The average of each region is also negative rate, starting with the central region at the annual change of -0.22%, followed by northern (-

0.25%), southern (-0.33%), and northeastern (-0.32%). A reason for the technical regress may come from variations in oil prices. Prices of chemical fertilizer are closely related to oil prices which fluctuated across the period of the study. Increasing in fertilizer prices may cause farmers to apply less fertilizer to their farms and cause a regression in the technical change.

In central, provinces that face the highest technical change in second rice are Chai Nat, Pathum Thani, Saraburi, and Sa Kaeo with the rate of 0.99%, 0.66%, 0.49%, and 0.42% per year, respectively. The most regress provinces in the central are Nonthaburi (-0.63%), Suphan Buri (-0.62%), Bangkok (-0.55%), and Nakhon Pathom (-0.47%).

For the northeastern region, Nakhon Ratchasima is the only province that faced technical progress in second rice production, with the rate of 0.17% annually. While the most regress provinces are Mukdahan, Amnat Charoen, Ubon Ratchathani, and Chaiyaphum with the change rate of -2.4%, -2.34%, -1.69, and -1.65% per annum, respectively.

There is also only one province in the northern region that has technical progress, Phrae at 0.13% per annum, while the most regress provinces are Lampang (-1.73%), Mae Hong Son (-1.57%), Lamphun (-1.2%), and Tak (-0.91%).

All the provinces in the southern region are facing technical regress in second rice. The least annual regress province are Songkhla (-0.13%), Phatthalung (-0.18%), and Nakhon Si Thammarat (-0.2%) while the most regress are Narathiwat (-1.75%), Pattani (-1.25%), and Yala (-1.06%).

Full results of the technical change of the second rice are shown in appendix A, Table A.12 and A.16.

Figure 5.8

Average technical change of the second rice on map

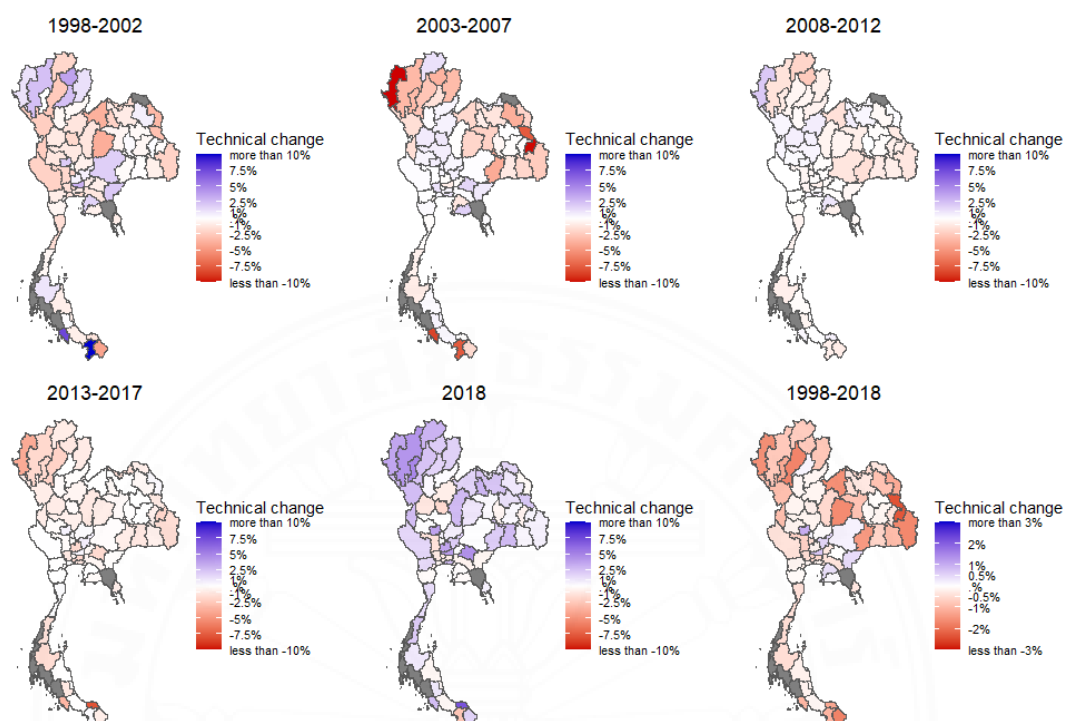


Table 5.10

Average technical change of the second rice by region weighted by shared paddy rice produced in based year

Province	Technical change rate of Second rice (%)					
	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Central	-0.62	0.19	-0.20	-0.52	1.08	-0.22
Northeastern	0.01	-0.75	-0.29	-0.44	0.58	-0.32
Northern	-1.22	0.66	0.08	-0.57	0.04	-0.25
Southern	-0.62	0.06	-0.19	-0.67	0.30	-0.33
Whole country	-0.79	0.27	-0.16	-0.56	0.56	-0.27

Note. Author's calculation

5.1.3 Discussion on the results of the first step of the analysis

The production efficiency of the second rice in Thailand, on average, is more efficient than the production of the main rice. The regional pattern shows that central and northern regions tend to be more efficient rice producer regions compare to

the northeastern and southern regions of Thailand. These regional rice efficiency patterns are similar to a study by Nunti et al. (2019), in which the northern region is the most efficient followed by central, northeastern, and southern regions.

Figure 5.9 and 5.10 illustrates the size of cultivation area and the amount of rice produced to the technical efficiency score. At first look, the size of farming area may not necessarily relate to how technically efficient the province is, but the correlation matrixes in Table 5.2 and Table 5.7 suggest different stages of production for the main rice and the second rice. The main rice production may operate under the decreasing returns to scale while the second rice may operate under the increasing returns to scale. From Figure 5.9 and 5.10, provincial planted areas already exceed 1,500,000 rai for the main rice, mostly by provinces in the northeastern region, while most of the provincial planted areas of the second rice are not over 1,000,000 rai. Decreasing returns to scale of production combined with relatively fewer big- and medium-irrigation projects may be another reason for the low technical efficiency score for the Northeastern region.

The second rice is mainly produced in the northern and central regions of Thailand because these regions have most of the big- and medium-irrigation projects. This allows provinces in these regions to do rice farming outside the rainy season and also helps prevent the negative impact of some natural disasters. The province in central and northern regions are also generally more technically efficient than other regions for both rice seasons.

Data about the level of appropriateness for rice farming areas, Table 5.11, from the Land Development Department may help us understand more about the result of the technical efficiency score. Central and northern regions that have relatively high efficiency score also have the rate of rice farming area in the high- and medium-appropriate levels of more than 80% of the total rice farming area.

Figure 5.9

Average provincial technical efficiency score of the main rice

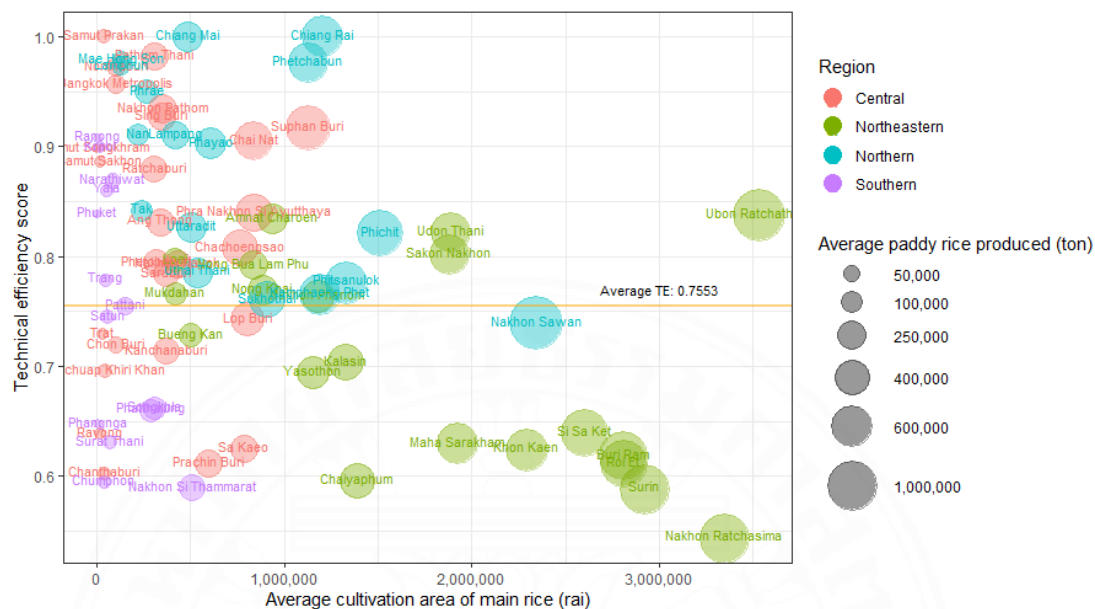


Figure 5.10

Average provincial technical efficiency score of the second rice

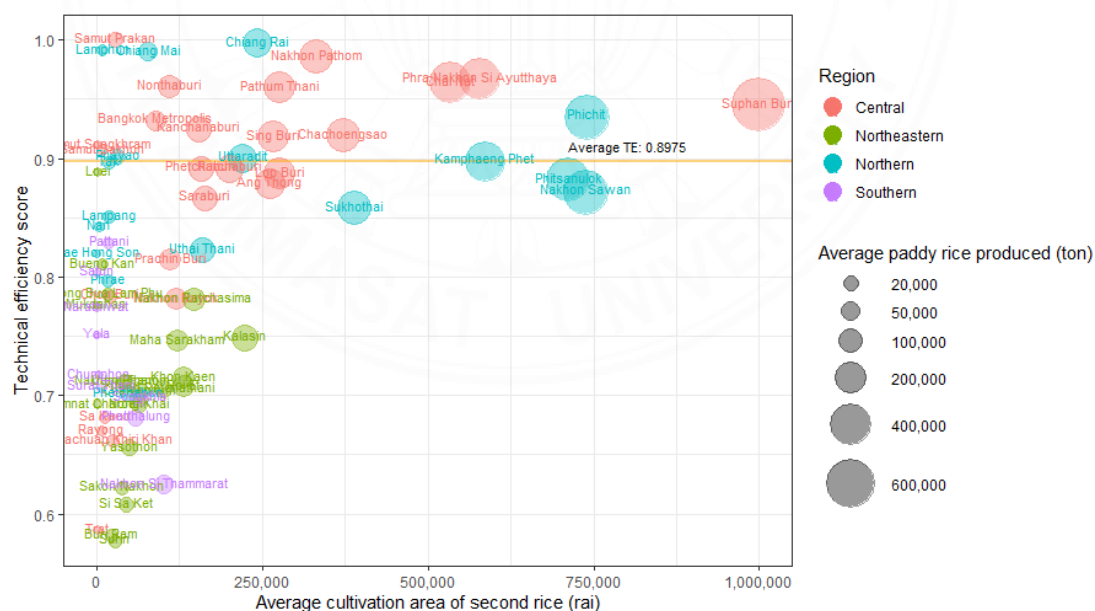


Table 5.11

Appropriateness of rice farming area, irrigation area, and TE score

	Central	Northeastern	Northern	Southern
High appropriate area	7,033,053.04 (71.19%)	3,099,676.24 (7.79%)	8,507,849.74 (55.14%)	822,186.42 (69.40%)
Medium appropriate area	1,485,185.62 (15.03%)	15,894,668.36 (39.93%)	4,835,349.66 (31.34%)	172,965.64 (14.60%)
Low appropriate area	1,043,391.93 (10.56%)	15,623,045.97 (39.24%)	1,337,293.10 (8.67%)	162,064.46 (13.68%)
Not appropriate area	317,682.44 (3.22%)	5,193,847.83 (13.05%)	747,957.21 (4.85%)	27,418.25 (2.31%)
Total rice farming area	9,879,313.03 (100%)	39,811,238.40 (100%)	15,428,449.71 (100%)	1,184,634.77 (100%)
Average irrigation area of small project	453,768 (3.89%)	2,743,194 (41.91%)	2,079,852 (25.41%)	481,414 (17.43%)
Average irrigation area of medium project	1,056,372 (9.07%)	1,168,779 (17.86%)	2,053,634 (25.09%)	837,192 (30.31%)
Average irrigation area of large project	10,141,701 (87.04%)	2,633,532 (40.23%)	4,052,530 (49.51%)	1,443,221 (52.26%)
Average total irrigation area	11,651,840 (100%)	6,545,504 (100%)	8,186,017 (100%)	2,761,827 (100%)
Weighted average TE score of main rice	0.8343	0.6771	0.8440	0.6723
Weighted average TE score of second rice	0.9366	0.7249	0.9006	0.6751

Note. The percentage of share area to the total rice farming area is in parenthesis.

In terms of the total factor productivity growth of rice, both main rice and second rice faced the TFP regress over the period of study. Northeast is the only region that faced TFP regress in the main rice, mostly due to the regress in technical efficiency change. the high share of the main rice produced in the northeastern region causes the average TFP change of the whole country to be a negative rate, even though other regions have positive TFP change.

For the second rice, the south is the only region that faced TFP progress, due to the improvement in technical efficiency. Average technical regress was found for all regions.

Figure 5.11

Average provincial TFP growth of the main rice

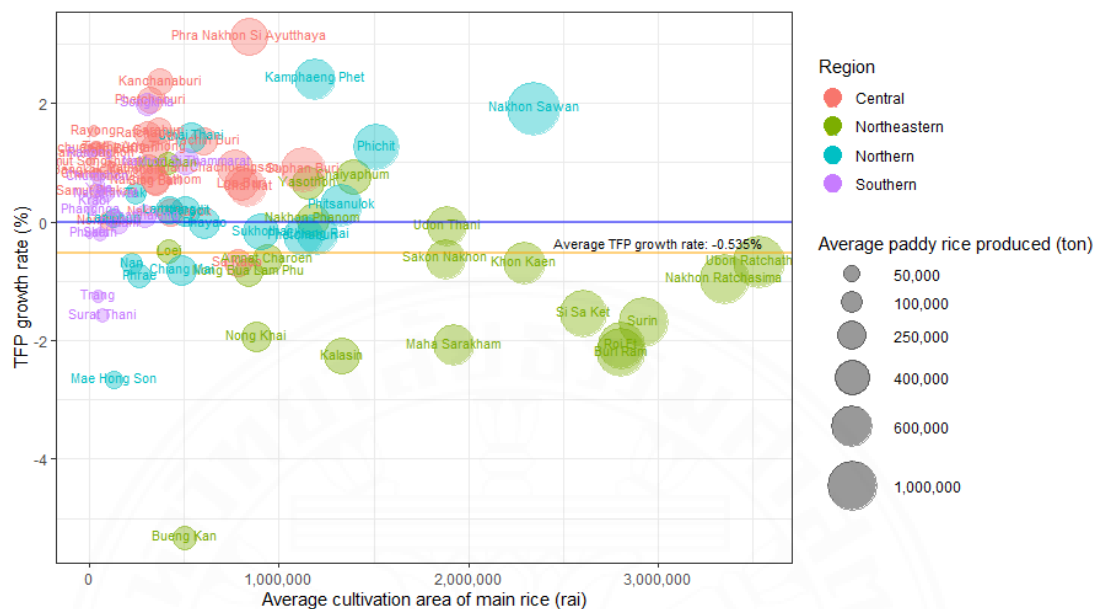
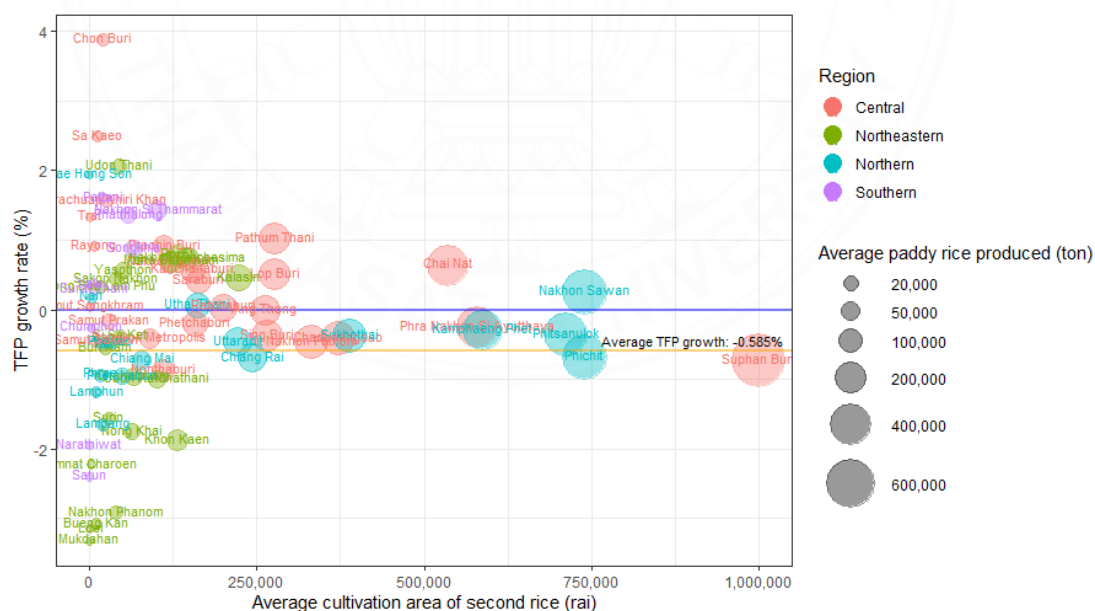


Figure 5.12

Average provincial TFP growth of the second rice



Comparing the sub-period results, the overall TFP growth of main rice in this study during 1999-2002 and 2007-2011 are compatible with Suphannachart (2013) in terms of the direction of the changes but not magnitudes. However, the overall

results seem to be inconsistent. The average TFP growth rate of main rice during 1995-2011 is 0.34% in Suphannachart (2013) while in this study is -0.24% during 1998 to 2011.

For the second rice, even regional TFP changes direction of the sub-period are more consistent with Suphannachart (2013), the Overall TFP changes of the whole country are more discordant in terms of direction and magnitude. The average TFP growth rate of second rice during 1995-2011 is 4.95% in Suphannachart (2013) while in this study is -0.8% during 1998 to 2011.

The reason for these differences may come from three parts. The first is from the different methods used for measuring TFP growth. Suphannachart (2013) used the growth-accounting method while this study used the Malmquist productivity index. Even these two methods are non-parametric approach for measuring TFP growth, the growth-accounting method may give misleading results in the presence of inefficiency in the production, Färe et al. (1994).

The second reason Is the difference in the inputs of the rice production in the model. Suphannachart (2013) used four inputs of rice product includes land, household, capital stock, and fertilizer while the inputs of this study includes land household, seed, and fertilizer. The capital stock, which is the stock of agricultural credit estimated using the perpetual inventory method in Suphannachart (2013), is not included in this study. But this study considers the amount of seed as an input of rice production.

The last reason that may cause the differences in TFP growth is the results of Suphannachart (2013) are measured and calculated at the regional level while the results in this study are calculated at the provincial level. The regional TFP growth, and other changes rate, shown in this study are the geometric mean of provincial TFP growth in that region weighted by paddy rice produced in each province of the based year. This may represent the average provincial TFP growth of each region not the regional TFP growth per se.

Another interesting result is that the regional technical change is positive for the main rice while negative for the second rice. This means main rice production has technical improvement while there is a technical regress in the second rice during the period of study. One of the possible reasons is that second rice farming

is used chemical fertilizer more intensively than main rice production. Fertilizer prices are closely related to oil prices which fluctuate but mostly rise during the period of the study. Cost of fertilizers may leave farmers with not enough money for investing in new technology. Nevertheless, the reasons that cause the difference in technical change between main rice and second rice is an interesting topic for further study. However, even though there is some average technical progress for the main rice, 0.28% annually, it is relatively small compared to the technical progress of rice in other countries, for example, 0.7% annually during 1971-1990 in Philippines (Umetsu et al., 2003), 1.271% annually during 1996-2006 in Japan (Kondo et al., 2017), 2.4% annually during 1994-2016 in India (Monga & Sidana, 2019), 3.1-3.3% annually during 1976-1997 in Vietnam (Coelli & Nghiem, 2002).

5.2 Spatial influence of TFP growth among the provinces of Thailand

5.2.1 Testing for the model specification

Table 5.12

Tests for model specification

Test	Main rice model	Second rice model
(1) Lagrange Multiplier Test for random effects H_a : significant random effects	-3.0739 (0.9989)	-3.6274 (0.9999)
(2) F test for individual effects H_a : significant fixed effects	0.82501 (0.8556)	0.71475 (0.9622)
(3) Moran's I statistic H_a : significant spatial effects	11.987 (0.00000000000000022)	5.3263 (0.00000005013)
(4) LM test for ρ (χ^2)	132.68 (0.00000000000000022)	26.306 (0.0000002913)
(5) LM test for λ (χ^2)	138.89 (0.00000000000000022)	26.796 (0.0000002261)
(6) Robust LM test for ρ (χ^2)	0.097614 (0.7547)	0.14933 (0.6992)
(7) Robust LM test for λ (χ^2)	6.308 (0.01202)	0.63917 (0.424)
(8) Marginal LM test for H_a : $\sigma_\mu^2 \neq 0$ (assuming $\lambda = 0$)	-3.0585 (1.998)	-2.3399 (1.981)

Table 5 12

Tests for model specification (Cont.)

Test	Main rice model	Second rice model
(9) Marginal LM test for $H_a: \lambda \neq 0$ (assuming $\sigma_\mu^2 = 0$)	11.825 (0.00000000000000022)	5.4253 (0.00000005786)
(10) One-side joint LM test for $H_a: \lambda \neq 0$ or $\sigma_\mu^2 \neq 0$	139.82 (0.00000000000000022)	29.434 (0.0000001304)
(11) Conditional LM test for $H_0: \lambda \neq 0$ (assuming $\sigma_\mu^2 \geq 0$)	11.494 (0.00000000000000022)	5.9926 (0.00000002065)
(12) Conditional LM test for $H_a: \sigma_\mu^2 \neq 0$ (assuming $\lambda \geq 0$)	3.0696 (0.002144)	2.8049 (0.005033)
(13) Spatial Hausman test (χ^2) for FE spatial lag vs RE spatial lag H_a : FE spatial lag	42.756 (0.0000001304)	45.311 (0.0000000406)
(14) Spatial Hausman test (χ^2) for FE spatial error vs RE spatial error H_a : FE spatial error	52.271 (0.00000001645)	59.632 (0.0000000005347)

Note. The table shows the test score of each test and the p-value are in parenthesis.

The TFP growth determinant models are first estimated as the pooled OLS. The tests for fixed effects and random effects are performed and the results are as (1) and (2) in Table 5.12. However, the test results show no significant effects for both the main rice and the second rice models. These mean individual effects are not found for both rice seasons when estimated as the pooled OLS.

Then the Morant's I test for the spatial autocorrelation in the residuals of the OLS model is applied as (3) in Table 5.12. Both the main rice and the second rice models are found to have spatial autocorrelation in the residual. This means the error term of the models between provinces are dependence, given their spatial order. In this case, pooled OLS model is not suitable for estimating the coefficient and the spatial lag model or the spatial error model should be applied for both the main rice and the second rice.

The LM test for detecting significant spatial dependence of the dependent variable, (4), and of the error terms, (5), are then used for both the main rice and the second rice models. Significant results are found for both models. This means spatial coefficient (spatial effects) in the pooled spatial lag model and pooled spatial

error model are statistically significant. Nevertheless, the robust version of LM tests, (6) and (7), suggest that the statistical significance of the spatial effects is only found in the case of the spatial error model for the main rice but not for others.

Tests (8) and (9) in Table 5.12 are marginal tests for the random effects and spatial autocorrelation, respectively, given no other effect in each test, i.e. the test for random effects assuming no spatial autocorrelation and vice versa. The result of these tests also suggests that there is the spatial autocorrelation in the error term of the main rice and the second rice models but there are no significant random effects in both models. However, test (8) and (9) may lead to misinference due to its assumption of no spatial correlation or no random effect when testing each other effects, as mentioned by Baltagi et al. (2003).

Baltagi et al. (2003) suggest a one-side joint LM test, (10), complemented with the conditional LM tests, (11) and (12), to confirm each effect. Results of the test (10) indicate that there exists either individual random effect or spatial dependence in the error term for both rice seasons. For both rice seasons, test (11) indicates that there is the existence of the spatial dependence in the error terms given the random effect can exist at the same time while test (12) indicates the other way around. The results of these three tests suggest that there are random effects and spatial autocorrelation at the same time for both the main rice and the second rice. This means both rice seasons should be estimated as the random effects spatial error model.

The last two tests, (13) and (14), are the Spatial Hausman tests which are used for determining whether fixed effects or random effects is more suitable for each specification. The results from the tests suggest that the fixed effects spatial lag model and fixed effects spatial error model should be applied for both main rice and second rice. For this reason, the interpretation of the results will be based on the fixed effects specification only.

5.2.2 Results of the TFP determinant model of the main rice

For the main rice, the fixed effects spatial lag model shows that there is a strongly significant spatial dependence effect (ρ) of the TFP growth between provinces. This means TFP growth in one province is influenced by the neighboring province and vice versa. However, with this spatial dependence term, the coefficient of explanatory variables in the spatial lag model cannot be directly interpreted as the

marginal effects of the relationship between the regressor and the dependent variable. Because the effect from the explanatory variables that affect the TFP growth of one province will also affect the TFP growth of neighboring provinces via its TFP growth and the same effects are also true for all provinces, which create feedback effects to each other.

The spatial error model does not have the spatial lag model feedback problem so we can interpret the coefficients of the fixed effects spatial error model as the marginal effect. Firstly, the statistically significant spatial error parameter (λ) of the main rice model means that the error term of the TFP determinant model is spatially related to the error term of neighbor provinces. The shared of high-yielding varieties planted is positively and significantly related to the TFP growth of main rice. One percent increase in the shared area increase TFP growth by 0.1156%. Surface temperature and the damaged area are negatively and significantly related to the TFP growth of main rice. An increase in surface temperature by 1% causes a decrease in TFP growth of main rice by 0.6328%. And an increase in the damaged area to the total planted area by 1% causes a decrease in the TFP growth of main rice by 0.7589%. However, irrigation area, total precipitation, and gross provincial product are not statistically significant explanatory variables for the main rice TFP growth.

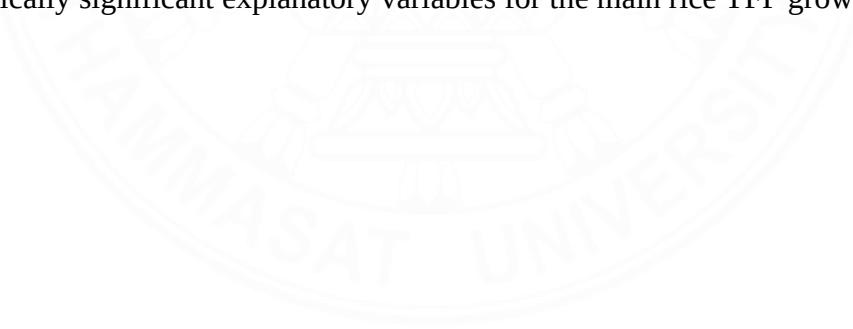


Table 5.13

Results of TFP growth determinant models

Items	Main rice model					Second rice model				
	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error
High-yielding shared	0.0141 (0.0124)	0.0146 (0.0117)	0.0217 (0.0142)	0.0963** (0.0298)	0.1156*** (0.0331)	0.0017 (0.0167)	-0.0095 (0.0159)	-0.0065 (0.0171)	0.0198 (0.0231)	0.024 (0.0138)
Irrigation area per planted area	-0.0071 (0.0233)	-0.0042 (0.0219)	0.0002 (0.0237)	-0.0564 (0.0343)	-0.0554 (0.0367)	0.0044** (0.0015)	0.0118*** (0.0018)	0.0121*** (0.0018)	0.0135*** (0.002)	0.0138*** (0.002)
ln(Surface temperature)	9.3304 (6.9702)	7.9988 (6.5707)	8.6765 (8.2154)	-50.7494* (21.4096)	-63.2781* (31.2393)	-9.9396+ (5.3873)	-5.7719 (5.0428)	-6.4208 (5.6046)	-53.33** (17.4303)	-64.2159** (19.7086)
ln(Total precipitation)	0.8261 (1.6117)	1.2486 (1.5193)	1.4549 (1.8576)	-1.3207 (2.5837)	-3.2151 (3.522)	2.1955* (0.7126)	3.2281*** (0.7448)	3.6072*** (0.8708)	3.7853** (1.3851)	4.0095* (1.5697)
Damaged area	-0.5928*** (0.0526)	-0.4988*** (0.0496)	-0.5823*** (0.057)	-0.6716*** (0.0587)	-0.7589*** (0.0644)	-0.6857*** (0.1037)	-0.9196*** (0.0988)	-0.9482*** (0.1012)	-1.0179*** (0.103)	-1.0424*** (0.1045)
GPP	-0.0004 (0.0009)	-0.0003 (0.0009)	0.0004 (0.0009)	0.0005 (0.0041)	0.0004 (0.0043)	0.0002 (0.0011)	-0.0001 (0.001)	-0.0001 (0.001)	-0.0009 (0.0038)	-0.0006 (0.0039)
Constant	-25.4412 (20.4982)	-20.3472 (19.3232)	-21.9057 (24.3403)			44.5218* (17.3333)	36.8656* (15.9739)	40.7855* (17.853)		
Spatial lag parameter (ρ)		0.3425*** (0.0311)		0.3304*** (0.0323)			0.1647*** (0.0339)		0.1322*** (0.0358)	
Spatial error parameter (λ)			0.358*** (0.0316)		0.3501*** (0.0332)			0.1711*** (0.0349)		0.1428*** (0.0367)
Log likelihood		-4802.35	-4800.048	-4773.214	-7564.923 ^a		-4912.356	-4912.102	-4887.637	-7596.534 ^a
R2	0.0926					0.0455				
Observation	1292	1292	1292	1292	1292	1441	1260	1260	1260	1260

Note: *** Means significant at 0.1%, ** Means significant at 1%, * Means significant at 5%, + Means significant at 10%, ^a Log likelihood function of fixed effects spatial error model is for optimize the models only and not directly comparable with other models as the selection criteria, Standard errors of estimated coefficients are in parenthesis

5.2.3 Results of TFP determinant of second rice

For the second rice model, the spatial lag parameter and spatial error parameter are also significant, but with lower magnitude compared to the main rice. By looking at the fixed effects spatial error model, irrigation, surface temperature, total precipitation, and damaged area are the statistically significant variables for explaining the TFP growth of second rice. An increase in the irrigation area per planted land by 1 causes an increase in the TFP growth of second rice by 0.0138%. An increase in total precipitation by 1% caused an increase in the TFP growth of second rice by 0.04%. In terms of the negative relationship to the TFP growth of second rice, an increase in surface temperature by 1% causes TFP growth to decrease by 0.6422% and an increase in the damaged area to the total planted area by 1% causes a decrease by 1.0424%. High-yielding varieties shared and gross provincial product are not found to be statistically significant explanatory variables for the second rice model.

5.2.4 Discussion of the results of the second step of the analysis

The statistical significance of the spatial coefficient in the spatial lag model means there is spatial dependence in the TFP growth of rice in both seasons. The TFP growth of rice in one province is positively related to its neighboring provinces, as captured by the spatial matrix. There are two ways to interpret spatial dependence of the TFP growth. First, we can interpret it as the spillover effects. If one province discovers technology or technique to improve its efficiency and TFP, this technology or technique could spill over to the nearby provinces. Farmers will eventually adopt technology and technique that can improve their production to maximize their profits in farming. Second, provinces that are near to each other are likely to share and have the same natural factor, e.g., soil quality, general weather, cultivating the same variety of rice, and using the same technique in farming. These nearby provinces, that share some similarities, are likely to have a similar level of TFP. However, natural disasters are also likely to affect a very large area and many provinces at the same time. This means the group of nearby provinces is also likely to face the same negative level of TFP change when there are disasters.

For the spatial error model, the statistical significance of the spatial coefficient indicates the existence of spatial dependence in the error term in the TFP determinant model. The implication of the spatial error coefficient suggests that the

model might not include all variables that determine the TFP growth of rice. The effects of these neglected variables are, still, captured in the residuals or the error terms. And these neglected variables influence not only the TFP growth of rice in its province but also influence TFP of neighboring provinces as well.

Irrigation area per planted area has positive effects on the TFP growth of second rice. The same directional effect of irrigation was also found in Suphannachart (2013) and Suphannachart (2018), however, this study did not find the effects of irrigation in the main rice. One way to interpret this is that the second rice relies on irrigated water more than the main rice, which is probably true because the second rice is the off-season rice. Together with the positive effect of total precipitation on the TFP of second rice, this suggests that the amount of rain in the off-season is so low that even supplied with irrigated water, the amount of total water is still not sufficient for farming rice efficiently and increases in rainfall during the off-season will result in more TFP of the second rice.

No significant effect of irrigation per planted area and of total precipitation on TFP growth on the main rice may come from two reasons. First, the main rice is rain-fed rice and is cultivated during the rainy season. So, increasing in the irrigation area will not help improve the TFP growth for this rice season, but may be helpful in the case of drought. Second, the average amount of rainfall during the rainy season in Thailand is enough for main rice farming already. Variations of rainfall above the average may not help in improving the production of the main rice or may even cause a burden to the production as the excessive rain will cause a flood, the coefficient of total precipitation is negative but not statistically significant.

One aspect that is normally used as the explanation of the TFP growth is the technological improvement. Variables that are commonly used for capturing the technology are the research budget and investment. But the provincial data on the research budget and investment are not available. This study, then, uses the high-yielding variety of rice to capture the technological change, and the spillover effect of the technology is partly captured by the spatial coefficient of the spatial lag model.

Increasing in the share of the high-yielding variety of rice to the total planted area means that farmers are adopting new technology in farming. However, high-yielding variety is found to have a positive significant effect in the case of the

main rice while it has only a positive effect but no statistical significance in the case of the second rice. The reason for non-significance in the case of the second rice may be due to lacking details about the variety of rice that is more severe for the second rice. More detail about this issue is in appendix B section c.

A negative impact of temperature on TFP growth on rice is found for both rice seasons. Kunimitsu et al. (2014) and Kunimitsu et al. (2016) also found the effect of temperature on the TFP growth of rice. They found that the area with an already high average temperature will get a negative impact from increasing in temperature. The asymmetrical effects of climate change are also found in Zhong et al. (2019). They found that in China, climate change has a negative effect on agricultural TFP in southern regions while a positive effect in northern regions. But in Thailand, which is a tropical country, increasing in temperature will mainly have a negative effect on rice production. Pakeechay et al. (2020) found that increases in the temperature not only reduce the yield of rice production in the central of Thailand but also increase the variance and downside risk of the production.

Natural factor measured as the damaged area to the total planted area capture the loss from natural disasters, e.g., drought, flood, pest epidemics etc., also have a negative impact on both rice seasons. This result may be intuitive but it can also capture the nature of the non-parametric method used in measuring the TFP growth of rice because all noises and measurement errors are included in the value.

These last two variables suggest that climate change may have a negative impact on the rice production of Thailand as it increases the average temperature as well as the likelihood of natural and weather shocks.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion of the study

This study measures the performance of rice production in Thailand. In terms of production efficiency, the second rice production is generally more efficient than the main rice, TE score is at 89.75% for the second rice compared to 75.53% for the main rice. Provinces in the central and northern regions tend to be more efficient at producing rice than that of the northeastern and southern regions for both rice seasons. The reasons may come from differences in the development of big- and medium irrigation projects and the difference in the appropriateness of rice farming areas. The Pearson correlation coefficient also suggests that the production of the main rice may be too big and already exceed the optimal level while the production of the second rice is still not reached the optimal level yet.

In terms of the TFP growth of rice production, both rice seasons faced average TFP regress during the period of study, with the average annual rate of -0.53% and -0.59% for the main rice and the second rice respectively. The average technical efficiency change of the whole country are negative for both rice seasons, however, there are differences in direction at the regional level. Northeast is the only region with the average technical efficiency regress for the main rice production while the south is the only region that has average technical efficiency progress. The decomposition of TFP change could give more insight about the differences in the TFP change.

There is a difference in technological adoption for rice production. The main rice production faced average technical progress (0.28%) while the second rice faced average technical regress (-0.27%). Increasing in fertilizer prices may leave farmers with not enough money for investing in new technology and causes technical regress for the second rice, which is usually more fertilizer intensive than the main rice. Even there is some technical improvement for the main rice, the rate is still relatively small compared to other countries. This means the government should design policies that encourage the farmer to adopt new technology to improve production performance,

given the yield of rice in Thailand is already lower than that of many rice-producing countries and also lower than the average yield of the world. Furthermore, the reasons that cause the difference in technical change between main rice and second rice is an interesting topic for further study.

For the TFP determinant model, this study estimates various models for both rice seasons. The result of the tests suggest that the fixed effects spatial error is the most suitable model for the main rice and the second rice. The spatial analysis of the TFP determinant model found the existence of spatial dependence of TFP growth for both rice seasons. The implications of the spatial coefficient of the spatial lag model are 1) there exist spillover effects of the TFP growth among Thai provinces and 2) neighboring provinces that are likely to share some similarity, e.g., soil quality, general weather, cultivating the same variety of rice, and using the same technique in farming, are also likely to have the similar level of performance and TFP improvement. While the implication of the spatial coefficient of the spatial error model indicates that the TFP determinant model used in this study may neglect some variables that influence TFP growth. The effect of the omitted variable influence not only the TFP growth of rice in its province (through the error terms) but also influence the TFP of neighboring provinces as well.

Technology adoption, as captured by the shared of high-yielding variety, plays an important role in the TFP growth of rice in Thailand. And if we consider the irrigation area as a form of technology development, it also has a positive influence over the TFP growth, at least for the second rice. No effects of irrigation on the TFP growth for the main rice may be interpreted in two ways. On the one hand, the main rice is rain-fed rice and the amount of rainfall in the rainy season in Thailand is already at the proper level for rice farming, which is why the total precipitation is not found to have an effect in the case of the main rice. On the other hand, if we consider irrigation as a technological development that should have a positive impact on rice farming in all seasons, no effect in the case of main rice may suggest that there is still room for improvement in irrigation management during the rainy season to be more useful for rice farming. It may also suggest that the different sizes of irrigation projects have different usefulness and different impact on rice farming. For example, the small irrigation project may serve mainly for many purposes but not for agricultural purposes.

So, increasing in the number of small irrigation projects would not help improve agricultural performance. These small irrigation projects also ubiquitously develop in the northeastern region of Thailand, where the main rice is mainly produced.

Lastly, climate change has detrimental effects on the TFP growth of rice in Thailand. This study found that an increase in average temperature and natural shocks reduce the TFP growth of rice. The likelihood of natural- and weather shocks and its severity are also likely to increase with the current climate change scenario. To ensure food security in Thailand, the government should address the climate change issues and invest in research and technology that prevent or mitigate its impact.

6.2 Policy implication

The findings of this study lead to many policy implications.

First, the low technical efficiency score means that farmers can improve their production efficiency by using managerial management. Inputs of rice production could be used at a more adequate level by taking insight from the more efficient provinces with similar conditions. The results also suggest that the production of the main rice is, maybe, too big, especially in the northeastern region, that it is already in the decreasing return to scale. Reducing the size of rice farming and changing to cultivate other agricultural products that are more suitable given the weather and soil quality conditions may help to improve the performance of rice production, increase resilience, and generate other sources of income for the farmer other than that of rice farming.

Second, technical efficiency regress is the main source that contributes to the regression in TFP for both rice seasons. This means some provinces cannot improve their efficiency level to catch up with the frontier provinces. Government should help in diffusing the practice of the frontier provinces to other provinces. Another reason for a regression in technical efficiency may come from natural shocks that hinder the production and yield of rice. Policies that help the farmer to be more resilience to these shocks are needed for improving technical efficiency as well as the TFP growth.

Third, the regression in technical change for the second rice means that some provinces cannot adopt new technology to improve their efficient frontier

compared to the frontier provinces. Even there is some technical progress for the main rice, the rate of improvement is relatively low compared to other countries. Government should encourage farmers to adopt new technologies, such as agricultural drones or precision farming systems, to improve the production of rice. However, these technologies are expensive or require a lot of investment. Government should have a subsidy for the rice farmer who is relatively financially poor compared to the laborers in other sectors. Some machines could be used for more than one farmer which means the benefit of new machines or technologies can spill over to other farmers as well. For example, agricultural drones can use for sowing, applying fertilizer and pesticide, and monitoring the field with more efficiency and less time. The owner of the agricultural drones can even be open for hire in this kind of work after finishing theirs.

Fourth, the existence of spatial dependence in the TFP of rice suggests that there are spillover effects of technology among provinces. This means improving the TFP of rice in one province will improve TFP for neighboring provinces as well. So, focusing on improving rice production and investing in new technology in the pilot province will eventually spill over to other provinces.

Lastly, climate change will have detrimental effects on the TFP growth of rice in Thailand for the near decades, as it increases the temperature, likelihood, and severity of natural shocks and disasters. Policymakers should address these issues by investing and developing systems and technology that improve the resilience of the farmer and help to overcome the negative impact of climate change. For example, the new variety of rice that can maintain a high yield in the high-temperature environment, tolerance to floods, drought, and pests, or even finding alternative agricultural products that are more suitable in such conditions.

In summary, research for new varieties of rice, introducing and encouraging farmers to new agricultural technologies as well as utilizing the spillover effects is very crucial for improving the performance of rice production in the short-run, at least to catching up with the yield of other rice producer countries. However, reconsidering the objective and position of rice farming might be another important decision to be made in order to secure food for domestic consumption as well as improve the resilience and economic condition of the rice farmers in the long-run.

6.3 Limitations and recommendations for further study

This study contains some limitations that can be improved for further study. The list is as follows:

- The DEA and Malmquist productivity index employed in this study are non-parametric approaches which are vulnerable to noises and measurement errors of the observations. A study with the parametric approach using the same data set may help to verify the effects and trends in each other. However, the sensitivity to noises and shocks helps to capture the effect of the natural impacts on rice production that is shown in the TFP determinant model.
- This study did not include capital as one of the inputs for rice production due to the lack of capital data at the provincial level. The technical change calculated in this study will represent only technology that is related to the input that used in the study, i.e., seed, fertilizer, and planted land. Systematic data collection about capital and machine used in rice farming at the provincial level is needed to understand the performance of rice farming accurately.
- The spatial effects in the results may come from the measurement problems and bias in the process of collecting and generating data as mentioned in Anselin (1998).
- The LM test used in this study is the testing for spatial error correlation or the random region effects given the existence of each other effects. But it needed more theoretical tests between spatial lag dependence and random regional effects as noted in Baltagi et al. (2003).
- The spatial regression model employed in this study is the static panel model, which means it does not include the lagged term in the spatial dependence part and in the spatial error part of the model. Further study with the spatial dynamics model may improve our understanding of the TFP change of rice production in Thailand.

- Study on what causes technological change is needed for a better understanding of rice production as well as what causes the difference between main and second rice (positive for main rice but negative for second rice).
- One reason that may cause regression in the TEC and TC is that now the farmer in Thailand owns smaller pieces of farmland over time. Small land farm owners may reluctant to invest in new technologies that have high costs because they may not be able to use these new technologies at its full capacity. Incorporating farm sizes into the TFP determinant analysis should be one interesting aspect for further study.
- Lack of the details in the data seems to be the important part that hinders the analysis. Collecting more data at the provincial level, or even at more detailed level, such as the data about the agricultural machine, research budget, etc., as well as improving the quality of the collecting process could help researchers and policymakers to get more precise insight about the agricultural sector in Thailand.

REFERENCES

Books and Book Articles

- Anselin, L. (1988). *Spatial Econometrics: Methods and Models*, Kluwer Academic Publishers, Dordrecht.
- Anselin, L., Gallo, J. L., & Jayet, H. (2008). Spatial Panel Econometrics. In L. Mátyás & P. Sevestre (Eds.), *The Econometrics of Panel Data: Fundamentals and Recent Developments in Theory and Practice* (pp. 625-660). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-75892-1_19
- Coelli, T., Rao, D. S., O'Donnell, C., & Battese, G. (2005). *An Introduction to Efficiency and Productivity Analysis 2nd ed.* Springer New York, NY.
- Comin, D. (2010). Total factor productivity. In S. N. Durlauf & L. E. Blume (Eds.), *The New Palgrave Economics Collection* (pp. 260-263). Palgrave Macmillan.
- Hicks, J. R. (1961). Measurement of capital in relation to the measurement of other economic aggregates. In Hague, D. C., (Ed.), *Theory of Capital* (pp. 18-31). New York, NY, Springer.
- Koopmans, T. C. (1951). An Analysis of Production as an Efficient Combination of Activities. In T. C. Koopmans (Ed.), *Activity Analysis of Production and Allocation* (pp. 33-97), Cowles Commission for Research in Economics, Monograph No. 13.
- NSTDA. (2020). *Smart Farming*. National Science and Technology Development Agency.
- OAE. (2014). *Definition of agricultural statistics*. Centre for Agricultural Information. Office of Agricultural Economics
- Rerkkasem, B. (2014). *Future of Thai Agriculture*. Chiang Mai University School of Public Policy.
- RID. (2020). *Information about irrigation projects 2563*. Royal Irrigation Department.
- Shephard, R. W. (1981). *Cost and Production Functions*. Springer-Verlag Berlin Heidelberg.

- Sickles, R., & Zelenyuk, V. (2019). *Measurement of Productivity and Efficiency: Theory and Practice*. Cambridge: Cambridge University Press.
- Suphannachart, W. (2018). Spatial Analysis of Research-Productivity Nexus: A Case of Thai Rice Sector. In N. Tsounis & A. Vlachvei (Eds.), *Advances in Panel Data Analysis in Applied Economic Research*. Springer International Publishing.

Articles

- Abedullah, Kouser, S., & Mushtaq, K. (2007). Analysis of technical efficiency of rice production in Punjab (Pakistan): Implications for Future Investment Strategies. *Pakistan Economic and Social Review*, 45(2), 231-244.
- Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6(1), 21-37. [https://doi.org/10.1016/0304-4076\(77\)90052-5](https://doi.org/10.1016/0304-4076(77)90052-5)
- Amien, I., Rejekiingrum, P., Pramudia, A., & Susanti, E. (1996). Effects of interannual climate variability and climate change on rice yield in Java, Indonesia. *Water, Air, and Soil Pollution*, 92(1), 29-39. <https://doi.org/10.1007/BF00175550>
- Anselin, L., Bera, A. K., Florax, R., & Yoon, M. J. (1996). Simple diagnostic tests for spatial dependence. *Regional Science and Urban Economics*, 26(1), 77-104. [https://doi.org/10.1016/0166-0462\(95\)02111-6](https://doi.org/10.1016/0166-0462(95)02111-6)
- Aumpon, S. D. (2018). Resource Misallocation and Rice Productivity in Thailand. *Montenegrin Journal of Economics*, 14(2), 143-153. <https://doi.org/10.14254/1800-5845/2018.14-2.9>
- Balcombe, K., Fraser, I., Latruffe, L., Rahman, M., & Smith, L. (2008). An Application of the DEA Double Bootstrap to Examine Sources of Efficiency in Bangladesh Rice Farming. *Applied Economics*, 40, 1919-1925. <https://doi.org/10.1080/00036840600905282>
- Baltagi, B. H., Song, S. H., & Koh, W. (2003). Testing panel data regression models with spatial error correlation. *Journal of Econometrics*, 117(1), 123-150. [https://doi.org/10.1016/S0304-4076\(03\)00120-9](https://doi.org/10.1016/S0304-4076(03)00120-9)

- Banker, R.D., Charnes, A., & Cooper, W.W. (1984) Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, 30, 1078-1092. <https://doi.org/10.1287/mnsc.30.9.1078>
- Boonwichai, S., Shrestha, S., Babel, M. S., Weesakul, S., & Datta, A. (2018). Climate change impacts on irrigation water requirement, crop water productivity and rice yield in the Songkhram River Basin, Thailand. *Journal of Cleaner Production*, 198, 1157-1164. <https://doi.org/10.1016/j.jclepro.2018.07.146>
- Bjurek, H. (1996). The Malmquist Total Factor Productivity Index. *The Scandinavian Journal of Economics*, 98(2), 303-313. <https://doi.org/10.2307/3440861>
- Butso, O., & Isvilanonda, S. (2010). Changes in the Efficiency of Rice Production in Thailand. *Kasetsart Journal*, 31(3), 436-444.
- Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity. *Econometrica*, 50(6), 1393-1414. <https://doi.org/10.2307/1913388>
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), 429-444. [https://doi.org/10.1016/0377-2217\(78\)90138-8](https://doi.org/10.1016/0377-2217(78)90138-8)
- Chen, C., van Groenigen, K. J., Yang, H., Hungate, B. A., Yang, B., Tian, Y., Chen, J., Dong, W., Huang, S., Deng, A., Jiang, Y., & Zhang, W. (2020). Global warming and shifts in cropping systems together reduce China's rice production. *Global Food Security*, 24, 100359. <https://doi.org/10.1016/j.gfs.2020.100359>
- Coelli, T., & Nghiem, S. (2002). The Effect of Incentive Reforms Upon Productivity: Evidence from the Vietnamese Rice Industry. *The Journal of Development Studies*, 39, 74-93. <https://doi.org/10.1080/00220380412331322671>
- Coelli, T., Rahman, S., & Thirtle, C. (2002). Technical, Allocative, Cost and Scale Efficiencies in Bangladesh Rice Cultivation: A Non-parametric Approach. *Journal of Agricultural Economics*, 53, 607-626. <https://doi.org/10.1111/j.1477-9552.2002.tb00040.x>
- Coelli, T. J., & Rao, D. S. P. (2005). Total factor productivity growth in agriculture: a Malmquist index analysis of 93 countries, 1980–2000. *Agricultural Economics*, 32(s1), 115-134. <https://doi.org/10.1111/j.0169-5150.2004.00018.x>

- Debreu, G. (1951). The Coefficient of Resource Utilization. *Econometrica*, 19(3), 273–292. <https://doi.org/10.2307/1906814>
- Ebers, A., Nguyen, T. T., & Grote, U. (2016). Production efficiency of rice farms in Thailand and Cambodia: a comparative analysis of Ubon Ratchathani and Stung Treng provinces. *Paddy and Water Environment*, 15(1), 79-92. <https://doi.org/10.1007/s10333-016-0530-6>
- Färe, R., Grosskopf, S., & Lovell, C. A. K. (1983). The Structure of Technical Efficiency. *The Scandinavian Journal of Economics*, 85(2), 181-190. <https://doi.org/10.2307/3439477>
- Färe, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries. *The American Economic Review*, 84(1), 66-83.
- Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. Series A (General)*, 120(3), 253-290. <https://doi.org/10.2307/2343100>
- Fuglie, K. (2015). Accounting for growth in global agriculture. *Bio-based and Applied Economics Journal*, 04(3), 201-234.
- Fulginiti, L. E., & Perrin, R. K. (1997). LDC agriculture: Nonparametric Malmquist productivity indexes. *Journal of Development Economics*, 53(2), 373-390. [https://doi.org/10.1016/S0304-3878\(97\)00022-9](https://doi.org/10.1016/S0304-3878(97)00022-9)
- Grifell-Tatjé, E., & Lovell, C. A. K. (1995). A note on the Malmquist productivity index. *Economics Letters*, 47(2), 169-175. [https://doi.org/10.1016/0165-1765\(94\)00497-P](https://doi.org/10.1016/0165-1765(94)00497-P)
- Hossain, M., Kamil, A., Baten, M. A., & Mustafa, A. (2012). Stochastic Frontier Approach and Data Envelopment Analysis to Total Factor Productivity and Efficiency Measurement of Bangladeshi Rice. *PloS ONE*, 7, e46081. <https://doi.org/10.1371/journal.pone.0046081>
- Isvilanonda, S., Ahmad, A., & Hossain, M. (2000). Recent Changes in Thailand's Rural Economy: Evidence from Six Villages. *Economic and Political Weekly*, 35(52/53), 4644-4649.

- Jin, S., Huang, J., Hu, R., & Rozelle, S. (2002). The Creation and Spread of Technology and Total Factor Productivity in China's Agriculture. *American Journal of Agricultural Economics*, 84(4), 916-930.
- Jirarud, S., & Suwanmaneepong, S. (2020). Technical efficiency of rice farmers under the large agricultural plot scheme in Khlong Khuean District, Chachoengsao Province, Thailand. *World Review of Entrepreneurship, Management and Sustainable Development*, 16(2), 228-240.
- Jorgenson, Dale, & Griliches, Z. (1971). Divisia Index Numbers and Productivity Measurement. *Review of Income and Wealth*, 17(2), 227-229. <https://doi.org/10.1111/j.1475-4991.1971.tb00775.x>
- Ke Chung Peng. (2020). Measurement of Technical Efficiency of Wet Season Rice Production in Northern Thailand: An Application of DEA Malmquist Index. *American Journal of Biomedical Science & Research*, 7(1), 11-15. <http://dx.doi.org/10.34297/AJBSR.2020.07.001104>
- Khai, H.V., & Yabe, M. (2011). Technical efficiency analysis of rice production in Vietnam. *Journal of ISSAAS*, 17, 135-146.
- Kim, H.-Y., Ko, J., Kang, S., & Tenhunen, J. (2013). Impacts of climate change on paddy rice yield in a temperate climate. *Global Change Biology*, 19(2), 548-562. <https://doi.org/10.1111/gcb.12047>
- Kondo, K., Yamamoto, Y., & Sasaki, J. (2017). Total Factor Productivity of the Japanese Rice Industry: JAPANESE RICE PRODUCTIVITY. *Asian Economic Journal*, 31, 331-353. <https://doi.org/10.1111/asej.12134>
- Krasachat, W. (2004). Technical efficiencies of rice farms in Thailand: A non-parametric approach. *The Journal of American Academy of Business, Cambridge*, 4(1), 64-69.
- Kumar, P., Kumar, A., & Mittal, S. (2004). Total Factor Productivity of Crop Sector in the Indo-Gangetic Plain of India: Sustainability issues revisited. *Indian Economic Review*, 39(1), 169-201.
- Kunimitsu, Y., Iizumi, T., & Yokozawa, M. (2014). Is long-term climate change beneficial or harmful for rice total factor productivity in Japan: evidence from a panel data analysis. *Paddy and Water Environment*, 12(2), 213-225. <https://doi.org/10.1007/s10333-013-0368-0>

- Kunimitsu, Y., Kudo, R., Iizumi, T., & Yokozawa, M. (2016). Technological spillover in Japanese rice productivity under long-term climate change: evidence from the spatial econometric model. *Paddy and Water Environment*, 14(1), 131-144. <https://doi.org/10.1007/s10333-015-0485-z>
- Liu, D. (2015). Production Efficiency Change and Convergence Analysis of Japonica Rice in China. *Asian Agricultural Research*, 7(11), 1-5.
- Liu, J., Wang, M., Yang, L., Rahman, S., & Sriboonchitta, S. (2020). Agricultural Productivity Growth and Its Determinants in South and Southeast Asian Countries. *Sustainability*, 12(12). <https://doi.org/10.3390/su12124981>
- Luh, Y.-H., Chang, C.-C., & Huang, F.-M. (2008). Efficiency change and productivity growth in agriculture: A comparative analysis for selected East Asian economies. *Journal of Asian Economics*, 19(4), 312-324. <https://doi.org/10.1016/j.asieco.2008.05.003>
- Malmquist, S. (1953). Index numbers and indifference surfaces. *Trabajos de Estadística*, 4(2), 209-242. <https://doi.org/10.1007/BF03006863>
- Md. Abdul, W. (2003). Technical, Allocative, and Economic Efficiency of Farms in Bangladesh: A Stochastic Frontier and DEA Approach. *The Journal of Developing Areas*, 37(1), 109-126.
- Meeusen, W., & van Den Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review*, 18(2), 435-444. <https://doi.org/10.2307/2525757>
- Monga, S. & Sidana, B., K. (2019). Performance of Productivity of Rice and Wheat Crops in India: A Malmquist Total Factor Productivity Analysis. *Research Journal of Agriculture Science*, 10(5/6), 733-740
- Moorsteen, R. H. (1961). On measuring productive potential and relative efficiency. *The Quarterly Journal of Economics*, 75(3), 151-167.
- Mutl, J., & Pfaffermayr, M. (2011). The Hausman test in a Cliff and Ord panel model. *The Econometrics Journal*, 14(1), 48-76. <https://doi.org/10.1111/j.1368-423X.2010.00325.x>
- Nunti, C., Boonyakunakorn, P., & Sriboonchitta, S. (2019). Technical efficiency of rice production in Thailand: copula-based stochastic frontier model. *Journal of*

- Physics: Conference Series*, 1324, 012107. <https://doi.org/10.1088/1742-6596/1324/1/012107>
- Osti, S. (2016). Effect of Drought Condition on the Technical Efficiency of Rice Farms in Thailand. *EC Agriculture*, 3, 674-680.
- Pakeechay, K., Sinnarong, N., Autchariyapanitkul, K., Supapunt, P. (2020). The Impact of Climate Change on Rice Product in the Central Region of Thailand. *Journal of Economics and Management Strategy*, 7(2), 1-22.
- Panpluem, N., Mustafa, A., Huang, X., Wang, S., & Yin, C. (2019). Measuring the Technical Efficiency of Certified Organic Rice Producing Farms in Yasothon Province: Northeast Thailand. *Sustainability*, 11(24). <https://doi.org/10.3390/su11246974>
- Pradhan, A. (2018). Measuring Technical Efficiency in Rice Productivity Using Data Envelopment Analysis: A Study of Odisha. *International Journal of Rural Management*, 14(1), 1-21. <https://doi.org/10.1177/0973005217750061>
- Rahman, S., Anik, A. R., & Sarker, J. R. (2022). Climate, Environment and Socio-Economic Drivers of Global Agricultural Productivity Growth. *Land*, 11(4), 512. <https://doi.org/10.3390/land11040512>
- Rahman, S., Barmon, B. K., & Anik, A. R. (2020). Productivity growth and efficiency changes in prawn-carp-rice farming in ‘Gher’ system in Bangladesh: A Färe-Primont index approach. *Aquaculture*, 522. <https://doi.org/10.1016/j.aquaculture.2020.735107>
- Rahman, S., & Salim, R. (2013). Six Decades of Total Factor Productivity Change and Sources of Growth in Bangladesh Agriculture (1948–2008). *Journal of Agricultural Economics*, 64(2), 275-294. <https://doi.org/10.1111/1477-9552.12009>
- Rahman, S., Wiboonpongse, A., Sriboonchitta, S., & Chaovanapoonphol, Y. (2009). Production Efficiency of Jasmine Rice Producers in Northern and North-eastern Thailand. *Journal of Agricultural Economics*, 60(2), 419-435. <https://doi.org/10.1111/j.1477-9552.2008.00198.x>
- Rungsuriyawiboon, S., & Wang, X. (2009). Agricultural productivity growth in traditional and transitional economies in Asia. *Asian-Pacific Economic Literature*, 23(2), 52-72. <https://doi.org/10.1111/j.1467-8411.2009.01236.x>

- Rungsuriyawiboon, S., & Wang, X. (2012). Investigating agricultural productivity improvements in transition economies. *China Agricultural Economic Review*, 4(4), 450-467. <https://doi.org/10.1108/17561371211284812>
- Sansri, B., Srisompun, O., Chitchamnong, S., & Siritrakulsak, P. (2014). Technical efficiency of Khao Dawk Mali 105 rice production in Roi-Et province. *Khon Kaen Agric. Journal*, 42, 136-141.
- Sarker, M. A. R., Alam, K., & Gow, J. (2012). Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data. *Agricultural Systems*, 112, 11-16. <https://doi.org/10.1016/j.agsy.2012.06.004>
- Solow, R. M. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*, 39(3), 312-320. <https://doi.org/10.2307/1926047>
- Songsrirote, N., & Singhapreecha, C. (2007). Technical Efficiency and the Determinants of Technical Inefficiency on Conventional and Certified Organic Jasmine Rice Farms in Yasothon Province. *Thammasat Economic Journal*, 25(2), 96-133.
- Sriboonchitta, S., & Wiboonpongse, A. (2001). The Effects of Production Input, Technical Efficiency and Other Factors on Jasmine and Non jasmine Rice Yields in Production Year 1999/2000 in Thailand. *Chiangmai University Journal of Economics*, 5(1), 106-129.
- Sriboonchitta, S., & Wiboonpongse, A. (2005). On estimation of stochastic production-frontiers with self-selectivity: jasmine and non-jasmine rice in Thailand. *CMU. Journal*, 4(1), 105-124.
- Srisompun, O., & Isvilanonda, S. (2012). Efficiency change in Thailand rice production: Evidence from panel data analysis. *Journal of Development and Agricultural Economics*, 4(4). <https://doi.org/10.5897/jdae11.122>
- Suhariyanto, K., & Thirtle, C. (2001). Asian Agricultural Productivity and Convergence. *Journal of Agricultural Economics*, 52, 96-110. <https://doi.org/10.1111/j.1477-9552.2001.tb00941.x>
- Sun, Z., & Li, X. (2021). Technical Efficiency of Chemical Fertilizer Use and Its Influencing Factors in China's Rice Production. *Sustainability*, 13(3). <https://doi.org/10.3390/su13031155>

- Suphannachart, W. (2013). Total Factor Productivity of Main and Second Rice Production in Thailand. *Applied Economics Journal*, 20(1), 1-22.
- Suphannachart, W. (2019). Returns on public and private investment in agricultural R&D in Thailand. *Khon Kaen AGR. Journal*, 47(5), 1077-1088.
- Taraka, K., Latif, I., & Shamsudin, M. N. (2010). A Nonparametric Approach to Evaluate Technical Efficiency of Rice Farms in Central Thailand. *Chulalongkorn Journal of Economics*, 22(1), 1-14.
- Taraka, K., Latif, I. A., Shamsudin, M. N., & Sidique, S. b. A. (2012). Estimation of Technical Efficiency for Rice Farms in Central Thailand Using Stochastic Frontier Approach. *Asian Journal of Agriculture and Development*, 9(2), 1-11. <https://doi.org/10.22004/ag.econ.199098>
- Thepent, V., & Chamsing, A. (2009, October). Agricultural mechanization development in Thailand. Paper presented at the 5th Session of the Technical Committee of APCAEM, Los Banos, Philippines.
- Trueblood, M., & Coggins, J. (2003). Intercountry Agricultural Efficiency and Productivity: A Malmquist Index Approach. Mimeo, World Bank, Washington DC.
- Umetsu, C., Lekprichakul, T., & Chakravorty, U. (2003). Efficiency and Technical Change in the Philippine Rice Sector: A Malmquist Total Factor Productivity Analysis. *American Journal of Agricultural Economics*, 85(4), 943-963. <https://doi.org/10.1111/1467-8276.00499>
- Wadud, Md. Abdul. (2003). Technical, Allocative, and Economic Efficiency of Farms in Bangladesh: A Stochastic Frontier and DEA Approach. *The Journal of Developing Areas*, 37(1), 109-126. <https://doi.org/10.1353/jda.2004.0019>
- Xu, X., & Jeffrey, S. R. (1998). Efficiency and technical progress in traditional and modern agriculture: evidence from rice production in China. *Agricultural Economics*, 18(2), 157-165. [https://doi.org/10.1016/S0169-5150\(98\)80004-2](https://doi.org/10.1016/S0169-5150(98)80004-2)
- Yao, F., Xu, Y., Lin, E., Yokozawa, M., & Zhang, J. (2007). Assessing the impacts of climate change on rice yields in the main rice areas of China. *Climatic Change*, 80(3), 395-409. <https://doi.org/10.1007/s10584-006-9122-6>

Zhong, Z., Hu, Y., & Jiang, L. (2019). Impact of Climate Change on Agricultural Total Factor Productivity Based on Spatial Panel Data Model: Evidence from China. *Sustainability*, 11(6). <https://doi.org/10.3390/su11061516>

Dissertations and Theses

Champhech, N. (2003). *An Analysis of Technical Efficiency on Jasmine Rice and Organic Jasmine Rice Production: A Case Study in Kudchum District, Yasothon Province* [Master's thesis, Thammasat University]. Thammasat University Digital Collections. https://digital.library.tu.ac.th/tu_dc/frontend/Info/item/dc:89660

Chitdecha, M. J. (2016). *The effect of human capital on income in Thailand: A Spatial effect analysis* [Master's thesis, Thammasat University]. Thammasat University Digital Collections. https://digital.library.tu.ac.th/tu_dc/frontend/Info/item/dc:91710

Kiatpathomchai, S. (2008). *Assessing Economic and Environmental Efficiency of Rice Production Systems in Southern Thailand: An Application of Data Envelopment Analysis* [Doctoral dissertation, Justus-Liebig, University Giessen]. <http://geb.uni-giessen.de/geb/volltexte/2008/6373/pdf/KiatpathomchaiSirirat-2008-09-02.pdf>

Online Data Base

Food and Agriculture Organization of the United Nations. (2021). FAOSTAT statistical database. Rome :FAO. <http://www.fao.org/faostat/en/#home>

United States Department of Agriculture. (2021). PSD Online data. Foreign Agricultural Service: USDA. <https://apps.fas.usda.gov/psdonline/app/index.html#/app/downloads>

Ministry of Agriculture and Cooperatives. (2022). Agri-Map Online. MOAC. <https://agri-map-online.moac.go.th>

Electronic Media

- Dasree, C. (2020, February 5). *IOT one-stop smart farming by KUBOTA*.
<https://techsauce.co/corp-innov/smart-farming-iot-kubota>
- Kwanmuang, K., Pongputhinan, T., Jabri, A., & Chitchumnung, P. (2020). *Small-Scale Farmers under Thailand's Smart Framing System*. FFTC Agricultural Policy Platform (FFTC-AP). <https://ap.ffc.org.tw/article /2647>
- SME Thailand Club. (2022, July 8). *ListenField: Innovations to Help Farmers reduce the risk of weather. The advanced level of farming in the smart farm era*.
<https://www.smethailandclub.com/tech/8257.html>
- Tongwaranan, T. (2018, October 29). *The future of rice production*. <https://www.bangkokpost.com/business/1566370/the-future-of-rice-production>.

Other Materials

- Arnade, C. A. (1994). *Using Data Envelopment Analysis to Measure International Agricultural Efficiency and Productivity*. USDA publications.
<https://naldc.nal.usda.gov/catalog /CAT10669001>
- Chaovanapoonphol, Y., Battese, G. E., & Chang, H.-S. C. (2005). *The Impact of Rural Financial Services on the Technical Efficiency of Rice Farmers in the Upper North of Thailand*. Australian Agricultural and Resource Economics Society (AARES), Coff's Harbour, Australia.
- Dhehibi, B., Frija, A., Aw-Hassan, A., Akroush, S., & Ibrahim, A. (2015). *Approaches to Total Factor Productivity Measurements in the Agriculture Economy. Amman, Jordan: CRP on Dryland Systems (DS)*. <https://repo.mel.cgiar.org/handle/20.500.11766/4389>
- IRR. (2016). *Rice that changed the world: Celebrating 50 years of IR8*. Rice Today.
http://books.irri.org/RT_Supplement-IR8.pdf
- Isvilanonda, S., Kaoien, S., Kongrithi, W., Butso, O. (2009). *Dynamics of Thailand's Rice Production Economy and The Future Outlook*. Thailand Research Fund.

Titapiwatanakun, B. (2012). *The Rice Situation in Thailand*. The Asian Development Bank. <https://www.adb.org/projects/documents/rice-situation-thailand-tacr>



The background of the page features a large, faint, circular watermark of the Thammasat University seal. The seal is centered and contains the university's name in Thai script at the top and "THAMMASAT UNIVERSITY" in English at the bottom. In the center of the seal is a stylized emblem featuring a lotus flower and a crown-like structure.

APPENDICES

APPENDIX A

RESULTS OF THE PERFORMANCE MEASUREMENT

This section shows the full performance index for each province and region for the main rice and the second rice.

(A) Results of the main rice

Table A.1

Average technical efficiency score of the main rice

Province	Efficiency score of the main rice						
	1997	2002	2007	2012	2017	2018	1997
	-	-	-	-			-
	2001	2006	2011	2016			2018
Bangkok Metropolis	0.9300	0.9644	0.9574	0.9558	1.0000	1.0000	0.9561
Samut Prakan	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Nonthaburi	1.0000	1.0000	0.9507	0.9525	0.9352	0.9388	0.9719
Pathum Thani	1.0000	0.9988	0.9587	0.9660	1.0000	1.0000	0.9824
Phra Nakhon Si Ayutthaya	0.7999	0.7917	0.8422	0.8861	0.9462	0.9658	0.8399
Ang Thong	0.7992	0.7871	0.8466	0.8599	0.9096	0.9430	0.8315
Lop Buri	0.7191	0.7494	0.7139	0.7611	0.8195	0.8004	0.7421
Sing Buri	0.9512	0.9057	0.9040	0.9284	0.9617	1.0000	0.9273
Chai Nat	0.8919	0.9296	0.8858	0.9095	0.9164	0.9150	0.9051
Saraburi	0.7691	0.7053	0.7396	0.8957	0.8819	0.8926	0.7839
Chon Buri	0.6703	0.6884	0.7621	0.7752	0.6216	0.7530	0.7190
Rayong	0.6255	0.5990	0.6393	0.6594	0.7120	0.7287	0.6381
Chanthaburi	0.6065	0.5416	0.5687	0.6787	0.6647	0.6659	0.6027
Trat	0.6904	0.6967	0.7168	0.7519	0.9119	0.8912	0.7289
Chachoengsao	0.8003	0.7581	0.7826	0.8641	0.8576	0.9029	0.8072
Prachin Buri	0.5900	0.5911	0.6199	0.6175	0.6807	0.6969	0.6117
Nakhon Nayok	0.8714	0.6902	0.7459	0.8449	0.9034	0.8613	0.7930
Sa Kaeo	0.6786	0.6361	0.6742	0.5399	0.5726	0.5815	0.6246
Ratchaburi	0.8760	0.8129	0.9152	0.8950	0.9221	0.9389	0.8789
Kanchanaburi	0.5560	0.6660	0.7941	0.8194	0.8513	0.8453	0.7129
Suphan Buri	0.8681	0.9049	0.9246	0.9472	0.9646	0.9973	0.9169
Nakhon Pathom	0.9636	0.8687	0.8967	0.9905	0.9855	1.0000	0.9342
Samut Sakhon	0.8288	0.8449	0.9077	0.9360	0.9623	0.9781	0.8862
Samut Songkhram	0.8918	0.8161	0.9170	0.9391	0.9924	0.9816	0.8982
Phetchaburi	0.7540	0.6824	0.7784	0.9279	0.9121	0.9570	0.7936
Prachuap Khiri Khan	0.6767	0.6016	0.6995	0.7716	0.7593	0.8647	0.6952
Central	0.8183	0.8003	0.8288	0.8667	0.8907	0.9049	0.8343
Nakhon Ratchasima	0.6295	0.5038	0.5438	0.5106	0.5720	0.4941	0.5435

Table A.1

Average technical efficiency score of the main rice (Cont.)

Province	Efficiency score of the main rice						
	1997	2002	2007	2012	2017	2018	1997
	-	-	-	-			-
	2001	2006	2011	2016			2018
Buri Ram	0.7586	0.6238	0.6058	0.5646	0.5852	0.3846	0.6178
Surin	0.6024	0.5836	0.5995	0.5835	0.6057	0.5011	0.5883
Si Sa Ket	0.6720	0.6649	0.6726	0.5858	0.5567	0.5570	0.6389
Ubon Ratchathani	0.9191	0.9133	0.8678	0.7202	0.7122	0.7125	0.8374
Yasothon	0.7306	0.6566	0.7020	0.6896	0.6656	0.7336	0.6946
Chaiyaphum	0.5855	0.5166	0.5728	0.6904	0.7061	0.6522	0.5958
Amnat Charoen	0.8911	0.8712	0.8098	0.7765	0.8009	0.8336	0.8341
Bueng Kan	-	-	0.8940	0.7123	0.7387	0.6526	0.7281
Nong Bua Lam Phu	0.8330	0.7592	0.8053	0.7516	0.8710	0.8106	0.7913
Khon Kaen	0.7514	0.6384	0.6246	0.5309	0.5719	0.5413	0.6243
Udon Thani	0.8153	0.7557	0.8658	0.8430	0.8616	0.8422	0.8218
Loei	0.9042	0.7060	0.7666	0.8119	0.8306	0.8026	0.7960
Nong Khai	0.8206	0.7545	0.7609	0.7681	0.7386	0.6864	0.7696
Maha Sarakham	0.7773	0.6071	0.6280	0.5690	0.5295	0.5177	0.6291
Roi Et	0.7373	0.5967	0.5920	0.5673	0.5545	0.5023	0.6110
Kalasin	0.8443	0.7144	0.6922	0.6293	0.5589	0.6252	0.7036
Sakon Nakhon	0.7537	0.8131	0.8634	0.7966	0.7378	0.7970	0.8021
Nakhon Phanom	0.7192	0.6513	0.7821	0.9180	0.8289	0.7412	0.7635
Mukdahan	0.7558	0.7267	0.7521	0.7942	0.8515	0.8746	0.7659
Northeastern	0.7467	0.6639	0.6820	0.6417	0.6424	0.6081	0.6771
Chiang Mai	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lamphun	0.9522	0.9636	0.9882	0.9781	1.0000	1.0000	0.9731
Lampang	0.9265	0.8615	0.9268	0.9178	0.9469	0.9364	0.9108
Uttaradit	0.7501	0.8576	0.8617	0.8277	0.8889	0.8427	0.8268
Phrae	0.9831	0.9503	0.9945	0.9042	0.8579	0.8972	0.9498
Nan	0.8724	0.8603	0.9297	0.9629	0.9713	0.9547	0.9105
Phayao	0.9166	0.8627	0.9705	0.8647	0.8952	0.9144	0.9027
Chiang Rai	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mae Hong Son	0.9509	0.9690	0.9877	1.0000	1.0000	1.0000	0.9788
Nakhon Sawan	0.6653	0.7309	0.7160	0.8038	0.8419	0.8916	0.7390
Uthai Thani	0.8188	0.7004	0.7332	0.8454	0.9075	0.9555	0.7854
Kamphaeng Phet	0.7212	0.7116	0.7329	0.8571	0.8803	0.9115	0.7655
Tak	0.8212	0.7871	0.8484	0.8672	0.9594	0.9653	0.8416
Sukhothai	0.8342	0.7341	0.7256	0.7625	0.7209	0.7495	0.7604
Phitsanulok	0.6977	0.7632	0.7700	0.8568	0.8442	0.8517	0.7767
Phichit	0.7625	0.7822	0.8098	0.8858	0.9131	1.0000	0.8211
Phetchabun	0.9821	1.0000	0.9771	0.9406	1.0000	1.0000	0.9770
Northern	0.8196	0.8226	0.8364	0.8741	0.8944	0.9203	0.8440
Nakhon Si Thammarat	0.5594	0.5216	0.5700	0.6642	0.7374	0.7170	0.5888

Table A.1

Average technical efficiency score of the main rice (Cont.)

Province	Efficiency score of the main rice						
	1997	2002	2007	2012	2017	2018	1997
	-	-	-	-			-
	2001	2006	2011	2016			2018
Krabi	0.8069	0.8815	1.0000	0.9619	0.7767	0.8391	0.8997
Phangnga	0.7596	0.7216	0.6569	0.5069	0.5471	0.6254	0.6471
Phuket	0.8762	0.8383	0.8253	0.7604	1.0000	1.0000	0.8386
Surat Thani	0.6236	0.7076	0.6122	0.6003	0.5996	0.5722	0.6300
Ranong	0.9384	0.8561	0.8422	0.9647	1.0000	1.0000	0.9076
Chumphon	0.5308	0.6592	0.6120	0.5713	0.6670	0.5858	0.5944
Songkhla	0.5875	0.6410	0.6565	0.7396	0.6898	0.8064	0.6618
Satun	0.8037	0.7645	0.7065	0.7367	0.6175	0.7463	0.7450
Trang	0.8955	0.7183	0.7798	0.7516	0.7116	0.7561	0.7789
Phatthalung	0.6945	0.6775	0.6548	0.6258	0.6026	0.6673	0.6600
Pattani	0.8213	0.6672	0.7925	0.7178	0.7610	0.9240	0.7551
Yala	0.7575	0.8963	0.9713	0.8604	0.8407	0.7424	0.8605
Narathiwat	0.7278	0.9069	0.9483	0.9491	0.7383	0.8413	0.8694
Southern	0.6490	0.6431	0.6719	0.7063	0.6967	0.7578	0.6723
Whole country	0.7788	0.7368	0.7547	0.7512	0.7577	0.7542	0.7553

Table A.2

Average TFP change of the main rice

Province	TFP change rate of the main rice (%)					
	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Bangkok Metropolis	2.87	-0.02	0.11	-0.38	5.38	0.86
Samut Prakan	4.97	0.86	2.68	-5.04	-5.19	0.50
Nonthaburi	1.39	0.21	-0.85	-0.51	-0.96	0.01
Pathum Thani	4.56	-0.55	0.17	-0.46	0.98	0.91
Phra Nakhon Si Ayutthaya	7.01	2.38	3.18	0.65	-0.01	3.12
Ang Thong	2.02	0.65	1.17	0.88	2.72	1.25
Lop Buri	1.26	1.65	1.23	-0.05	-6.94	0.63
Sing Buri	0.50	1.86	-1.52	1.11	4.77	0.68
Chai Nat	2.40	0.97	-1.56	0.71	-0.18	0.58
Saraburi	-0.30	1.93	4.05	0.69	0.30	1.52
Chon Buri	4.55	4.77	0.16	-6.87	15.81	1.22
Rayong	4.82	0.32	1.74	-0.15	-1.13	1.53
Chanthaburi	2.14	-2.19	8.06	-3.48	-3.81	0.80
Trat	1.51	1.19	2.81	0.89	-5.44	1.25
Chachoengsao	1.92	-0.20	1.77	-0.01	1.74	0.91
Prachin Buri	5.21	0.05	-2.71	3.88	-2.47	1.36
Nakhon Nayok	-2.39	0.99	4.55	-1.04	-6.34	0.16
Sa Kaeo	0.12	0.78	-2.76	-0.32	-3.38	-0.69

Table A.2

Average TFP change of the main rice (Cont.)

TFP change rate of the main rice (%)						
Province	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Ratchaburi	2.76	3.66	-1.19	0.54	2.50	1.47
Kanchanaburi	3.95	3.89	2.13	0.26	-1.59	2.35
Suphan Buri	3.19	0.06	-0.79	0.71	2.76	0.87
Nakhon Pathom	-0.40	0.75	3.26	-0.85	0.96	0.69
Samut Sakhon	2.03	0.15	2.24	1.01	-2.68	1.16
Samut Songkhram	4.40	-0.45	-0.92	2.12	-4.20	1.00
Phetchaburi	1.58	1.37	6.26	-0.98	2.41	2.04
Prachuap Khiri Khan	-1.96	1.46	5.48	-1.82	11.54	1.23
Central	2.02	0.83	0.07	0.15	0.16	0.74
Nakhon Ratchasima	-4.72	3.72	-1.88	2.88	-17.51	-0.97
Buri Ram	1.71	0.54	-3.82	1.52	-36.98	-2.21
Surin	-3.34	2.07	-2.95	1.76	-20.48	-1.70
Si Sa Ket	-1.78	1.08	-1.34	-3.56	-4.12	-1.54
Ubon Ratchathani	1.45	1.98	-0.45	-4.99	-3.29	-0.67
Yasothon	4.27	0.09	-1.52	-1.13	5.59	0.65
Chaiyaphum	1.78	0.42	5.94	-2.55	-10.24	0.77
Amnat Charoen	1.23	-1.31	-3.11	0.81	-0.98	-0.63
Bueng Kan	-	-	-16.35	-1.01	-14.29	-5.33
Nong Bua Lam Phu	0.88	-2.39	-2.95	2.89	-9.06	-0.85
Khon Kaen	3.54	-0.60	-4.24	0.41	-8.99	-0.70
Udon Thani	-0.42	0.79	-0.57	1.12	-5.91	-0.07
Loei	4.67	-6.94	0.93	-0.41	-0.26	-0.51
Nong Khai	-1.19	-0.97	-0.78	-2.86	-11.18	-1.94
Maha Sarakham	-2.52	-0.66	-2.18	-2.10	-6.46	-2.09
Roi Et	-0.06	-4.59	-3.85	2.72	-13.12	-2.08
Kalasin	-2.49	-3.35	-3.77	-1.24	7.12	-2.27
Sakon Nakhon	0.93	-1.67	-0.61	-1.87	3.19	-0.62
Nakhon Phanom	0.35	0.61	7.82	-5.37	-13.03	0.04
Mukdahan	7.79	-7.27	-0.87	5.15	0.07	0.99
Northeastern	-0.72	-0.24	-1.92	-0.75	-10.93	-1.41
Chiang Mai	-0.28	-1.41	0.36	-1.03	-5.38	-0.82
Lamphun	2.07	-0.88	-1.37	0.15	1.33	0.05
Lampang	1.09	-0.25	-0.35	-0.03	1.69	0.19
Uttaradit	0.45	0.59	1.68	-0.22	-8.43	0.17
Phrae	1.26	-2.14	0.07	-3.68	3.38	-0.93
Nan	-0.45	-1.43	-0.54	-0.66	0.43	-0.71
Phayao	-1.27	3.06	0.45	-1.94	-1.68	-0.03
Chiang Rai	1.98	0.33	1.61	-4.29	-2.16	-0.22
Mae Hong Son	-4.67	-7.95	3.42	-2.54	4.67	-2.67
Nakhon Sawan	7.88	0.07	0.29	-0.92	4.72	1.91
Uthai Thani	0.45	1.62	3.04	0.86	0.30	1.43

Table A.2

Average TFP change of the main rice (Cont.)

TFP change rate of the main rice (%)						
Province	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Kamphaeng Phet	7.33	-0.63	4.83	-0.70	-2.30	2.41
Tak	3.37	-2.32	0.89	-0.07	0.86	0.46
Sukhothai	2.25	-2.36	1.89	-2.39	-0.07	-0.17
Phitsanulok	1.49	-0.18	2.22	-1.60	-3.53	0.28
Phichit	1.69	-0.05	2.58	-0.52	8.27	1.26
Phetchabun	6.84	-3.83	-3.31	0.73	-5.16	-0.23
Northern	2.36	-0.70	0.78	-1.34	0.04	0.25
Nakhon Si Thammarat	0.03	0.61	4.41	0.67	-6.89	1.00
Krabi	4.11	2.14	-2.48	-6.17	23.41	0.35
Phangnga	7.61	-2.24	-6.88	1.06	9.31	0.18
Phuket	-6.51	2.90	-2.52	6.05	-1.56	-0.21
Surat Thani	7.66	-7.68	-4.96	0.71	-8.33	-1.59
Ranong	1.07	-2.04	-1.62	3.87	19.86	1.15
Chumphon	10.77	-4.13	-3.21	3.36	-13.60	0.75
Songkhla	3.90	0.29	5.26	-3.48	13.81	1.99
Satun	7.84	-7.65	0.93	-4.25	15.89	-0.21
Trang	-3.02	4.02	-4.56	-1.78	1.52	-1.25
Phatthalung	-0.24	1.38	-2.21	-0.27	9.14	0.09
Pattani	1.20	-2.46	1.36	-3.73	19.49	-0.04
Yala	14.99	-6.57	-7.46	4.20	-6.25	0.54
Narathiwat	1.99	1.99	0.12	-4.22	11.58	0.46
Southern	1.69	-0.45	1.61	-1.75	5.94	0.53
Whole country	0.71	-0.13	-0.85	-0.85	-5.39	-0.53

Table A.3

Average technical efficiency change of the main rice

Technical efficiency change rate of the main rice (%)						
Province	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Bangkok Metropolis	0.00	-0.92	0.27	0.66	0.00	0.00
Samut Prakan	0.00	0.00	0.00	0.00	0.00	0.00
Nonthaburi	0.00	0.00	-1.22	-0.11	0.39	-0.30
Pathum Thani	0.00	-0.20	-0.17	0.37	0.00	0.00
Phra Nakhon Si Ayutthaya	1.90	1.92	0.56	1.87	2.07	1.58
Ang Thong	0.05	0.21	0.63	0.89	3.66	0.60
Lop Buri	-2.98	1.11	0.37	1.33	-2.32	-0.17
Sing Buri	-2.38	1.71	-0.93	0.96	3.98	0.02
Chai Nat	-0.54	0.71	-2.09	0.83	-0.16	-0.27
Saraburi	-3.18	1.40	3.41	0.44	1.21	0.52
Chon Buri	0.09	8.16	-2.12	-4.02	21.14	1.32

Table A.3

Average technical efficiency change of the main rice (Cont.)

Technical efficiency change rate of the main rice (%)						
Province	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Rayong	2.83	0.07	-0.14	2.34	2.36	1.32
Chanthaburi	-1.89	-2.12	5.42	0.04	0.18	0.31
Trat	-1.08	-0.57	0.49	4.38	-2.27	0.64
Chachoengsao	-1.39	-0.09	1.18	0.51	5.29	0.29
Prachin Buri	1.44	-0.51	-2.10	5.96	2.38	1.21
Nakhon Nayok	-5.62	0.38	3.29	1.72	-4.66	-0.34
Sa Kaeo	-3.64	0.64	-3.03	1.73	1.56	-0.98
Ratchaburi	0.70	2.69	-0.33	0.92	1.82	1.03
Kanchanaburi	0.41	2.75	1.47	0.73	-0.70	1.24
Suphan Buri	0.98	-0.11	-0.13	1.12	3.39	0.60
Nakhon Pathom	-2.98	0.45	2.53	-0.21	1.47	0.00
Samut Sakhon	-0.49	0.08	1.15	1.30	1.65	0.56
Samut Songkhram	0.20	-0.81	-0.69	2.93	-1.08	0.33
Phetchaburi	-0.96	0.70	6.01	-0.46	4.92	1.46
Prachuap Khiri Khan	-5.63	0.66	4.94	-0.34	13.89	0.46
Central	-1.17	0.52	-0.32	0.95	1.69	0.07
Nakhon Ratchasima	-6.98	2.77	-3.27	5.50	-13.62	-1.28
Buri Ram	-1.05	-0.45	-5.22	3.82	-34.29	-2.70
Surin	-5.87	1.21	-3.90	3.92	-17.26	-2.07
Si Sa Ket	-3.95	-0.71	-3.60	0.21	0.06	-1.93
Ubon Ratchathani	-0.46	-0.76	-3.62	-0.43	0.04	-1.26
Yasothon	2.15	-1.28	-2.40	1.79	10.22	0.51
Chaiyaphum	-1.60	0.36	5.38	0.14	-7.65	0.61
Amnat Charoen	0.62	-3.48	-3.85	3.71	4.09	-0.57
Buang Kan	-	-	-25.17	2.00	-11.65	-4.40
Nong Bua Lam Phu	-3.35	-1.62	-2.58	5.81	-6.93	-0.82
Khon Kaen	1.95	-2.37	-4.58	3.22	-5.35	-0.73
Udon Thani	-2.04	0.82	-1.69	3.82	-2.25	0.09
Loei	4.15	-3.33	0.05	1.57	-3.37	0.38
Nong Khai	-4.01	2.79	-2.86	0.05	-7.06	-1.34
Maha Sarakham	-3.02	-2.61	-3.87	1.14	-2.23	-2.12
Roi Et	-2.14	-6.09	-5.20	5.43	-9.42	-2.47
Kalasin	-1.77	-5.60	-5.90	2.02	11.87	-2.21
Sakon Nakhon	1.25	-3.84	-1.60	1.61	8.02	-0.28
Nakhon Phanom	-0.61	0.09	6.18	-2.36	-10.58	0.20
Mukdahan	6.81	-7.70	-2.82	7.96	2.71	0.94
Northeastern	-2.52	-1.39	-3.40	2.28	-7.40	-1.58
Chiang Mai	0.00	0.00	0.00	0.00	0.00	0.00
Lamphun	1.22	-0.29	-0.93	1.45	0.00	0.34
Lampang	-1.07	0.07	0.28	0.73	-1.11	-0.05
Uttaradit	-2.96	-0.07	0.21	1.04	-5.20	-0.69

Table A.3

Average technical efficiency change of the main rice (Cont.)

Technical efficiency change rate of the main rice (%)						
Province	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Phrae	0.00	0.00	-0.01	-3.01	4.57	-0.52
Nan	-1.61	2.26	-0.20	0.13	-1.71	0.05
Phayao	-3.02	3.25	-1.29	0.35	2.14	-0.09
Chiang Rai	0.00	0.00	0.00	0.00	0.00	0.00
Mae Hong Son	0.00	-0.37	0.37	0.00	0.00	0.00
Nakhon Sawan	2.91	-1.10	1.45	1.55	5.89	1.41
Uthai Thani	-3.30	0.19	3.80	2.06	5.28	0.87
Kamphaeng Phet	2.36	-1.53	4.04	1.07	3.54	1.56
Tak	0.31	-0.86	0.22	2.67	0.61	0.58
Sukhothai	-2.44	-1.49	0.83	-0.78	3.97	-0.75
Phitsanulok	-2.29	0.21	1.99	0.30	0.89	0.08
Phichit	-1.93	-1.36	1.95	1.95	9.52	0.56
Phetchabun	0.00	0.00	-2.67	2.75	0.00	0.00
Northern	-1.13	-0.49	0.55	0.77	2.88	0.06
Nakhon Si Thammarat	-1.88	0.14	3.07	2.69	-2.77	0.80
Krabi	0.63	5.92	0.00	-4.93	8.04	0.69
Phangnga	4.56	-2.39	-6.14	1.40	14.33	-0.06
Phuket	-8.46	5.73	-2.22	5.80	0.00	0.03
Surat Thani	5.90	-5.60	-5.43	2.03	-4.57	-1.08
Ranong	-0.41	-1.50	-0.77	3.11	0.00	0.09
Chumphon	8.33	-2.96	-3.87	4.25	-12.18	0.63
Songkhla	1.65	-0.23	4.06	-2.77	16.91	1.36
Satun	6.56	-6.31	0.56	-2.39	20.85	0.42
Trang	-5.94	4.71	-4.82	-0.34	6.26	-1.32
Phatthalung	-2.13	0.56	-3.37	0.09	10.74	-0.69
Pattani	-1.24	-0.32	1.39	-0.23	21.41	0.83
Yala	10.11	-0.94	-7.28	5.17	-11.69	0.88
Narathiwat	-0.61	4.30	-0.11	-5.01	13.95	0.23
Southern	-0.38	-0.17	0.72	-0.49	8.75	0.32
Whole country	-1.87	-0.64	-1.78	1.41	-2.45	-0.81

Table A.4

Technical change of the main rice

Technical change rate of the main rice (%)						
Province	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Bangkok Metropolis	2.87	0.91	-0.16	-1.03	5.38	0.86
Samut Prakan	4.97	0.86	2.68	-5.04	-5.19	0.50
Nonthaburi	1.39	0.21	0.37	-0.40	-1.34	0.31
Pathum Thani	4.56	-0.35	0.34	-0.83	0.98	0.91

Table A.4

Technical change of the main rice (Cont.)

Technical change rate of the main rice (%)						
Province	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Phra Nakhon Si Ayutthaya	5.01	0.45	2.61	-1.20	-2.03	1.51
Ang Thong	1.96	0.44	0.53	-0.01	-0.91	0.65
Lop Buri	4.37	0.53	0.86	-1.36	-4.73	0.80
Sing Buri	2.96	0.14	-0.59	0.15	0.76	0.66
Chai Nat	2.96	0.26	0.54	-0.12	-0.02	0.86
Saraburi	2.97	0.52	0.62	0.25	-0.90	0.99
Chon Buri	4.45	-3.14	2.32	-2.97	-4.40	-0.11
Rayong	1.93	0.25	1.89	-2.43	-3.40	0.21
Chanthaburi	4.11	-0.07	2.51	-3.52	-3.99	0.49
Trat	2.62	1.76	2.32	-3.34	-3.25	0.61
Chachoengsao	3.36	-0.11	0.58	-0.52	-3.37	0.61
Prachin Buri	3.72	0.57	-0.63	-1.97	-4.74	0.15
Nakhon Nayok	3.43	0.61	1.22	-2.71	-1.76	0.50
Sa Kaeo	3.90	0.14	0.28	-2.01	-4.87	0.29
Ratchaburi	2.05	0.94	-0.87	-0.37	0.67	0.44
Kanchanaburi	3.53	1.11	0.65	-0.46	-0.89	1.10
Suphan Buri	2.19	0.16	-0.66	-0.41	-0.61	0.27
Nakhon Pathom	2.66	0.30	0.71	-0.64	-0.50	0.69
Samut Sakhon	2.54	0.07	1.08	-0.28	-4.26	0.60
Samut Songkhram	4.19	0.36	-0.24	-0.79	-3.16	0.67
Phetchaburi	2.56	0.67	0.24	-0.53	-2.39	0.58
Prachuap Khiri Khan	3.89	0.79	0.51	-1.49	-2.06	0.77
Central	3.23	0.31	0.39	-0.79	-1.50	0.67
Nakhon Ratchasima	2.42	0.92	1.44	-2.48	-4.50	0.31
Buri Ram	2.78	1.00	1.47	-2.21	-4.09	0.51
Surin	2.68	0.85	0.99	-2.07	-3.90	0.38
Si Sa Ket	2.26	1.80	2.34	-3.76	-4.17	0.39
Ubon Ratchathani	1.92	2.76	3.29	-4.58	-3.33	0.59
Yasothon	2.08	1.39	0.90	-2.86	-4.20	0.14
Chaiyaphum	3.44	0.05	0.53	-2.68	-2.81	0.16
Amnat Charoen	0.61	2.25	0.77	-2.80	-4.88	-0.06
Bueng Kan	-	-	11.79	-2.96	-2.99	-0.98
Nong Bua Lam Phu	4.37	-0.78	-0.37	-2.75	-2.28	-0.03
Khon Kaen	1.55	1.82	0.35	-2.72	-3.84	0.04
Udon Thani	1.65	-0.03	1.14	-2.61	-3.74	-0.16
Loei	0.50	-3.73	0.89	-1.95	3.22	-0.89
Nong Khai	2.94	-3.66	2.13	-2.90	-4.43	-0.61
Maha Sarakham	0.51	2.00	1.77	-3.20	-4.32	0.02
Roi Et	2.13	1.60	1.42	-2.57	-4.09	0.40
Kalasin	-0.73	2.39	2.27	-3.20	-4.24	-0.06
Sakon Nakhon	-0.32	2.26	1.01	-3.42	-4.47	-0.35

Table A.4

Technical change of the main rice (Cont.)

Technical change rate of the main rice (%)						
Province	1998-2002	2003-2007	2008-2012	2013-2017	2018	1998-2018
Nakhon Phanom	0.96	0.52	1.54	-3.09	-2.74	-0.16
Mukdahan	0.92	0.47	2.00	-2.61	-2.57	0.05
Northeastern	1.84	1.17	1.52	-2.96	-3.81	0.17
Chiang Mai	-0.28	-1.41	0.36	-1.03	-5.38	-0.82
Lamphun	0.84	-0.59	-0.44	-1.29	1.33	-0.29
Lampang	2.18	-0.31	-0.63	-0.75	2.84	0.24
Uttaradit	3.52	0.66	1.47	-1.24	-3.41	0.87
Phrae	1.26	-2.14	0.08	-0.69	-1.14	-0.42
Nan	1.17	-3.61	-0.34	-0.79	2.18	-0.76
Phayao	1.80	-0.18	1.77	-2.29	-3.74	0.07
Chiang Rai	1.98	0.33	1.61	-4.29	-2.16	-0.22
Mae Hong Son	-4.67	-7.61	3.03	-2.54	4.67	-2.67
Nakhon Sawan	4.83	1.19	-1.14	-2.44	-1.11	0.49
Uthai Thani	3.88	1.42	-0.73	-1.17	-4.73	0.56
Kamphaeng Phet	4.85	0.91	0.75	-1.76	-5.64	0.83
Tak	3.05	-1.48	0.67	-2.67	0.24	-0.11
Sukhothai	4.81	-0.88	1.05	-1.62	-3.89	0.58
Phitsanulok	3.87	-0.39	0.23	-1.89	-4.38	0.20
Phichit	3.70	1.33	0.62	-2.42	-1.14	0.69
Phetchabun	6.84	-3.83	-0.65	-1.97	-5.16	-0.23
Northern	3.52	-0.21	0.23	-2.10	-2.76	0.19
Nakhon Si Thammarat	1.95	0.46	1.30	-1.97	-4.24	0.20
Krabi	3.46	-3.57	-2.48	-1.31	14.23	-0.33
Phangnga	2.91	0.16	-0.78	-0.34	-4.38	0.24
Phuket	2.13	-2.67	-0.31	0.23	-1.56	-0.24
Surat Thani	1.66	-2.20	0.50	-1.29	-3.93	-0.52
Ranong	1.49	-0.55	-0.86	0.74	19.86	1.06
Chumphon	2.25	-1.21	0.68	-0.85	-1.61	0.12
Songkhla	2.22	0.52	1.16	-0.72	-2.65	0.62
Satun	1.19	-1.43	0.37	-1.90	-4.10	-0.63
Trang	3.11	-0.66	0.27	-1.44	-4.46	0.07
Phatthalung	1.93	0.81	1.20	-0.36	-1.44	0.78
Pattani	2.46	-2.14	-0.02	-3.51	-1.58	-0.86
Yala	4.43	-5.68	-0.19	-0.92	6.17	-0.34
Narathiwat	2.61	-2.22	0.23	0.84	-2.08	0.24
Southern	2.08	-0.28	0.88	-1.27	-2.59	0.20
Whole country	2.62	0.51	0.95	-2.23	-3.01	0.28

Table A.5

Full result of efficiency score of the main rice

Efficiency score of the main rice																						
Province	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bangkok Metropolis	1.000	0.998	0.812	0.888	0.967	1.000	1.000	1.000	1.000	0.834	0.955	1.000	1.000	1.000	0.842	0.968	0.997	0.845	0.987	0.990	1.000	1.000
Samut Prakan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Nonthaburi	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.777	0.940	0.959	0.904	0.997	0.965	0.935	0.939
Pathum Thani	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.994	0.990	1.000	1.000	0.897	0.912	0.981	0.992	0.880	1.000	0.981	1.000	1.000
Phra Nakhon Si Ayutthaya	0.694	0.892	0.823	0.805	0.799	0.763	0.763	0.794	0.834	0.807	0.839	0.875	1.000	0.885	0.653	0.863	0.906	0.833	0.921	0.911	0.946	0.966
Ang Thong	0.832	0.788	0.794	0.803	0.780	0.834	0.824	0.879	0.853	0.586	0.843	0.931	0.893	0.809	0.767	0.870	0.854	0.815	0.879	0.884	0.910	0.943
Lop Buri	0.829	0.794	0.814	0.513	0.700	0.712	0.782	0.797	0.756	0.704	0.753	0.759	0.833	0.708	0.550	0.767	0.756	0.672	0.811	0.808	0.819	0.800
Sing Buri	0.996	0.989	1.000	0.964	0.820	0.883	0.894	0.958	0.986	0.818	0.961	0.987	0.989	0.888	0.725	0.917	0.921	0.891	0.947	0.968	0.962	1.000
Chai Nat	0.969	0.930	0.853	0.809	0.907	0.943	0.890	0.996	0.950	0.874	0.977	0.927	0.908	0.795	0.834	0.879	0.896	0.878	0.953	0.945	0.916	0.915
Saraburi	0.800	0.869	0.766	0.658	0.768	0.680	0.715	0.727	0.710	0.695	0.729	0.730	0.751	0.754	0.734	0.863	0.863	0.905	0.911	0.940	0.882	0.893
Chon Buri	0.571	0.629	0.822	0.750	0.611	0.574	0.644	0.670	0.784	0.796	0.849	0.689	0.680	0.789	0.819	0.763	0.766	0.819	0.782	0.748	0.622	0.753
Rayong	0.554	0.661	0.691	0.655	0.578	0.637	0.582	0.582	0.586	0.609	0.639	0.606	0.622	0.660	0.672	0.634	0.595	0.697	0.687	0.690	0.712	0.729
Chanthaburi	0.624	0.681	0.604	0.558	0.573	0.567	0.570	0.545	0.531	0.498	0.509	0.571	0.549	0.552	0.675	0.663	0.650	0.702	0.719	0.662	0.665	0.666
Trat	0.780	0.682	0.586	0.679	0.741	0.739	0.729	0.678	0.675	0.666	0.718	0.672	0.686	0.719	0.795	0.736	0.734	0.752	0.802	0.738	0.912	0.891
Chachoengsao	0.849	0.859	0.762	0.721	0.819	0.792	0.818	0.708	0.740	0.739	0.788	0.749	0.780	0.757	0.843	0.836	0.866	0.829	0.897	0.894	0.858	0.903
Prachin Buri	0.541	0.732	0.661	0.502	0.544	0.581	0.606	0.583	0.610	0.576	0.567	0.578	0.675	0.625	0.663	0.510	0.516	0.637	0.749	0.715	0.681	0.697
Nakhon Nayok	0.925	1.000	0.884	0.676	0.908	0.693	0.713	0.696	0.696	0.655	0.706	0.720	0.758	0.779	0.769	0.830	0.827	0.820	0.959	0.798	0.903	0.861
Sa Kaeo	0.714	0.643	0.693	0.728	0.621	0.594	0.669	0.629	0.629	0.662	0.613	0.625	0.704	0.691	0.747	0.525	0.581	0.561	0.499	0.536	0.573	0.582
Ratchaburi	0.757	1.000	1.000	0.892	0.763	0.784	0.778	0.795	0.812	0.902	0.896	0.925	0.973	0.868	0.917	0.881	0.898	0.857	0.924	0.917	0.922	0.939
Kanchanaburi	0.653	0.518	0.513	0.508	0.602	0.666	0.685	0.603	0.677	0.703	0.763	0.767	0.775	0.814	0.855	0.821	0.834	0.753	0.825	0.868	0.851	0.845
Suphan Buri	0.879	0.964	0.849	0.854	0.803	0.923	0.897	0.913	0.904	0.888	0.918	0.972	0.933	0.845	0.960	0.912	0.928	0.937	0.968	0.994	0.965	0.997
Nakhon Pathom	1.000	1.000	0.976	1.000	0.851	0.860	0.897	0.878	0.896	0.816	0.879	0.911	0.960	0.928	0.813	0.996	1.000	0.958	1.000	0.999	0.986	1.000
Samut Sakhon	0.870	0.833	0.825	0.838	0.781	0.849	0.873	0.818	0.829	0.857	0.852	0.879	0.960	0.931	0.921	0.902	0.925	0.887	0.971	1.000	0.962	0.978

Table A.5

Full result of efficiency score of the main rice (Cont.)

Efficiency score of the main rice																						
Province	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Samut Songkhram	0.916	1.000	0.983	0.867	0.722	0.926	0.817	0.792	0.771	0.785	0.889	0.919	0.968	0.820	1.000	0.859	0.950	0.918	1.000	0.975	0.992	0.982
Phetchaburi	0.707	0.782	0.817	0.787	0.686	0.673	0.661	0.682	0.687	0.709	0.697	0.753	0.754	0.766	0.943	0.933	0.936	0.883	0.964	0.925	0.912	0.957
Prachuap Khiri Khan	0.785	0.699	0.641	0.619	0.652	0.587	0.599	0.604	0.609	0.608	0.607	0.673	0.691	0.765	0.775	0.772	0.781	0.775	0.768	0.762	0.759	0.865
Central	0.834	0.874	0.828	0.772	0.787	0.799	0.805	0.811	0.814	0.774	0.823	0.837	0.870	0.810	0.805	0.847	0.861	0.830	0.902	0.895	0.891	0.905
Nakhon Ratchasima	0.647	0.682	0.608	0.707	0.521	0.451	0.510	0.539	0.513	0.510	0.517	0.519	0.533	0.475	0.701	0.438	0.487	0.515	0.555	0.569	0.572	0.494
Buri Ram	0.684	0.711	0.851	0.984	0.617	0.649	0.592	0.602	0.652	0.627	0.634	0.555	0.551	0.665	0.632	0.485	0.516	0.560	0.652	0.627	0.585	0.385
Surin	0.777	0.509	0.586	0.656	0.522	0.574	0.587	0.549	0.614	0.596	0.610	0.590	0.591	0.629	0.579	0.500	0.571	0.598	0.647	0.613	0.606	0.501
Si Sa Ket	0.839	0.592	0.619	0.684	0.651	0.686	0.676	0.690	0.641	0.634	0.662	0.645	0.654	0.694	0.710	0.551	0.556	0.577	0.647	0.604	0.557	0.557
Ubon Ratchathani	0.930	0.767	0.984	0.935	1.000	0.909	0.918	0.986	0.887	0.870	0.875	0.873	0.931	0.843	0.821	0.728	0.695	0.660	0.776	0.748	0.712	0.712
Yasothon	0.659	0.704	0.746	0.746	0.807	0.733	0.697	0.592	0.640	0.630	0.688	0.649	0.662	0.756	0.763	0.609	0.656	0.725	0.748	0.720	0.666	0.734
Chaiyaphum	0.575	0.579	0.537	0.686	0.562	0.530	0.540	0.486	0.495	0.535	0.540	0.543	0.583	0.580	0.623	0.701	0.673	0.666	0.701	0.712	0.706	0.652
Amnat Charoen	0.940	0.936	1.000	0.689	0.927	0.970	0.947	0.869	0.835	0.753	0.812	0.823	0.744	0.842	0.831	0.667	0.808	0.815	0.807	0.796	0.801	0.834
Bueng Kan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.894	0.669	0.762	0.680	0.667	0.792	0.739	0.653
Nong Bua Lam Phu	0.963	0.804	0.803	0.818	0.788	0.813	0.881	0.672	0.737	0.712	0.749	0.742	0.746	0.868	0.943	0.657	0.756	0.779	0.781	0.793	0.871	0.811
Khon Kaen	0.632	0.693	0.723	0.936	0.808	0.696	0.584	0.626	0.667	0.625	0.617	0.613	0.644	0.639	0.610	0.488	0.495	0.520	0.545	0.615	0.572	0.541
Udon Thani	0.827	0.804	0.869	0.907	0.687	0.746	0.880	0.684	0.758	0.724	0.778	0.807	0.831	0.933	1.000	0.714	0.774	0.864	0.952	0.936	0.862	0.842
Loei	0.741	1.000	0.941	1.000	0.867	0.908	0.662	0.656	0.743	0.598	0.767	0.735	0.750	0.692	0.905	0.768	0.825	0.845	0.805	0.818	0.831	0.803
Nong Khai	0.911	0.831	0.813	0.804	0.753	0.742	0.728	0.715	0.780	0.812	0.852	0.747	0.681	0.791	0.744	0.737	0.748	0.754	0.791	0.813	0.739	0.686
Maha Sarakham	0.811	0.655	0.764	0.881	0.794	0.696	0.648	0.577	0.542	0.584	0.610	0.584	0.611	0.664	0.675	0.500	0.550	0.587	0.613	0.603	0.530	0.518
Roi Et	0.848	0.649	0.740	0.748	0.715	0.761	0.571	0.573	0.567	0.536	0.556	0.583	0.604	0.637	0.584	0.426	0.550	0.606	0.647	0.641	0.554	0.502
Kalasin	1.000	0.791	0.775	0.977	0.716	0.915	0.698	0.653	0.671	0.666	0.685	0.688	0.678	0.760	0.654	0.506	0.610	0.663	0.715	0.674	0.559	0.625
Sakon Nakhon	0.844	0.734	0.772	0.695	0.732	0.898	0.842	0.778	0.758	0.797	0.739	0.912	0.968	0.867	0.849	0.681	0.790	0.775	0.814	0.945	0.738	0.797
Nakhon Phanom	0.710	0.823	0.795	0.674	0.615	0.689	0.682	0.681	0.566	0.648	0.692	0.776	0.778	0.849	0.825	0.934	0.929	0.893	0.892	0.943	0.829	0.741

Table A.5

Full result of efficiency score of the main rice (Cont.)

Efficiency score of the main rice																						
Province	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mukdahan	0.719	1.000	0.693	0.638	0.775	1.000	0.802	0.680	0.621	0.598	0.670	0.797	0.751	0.706	0.850	0.581	0.801	0.868	0.861	0.908	0.852	0.875
Northeastern	0.781	0.704	0.751	0.799	0.703	0.704	0.672	0.649	0.653	0.643	0.662	0.661	0.673	0.700	0.716	0.574	0.618	0.641	0.692	0.692	0.642	0.608
Chiang Mai	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Lamphun	0.931	0.926	0.908	1.000	1.000	0.989	0.953	0.989	0.957	0.932	0.975	1.000	1.000	0.967	1.000	0.930	0.972	1.000	0.990	1.000	1.000	1.000
Lampang	0.947	0.964	0.909	0.871	0.945	0.897	0.839	0.850	0.852	0.869	0.900	0.933	0.916	0.899	0.988	0.913	0.946	0.905	0.901	0.924	0.947	0.936
Uttaradit	0.974	0.667	0.652	0.655	0.856	0.839	0.863	0.867	0.892	0.829	0.836	0.855	0.851	0.856	0.912	0.844	0.860	0.853	0.721	0.871	0.889	0.843
Phrae	1.000	1.000	1.000	1.000	0.918	1.000	0.885	0.925	1.000	0.947	1.000	1.000	1.000	0.973	1.000	1.000	0.965	0.832	0.861	0.876	0.858	0.897
Nan	0.945	0.911	0.858	0.883	0.775	0.872	0.790	0.839	0.951	0.858	0.975	0.936	0.890	0.940	0.910	0.965	0.938	0.949	0.982	0.981	0.971	0.955
Phayao	0.932	0.929	1.000	0.991	0.753	0.800	0.867	0.857	0.905	0.888	0.939	0.942	1.000	0.978	0.996	0.880	0.906	0.907	0.823	0.812	0.895	0.914
Chiang Rai	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mae Hong Son	1.000	1.000	0.778	1.000	1.000	1.000	1.000	1.000	0.888	0.963	0.982	1.000	1.000	0.958	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Nakhon Sawan	0.664	0.576	0.649	0.721	0.729	0.767	0.760	0.706	0.744	0.681	0.725	0.781	0.815	0.712	0.572	0.779	0.808	0.800	0.913	0.730	0.842	0.892
Uthai Thani	0.797	0.907	0.806	0.897	0.704	0.674	0.677	0.790	0.676	0.692	0.680	0.771	0.771	0.668	0.784	0.820	0.821	0.808	0.920	0.863	0.908	0.955
Kamphaeng Phet	0.658	0.757	0.746	0.681	0.770	0.739	0.788	0.684	0.665	0.689	0.685	0.720	0.719	0.749	0.797	0.834	0.867	0.831	0.883	0.871	0.880	0.911
Tak	0.855	0.688	0.748	0.882	0.962	0.868	0.803	0.744	0.768	0.758	0.832	0.785	0.791	0.963	0.884	0.841	0.850	0.880	0.883	0.883	0.959	0.965
Sukhothai	0.878	0.919	0.981	0.759	0.673	0.776	0.802	0.723	0.702	0.676	0.719	0.711	0.725	0.753	0.720	0.750	0.779	0.785	0.686	0.819	0.721	0.750
Phitsanulok	0.838	0.739	0.575	0.697	0.666	0.746	0.794	0.824	0.799	0.664	0.754	0.766	0.810	0.868	0.667	0.832	0.860	0.855	0.862	0.876	0.844	0.852
Phichit	0.889	0.861	0.524	0.729	0.882	0.806	0.801	0.831	0.784	0.697	0.753	0.834	0.860	0.890	0.724	0.829	0.855	0.839	0.977	0.939	0.913	1.000
Phetchabun	1.000	1.000	1.000	0.914	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.891	0.873	0.905	0.934	1.000	0.998	1.000	1.000
Northern	0.857	0.827	0.786	0.804	0.826	0.836	0.842	0.828	0.823	0.784	0.817	0.848	0.864	0.855	0.799	0.851	0.872	0.863	0.904	0.881	0.894	0.920
Nakhon Si Thammarat	0.606	0.590	0.549	0.564	0.495	0.551	0.560	0.493	0.491	0.516	0.555	0.544	0.590	0.558	0.604	0.646	0.646	0.652	0.771	0.616	0.737	0.717
Krabi	0.727	0.948	0.847	0.750	0.783	0.750	0.869	0.870	0.939	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.995	0.933	0.887	1.000	0.777	0.839
Phangnga	0.633	1.000	0.950	0.826	0.509	0.791	0.785	0.684	0.672	0.685	0.701	0.792	0.784	0.537	0.524	0.510	0.497	0.505	0.502	0.521	0.547	0.625

Table A.5

Full result of efficiency score of the main rice (Cont.)

Efficiency score of the main rice																						
Province	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Phuket	0.994	0.765	1.000	0.899	0.755	0.639	0.986	0.844	0.786	0.992	0.844	0.932	0.692	1.000	0.703	0.754	0.735	0.733	0.774	0.808	1.000	1.000
Surat Thani	0.718	0.624	0.654	0.523	0.614	0.957	0.704	0.618	0.640	0.666	0.717	0.691	0.683	0.448	0.568	0.542	0.582	0.594	0.674	0.616	0.600	0.572
Ranong	0.982	0.972	1.000	1.000	0.763	0.962	0.941	0.928	0.749	0.731	0.892	0.854	0.816	0.839	0.813	0.858	0.974	1.000	1.000	1.000	1.000	1.000
Chumphon	0.514	0.477	0.535	0.584	0.549	0.767	0.825	0.599	0.557	0.589	0.660	0.649	0.627	0.526	0.608	0.542	0.542	0.575	0.571	0.631	0.667	0.586
Songkhla	0.607	0.591	0.636	0.523	0.586	0.658	0.641	0.645	0.617	0.645	0.651	0.669	0.671	0.606	0.689	0.794	0.732	0.750	0.836	0.608	0.690	0.806
Satun	0.683	0.938	0.865	0.908	0.666	0.939	0.676	0.738	0.759	0.734	0.678	0.752	0.656	0.777	0.678	0.697	0.719	0.662	0.747	0.876	0.618	0.746
Trang	1.000	0.985	1.000	0.946	0.618	0.736	0.738	0.692	0.646	0.787	0.927	0.727	0.738	0.799	0.725	0.724	0.742	0.727	0.759	0.810	0.712	0.756
Phatthalung	0.771	0.723	0.795	0.607	0.601	0.692	0.659	0.698	0.641	0.699	0.712	0.713	0.680	0.556	0.627	0.600	0.668	0.613	0.665	0.588	0.603	0.667
Pattani	0.777	0.999	0.752	0.756	0.847	0.730	0.752	0.679	0.582	0.610	0.719	0.798	0.745	0.823	0.889	0.770	0.766	0.666	0.656	0.740	0.761	0.924
Yala	0.618	0.735	0.787	0.698	1.000	1.000	0.994	0.800	0.864	0.842	0.954	0.990	0.943	0.971	1.000	0.654	0.984	0.913	1.000	0.803	0.841	0.742
Narathiwat	0.802	0.879	0.719	0.510	0.791	0.778	0.962	1.000	0.924	0.888	0.960	0.896	0.891	1.000	1.000	0.955	1.000	0.825	1.000	0.977	0.738	0.841
Southern	0.680	0.687	0.677	0.607	0.601	0.675	0.661	0.636	0.607	0.638	0.671	0.672	0.676	0.639	0.703	0.708	0.708	0.691	0.775	0.655	0.697	0.758
Whole country	0.807	0.776	0.775	0.786	0.752	0.761	0.747	0.733	0.733	0.710	0.740	0.751	0.767	0.761	0.754	0.710	0.741	0.741	0.788	0.779	0.758	0.754

Table A.6

Full result of TFP change of the main rice

TFP change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bangkok Metropolis	-1.35	-17.99	11.29	20.86	5.84	5.14	-1.52	3.99	-17.90	13.00	4.13	0.24	2.61	-30.30	34.71	0.51	-6.21	-4.92	13.37	-3.43	5.38
Samut Prakan	5.57	3.73	5.36	16.34	-5.03	5.76	-6.57	3.95	2.74	-1.10	-8.02	-5.49	0.67	7.92	20.86	-9.58	7.02	-21.06	3.86	-2.69	-5.19
Nonthaburi	1.40	-3.72	4.08	16.97	-9.86	5.17	-3.53	1.34	-2.87	1.19	-0.80	2.22	-1.02	-31.02	38.38	1.24	-2.40	-0.91	0.64	-1.09	-0.96
Pathum Thani	2.98	16.83	-2.18	4.45	1.66	8.43	-8.66	3.51	-6.13	1.10	4.09	0.64	-11.20	-12.92	24.48	-0.20	-8.03	0.78	0.73	4.87	0.98
Phra Nakhon Si Ayutthaya	34.55	-2.07	-0.33	7.33	-0.45	4.65	2.37	8.36	-4.28	1.22	1.82	15.11	-13.02	-25.26	53.48	3.09	-1.45	-4.66	2.80	3.75	-0.01
Ang Thong	-3.26	0.58	0.58	16.88	-3.39	2.78	3.36	-1.07	-32.50	45.60	8.46	-1.69	-9.90	-8.16	20.11	-1.36	-1.89	-0.28	3.47	4.63	2.72
Lop Buri	-1.47	6.01	-33.46	49.29	2.61	11.67	1.15	-3.11	-5.73	5.19	-2.57	4.20	-15.16	-21.87	58.01	-3.09	-7.29	8.60	5.63	-3.21	-6.94
Sing Buri	1.12	4.70	-0.58	-2.15	-0.44	6.50	3.47	5.00	-18.81	16.73	0.79	-3.50	-10.12	-20.97	34.10	0.71	-0.81	-0.30	3.04	2.96	4.77
Chai Nat	-4.43	-4.40	-1.82	23.02	2.02	0.16	5.03	-0.59	-9.61	11.03	-4.99	-0.15	-12.25	-6.48	18.73	2.09	0.96	-2.24	1.10	1.71	-0.18
Saraburi	10.54	-9.84	-9.70	31.35	-16.67	12.09	-2.67	1.45	-4.42	4.01	-0.32	2.66	0.33	-11.31	33.94	-0.94	10.97	-10.54	6.88	-1.51	0.30
Chon Buri	24.40	13.38	0.02	-6.36	-5.45	14.31	2.02	0.35	6.10	1.66	-15.99	-6.98	18.29	4.06	4.80	-1.65	6.07	-13.91	-2.44	-20.06	15.81
Rayong	16.10	6.94	-3.17	0.99	4.21	-0.17	-3.49	1.27	0.58	3.53	-7.79	0.05	6.37	1.14	9.83	-7.84	16.15	-9.71	1.05	1.64	-1.13
Chanthaburi	12.11	-8.23	-4.20	16.60	-3.26	9.52	-8.27	-1.64	-8.91	-0.52	11.69	-5.49	4.63	19.92	11.27	-4.05	5.30	-7.56	-7.22	-3.31	-3.81
Trat	-10.75	-14.75	19.68	21.95	-2.92	7.30	-8.09	3.02	-2.11	6.66	-7.71	0.87	6.05	8.92	6.85	-1.67	-0.14	-4.79	-7.59	21.00	-5.44
Chachoengsao	-2.80	-5.15	-3.30	24.44	-0.88	9.65	-18.29	8.99	-1.30	2.72	-5.80	-1.40	-3.02	7.68	12.57	2.54	2.24	-6.11	3.94	-2.30	1.74
Prachin Buri	40.09	-7.71	-19.26	14.10	8.23	5.16	-4.19	6.71	-2.94	-3.93	-7.07	6.83	-7.03	6.83	-11.61	-1.32	24.90	9.25	-0.79	-9.46	-2.47
Nakhon Nayok	9.91	-8.85	-18.31	39.41	-22.33	8.11	-5.46	6.68	-7.25	3.89	-0.84	2.62	1.83	-3.24	24.60	-2.18	5.76	-4.83	-6.20	2.78	-6.34
Sa Kaeo	-7.33	9.51	8.01	-5.14	-3.26	13.03	-5.69	0.00	6.38	-8.33	-2.03	6.25	-2.48	6.58	-19.65	8.78	-1.51	-19.65	12.02	2.07	-3.38
Ratchaburi	35.15	0.59	-10.20	0.27	-6.38	6.35	-0.28	3.72	9.25	-0.43	0.35	1.38	-10.47	2.99	0.41	2.21	-1.97	1.04	1.02	0.45	2.50
Kanchanaburi	-17.37	-0.34	4.13	34.82	5.00	12.16	-15.38	16.40	2.15	7.25	-3.58	-1.92	6.13	6.29	4.13	1.53	-7.57	1.96	6.63	-0.69	-1.59
Suphan Buri	10.95	-12.25	0.28	12.17	6.85	2.14	-3.40	2.25	-4.91	4.54	3.84	-3.72	-10.56	6.13	1.26	2.07	3.77	-4.04	4.27	-2.26	2.76
Nakhon Pathom	3.27	-2.96	1.82	2.09	-5.91	8.14	-4.36	2.36	-10.28	9.30	2.76	4.91	-3.00	-17.79	36.54	0.87	-1.48	-3.60	-0.14	0.17	0.96
Samut Sakhon	0.84	-0.55	-0.22	8.40	1.96	6.85	-9.60	3.22	1.96	-0.90	0.58	3.53	-2.72	2.32	7.76	2.63	-1.54	1.95	16.05	-12.02	-2.68

Table A.6

Full result of TFP change of the main rice (Cont.)

TFP change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Samut Songkhram	14.26	-1.28	-8.79	-0.37	21.02	-6.41	-7.60	0.43	-0.64	13.31	1.67	2.39	-14.86	21.15	-11.07	11.02	-0.96	1.61	-0.13	-0.45	-4.20
Phetchaburi	13.59	4.20	-1.37	2.08	-9.27	3.54	0.90	2.20	1.83	-1.53	5.65	-0.59	1.75	23.29	2.84	0.58	-3.47	1.78	-1.45	-2.26	2.41
Prachuap Khiri Khan	0.25	-15.19	0.31	25.24	-15.18	9.48	-1.80	1.65	0.59	-2.21	5.86	-1.71	11.72	2.61	9.45	-0.76	-0.12	-6.22	1.71	-3.54	11.54
Central	0.06	-0.03	-0.05	0.15	-0.02	0.06	-0.03	0.03	-0.06	0.05	-0.01	0.02	-0.08	-0.07	0.15	0.01	0.00	-0.03	0.03	0.00	0.00
Nakhon Ratchasima	7.13	-10.41	18.49	-17.70	-16.11	16.96	5.35	-3.74	0.17	1.05	-2.32	-3.27	-10.50	47.26	-26.98	9.55	3.91	0.47	5.03	-4.04	-17.51
Buri Ram	5.97	22.44	16.07	-28.33	0.81	-1.69	-1.83	13.44	-4.87	-1.36	-14.43	-4.82	20.40	-5.84	-10.86	4.64	6.69	8.65	-0.65	-10.51	-36.98
Surin	-32.52	17.02	12.73	-10.11	5.45	7.94	-7.64	16.39	-4.23	-0.31	-4.77	-3.43	6.37	-7.14	-5.22	12.54	3.33	0.87	-1.48	-5.57	-20.48
Si Sa Ket	-29.36	6.29	11.73	6.73	2.07	6.91	1.28	-2.89	-1.81	2.21	-4.88	0.51	5.38	1.52	-8.60	-0.79	0.03	0.25	-6.31	-10.49	-4.12
Ubon Ratchathani	-17.30	29.35	-5.27	24.69	-14.95	9.30	10.83	-5.29	-2.48	-1.42	-3.96	7.19	-8.93	-3.16	7.68	-6.07	-11.63	6.26	-5.15	-7.46	-3.29
Yasothon	6.60	7.33	0.87	22.56	-12.85	3.41	-14.27	8.92	-3.16	7.43	-2.23	-6.13	13.23	2.42	-12.95	8.35	5.61	-2.36	-5.09	-10.90	5.59
Chaiyaphum	7.30	-6.87	30.60	-9.38	-7.65	10.34	-11.26	-0.08	8.44	-3.77	4.33	-0.58	-1.39	8.39	20.37	-3.57	-5.34	0.34	1.04	-5.02	-10.24
Amnat Charoen	-5.03	9.72	-31.47	52.95	-2.65	6.26	-7.39	0.40	-10.41	5.77	-1.77	-10.05	11.84	0.67	-14.16	21.70	-3.45	-5.74	-3.64	-2.44	-0.98
Bueng Kan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-16.35	12.60	-13.77	-6.50	13.69	-7.90	-14.29
Nong Bua Lam Phu	-7.67	-5.61	13.29	6.85	-0.96	16.68	-22.17	1.44	-4.65	0.88	-0.25	-8.03	15.31	12.53	-27.66	15.46	-1.31	-4.60	0.58	5.48	-9.06
Khon Kaen	11.31	5.01	30.28	-4.96	-17.79	-9.32	7.04	10.49	-6.91	-2.79	-0.76	-2.52	-2.02	-2.98	-12.45	1.99	0.56	-0.38	11.43	-10.37	-8.99
Udon Thani	-2.27	5.95	6.02	-15.79	5.91	28.42	-20.89	6.05	-6.11	2.81	6.82	-2.79	11.39	12.00	-24.98	8.51	7.24	5.06	-4.20	-9.73	-5.91
Loei	48.64	-16.92	15.95	-5.69	-6.97	-12.27	-11.55	-4.89	-10.34	5.48	0.90	0.02	3.43	11.89	-10.30	3.67	1.35	-7.46	3.74	-2.89	-0.26
Nong Khai	-3.60	-11.95	7.47	4.85	-1.50	2.52	-4.14	-6.34	7.94	-4.14	-8.01	-11.84	15.03	-6.48	10.20	0.20	-2.93	-0.07	0.18	-11.16	-11.18
Maha Sarakham	-23.43	17.84	14.23	1.02	-15.49	1.22	-10.66	-2.46	6.96	2.54	-6.05	-0.29	7.14	1.54	-12.09	7.65	3.26	-3.42	-0.25	-16.01	-6.46
Roi Et	-23.77	15.91	1.81	8.18	2.43	-19.44	-1.05	3.83	-5.66	1.25	2.06	-2.24	6.26	-8.42	-15.36	27.27	8.42	-0.90	1.07	-17.25	-13.12
Kalasin	-27.44	-2.40	27.19	-19.62	21.78	-17.83	-4.30	7.20	-1.15	1.21	-3.35	-0.87	8.33	-12.70	-8.94	20.57	3.05	2.20	-9.23	-18.50	7.12
Sakon Nakhon	-18.27	2.59	-8.82	18.12	15.96	0.78	-4.14	2.54	3.46	-10.29	12.91	6.52	-8.03	-2.45	-10.12	14.59	-5.44	-1.10	11.54	-23.88	3.19
Nakhon Phanom	15.01	-6.94	-11.76	0.83	6.86	6.80	-0.93	-13.49	15.23	-2.29	11.09	-2.03	12.42	-1.41	20.80	-1.81	-7.33	-4.95	3.79	-15.49	-13.03

Table A.6

Full result of TFP change of the main rice (Cont.)

TFP change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mukdahan	27.15	-29.34	-2.32	33.49	24.23	-13.30	-14.89	-7.17	-3.60	3.86	22.12	-6.95	-0.92	15.76	-26.56	33.68	7.32	-6.92	-0.48	-3.29	0.07
Northeastern	-0.11	0.06	0.08	-0.02	-0.03	0.02	-0.04	0.03	-0.02	0.00	-0.02	-0.02	0.04	0.01	-0.10	0.07	0.00	0.01	0.00	-0.11	-0.11
Chiang Mai	-12.59	12.07	-1.23	10.59	-7.86	16.28	-8.21	-5.66	5.12	-11.98	-3.19	0.48	3.19	-3.08	4.65	-0.47	-1.06	-1.41	-3.70	1.57	-5.38
Lamphun	-11.06	2.82	14.02	7.50	-1.15	1.28	-4.19	3.72	-6.05	1.18	-0.46	3.85	-5.57	-2.99	-1.43	3.09	5.12	-6.40	0.86	-1.52	1.33
Lampang	-8.01	1.63	0.03	19.01	-5.16	1.08	-2.50	1.71	-1.67	0.21	0.27	-1.27	1.98	2.58	-5.13	2.55	-2.50	-2.53	2.94	-0.47	1.69
Uttaradit	-27.08	-2.47	3.83	51.63	-8.64	9.53	-1.86	3.92	-8.03	0.24	0.04	-2.14	0.80	9.73	0.41	1.40	1.10	-20.44	25.95	-3.72	-8.43
Phrae	-1.78	1.89	0.39	1.70	4.19	-0.72	1.23	-3.14	-0.80	-7.06	-0.27	3.22	-2.76	0.00	0.25	-3.88	-13.60	0.40	1.38	-1.91	3.38
Nan	-5.96	-3.97	2.55	-0.92	6.53	1.71	0.24	-2.67	-5.22	-1.06	-1.87	-3.03	5.17	-12.26	10.85	-4.66	2.52	0.91	1.13	-3.01	0.43
Phayao	0.49	5.06	3.25	-15.52	1.85	18.11	-3.10	3.69	-1.05	-0.97	3.88	3.21	-2.04	0.19	-2.79	2.50	-1.76	-12.81	-3.95	7.49	-1.68
Chiang Rai	5.63	-7.85	7.47	8.71	-3.03	7.50	2.14	-3.47	-1.44	-2.67	-2.12	-3.58	1.59	-2.82	16.24	-0.74	-6.19	-7.29	-3.51	-3.59	-2.16
Mae Hong Son	-19.77	-29.88	26.86	30.85	-15.67	23.22	-27.26	-25.42	15.84	-14.67	13.10	0.09	8.61	-11.80	9.08	-2.29	-4.09	-4.58	3.98	-5.43	4.67
Nakhon Sawan	-8.41	17.96	20.72	6.35	5.36	2.60	-7.42	9.69	-7.05	3.60	-2.28	-5.30	-12.27	-21.30	58.82	1.43	5.30	-5.02	-10.36	4.98	4.72
Uthai Thani	35.37	-19.08	14.14	-11.18	-7.89	5.54	14.55	-11.19	4.39	-3.34	6.70	-8.46	-13.25	18.80	15.40	0.42	0.74	4.72	-0.50	-0.98	0.30
Kamphaeng Phet	20.60	-1.06	-6.02	32.82	-4.39	8.26	-13.47	-0.85	4.20	0.12	-0.82	-5.70	4.23	8.51	19.67	1.26	-1.63	-3.22	4.40	-4.07	-2.30
Tak	-15.18	10.20	20.63	21.19	-13.65	1.77	-10.26	-3.29	3.63	-2.86	-2.80	-3.39	26.27	-13.43	1.82	1.29	-1.02	-4.88	1.63	2.82	0.86
Sukhothai	22.94	-4.79	-18.83	5.15	11.90	4.18	-12.43	-4.49	-0.86	2.73	-6.26	-3.53	4.81	-0.31	16.19	2.66	1.74	-18.71	25.43	-16.80	-0.07
Phitsanulok	-5.55	-21.63	27.77	11.45	2.15	7.69	1.11	-3.20	-14.54	10.02	-5.72	-0.68	8.91	-19.49	35.94	0.89	0.42	-7.04	7.50	-8.89	-3.53
Phichit	2.94	-37.60	47.50	24.26	-7.64	2.11	2.52	-1.05	-8.63	5.42	0.62	-6.40	5.82	-15.04	34.13	0.56	3.30	-0.91	5.26	-10.06	8.27
Phetchabun	21.70	-14.74	-5.77	27.96	11.27	-10.14	0.58	-11.43	0.46	2.31	9.35	-16.72	0.43	-13.87	7.31	2.23	1.09	1.12	1.86	-2.60	-5.16
Northern	0.01	-0.09	0.08	0.13	0.00	0.04	-0.03	-0.01	-0.04	0.01	0.00	-0.05	0.00	-0.08	0.20	0.01	0.00	-0.06	0.02	-0.04	0.00
Nakhon Si Thammarat	-3.05	-7.17	4.85	3.04	2.99	10.93	-15.76	0.29	3.04	6.72	-5.65	4.74	-3.54	7.62	20.94	-0.54	1.11	9.48	-17.61	13.97	-6.89
Krabi	16.54	3.31	-10.94	14.05	0.02	-1.10	9.23	-5.06	5.92	2.34	-4.50	-1.68	5.05	-4.98	-5.90	-7.58	-2.02	-5.38	10.86	-23.45	23.41
Phangnga	45.99	12.16	-13.97	-32.71	52.22	5.85	-14.89	-1.31	0.17	0.25	6.19	1.82	-31.05	-7.86	1.94	-3.11	1.69	-2.67	2.85	6.88	9.31

Table A.6

Full result of TFP change of the main rice (Cont.)

TFP change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Phuket	-33.23	51.25	-12.37	-7.56	-12.71	32.39	-3.04	-17.11	25.52	-13.60	3.60	-24.32	93.49	-46.98	9.41	-2.98	-0.79	1.96	3.78	31.69	-1.56
Surat Thani	-18.52	8.73	-17.28	33.36	47.99	-21.08	-16.65	-4.75	7.31	-0.25	-5.72	-2.14	-34.26	29.04	-0.94	6.35	2.74	9.00	-7.00	-6.46	-8.33
Ranong	-5.65	17.37	7.89	-25.43	18.41	8.04	-5.30	-22.91	4.19	9.78	-7.53	2.48	8.10	-11.64	1.83	5.85	10.83	1.13	12.49	-9.41	19.86
Chumphon	-10.24	16.09	12.49	2.63	38.64	9.60	-31.68	-2.83	1.27	9.90	-5.09	-4.24	-14.15	14.87	-5.24	-0.63	5.02	-3.73	10.44	6.30	-13.60
Songkhla	-3.43	8.38	-15.66	30.57	5.04	5.16	-3.35	-1.71	1.35	0.18	1.04	-0.73	-8.98	15.66	22.38	-8.19	3.92	6.52	-24.81	9.63	13.81
Satun	24.84	-2.10	7.61	-20.59	39.60	-28.18	1.49	8.06	-5.28	-9.95	4.22	-11.40	21.42	-16.62	12.04	2.20	-9.57	5.17	9.51	-24.39	15.89
Trang	-12.19	22.40	-8.16	-28.20	21.06	-0.13	-9.92	-4.96	20.23	18.47	-25.36	7.76	5.75	-13.67	7.81	1.79	-1.77	-0.60	-1.20	-6.89	1.52
Phatthalung	-6.00	9.93	-22.89	12.03	10.67	4.06	0.86	-5.48	6.65	1.22	-1.19	-4.10	-16.83	12.45	0.92	10.83	-7.63	4.82	-10.16	2.31	9.14
Pattani	13.81	-16.33	3.98	21.70	-11.93	-4.33	-11.59	-10.29	2.98	13.02	3.55	-5.55	13.30	5.58	-8.54	-1.25	-15.23	-6.84	6.90	-0.81	19.49
Yala	4.09	21.77	-10.83	66.07	7.14	-26.88	-13.04	1.94	-3.55	13.89	1.68	-6.45	5.36	2.14	-33.70	50.16	-9.02	9.89	-27.19	12.39	-6.25
Narathiwat	-3.21	-7.66	-26.65	72.02	-2.14	15.31	13.50	-16.86	-4.89	6.63	-9.31	4.13	16.75	2.09	-10.63	5.77	-17.64	28.67	-9.91	-20.17	11.58
Southern	-0.03	0.02	-0.09	0.13	0.07	0.02	-0.08	-0.03	0.03	0.04	-0.03	-0.01	-0.04	0.08	0.08	0.00	-0.02	0.07	-0.16	0.05	0.06
Whole country	-0.04	0.00	0.04	0.06	-0.02	0.04	-0.04	0.01	-0.03	0.01	-0.01	-0.02	0.00	-0.03	0.02	0.04	0.00	-0.02	0.01	-0.07	-0.05

Table A.7

Full result of technical efficiency change of the main rice

Technical efficiency change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bangkok Metropolis	-0.18	-18.64	9.30	8.94	3.41	0.00	0.00	0.00	-16.58	14.45	4.74	0.00	0.00	-15.75	14.87	3.07	-15.30	16.88	0.30	0.96	0.00
Samut Prakan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nonthaburi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-22.33	21.07	1.96	-5.74	10.31	-3.22	-3.08	0.39
Pathum Thani	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.58	-0.42	1.00	0.00	-10.31	1.69	7.62	1.09	-11.26	13.57	-1.92	1.96	0.00
Phra Nakhon Si Ayutthaya	28.46	-7.77	-2.12	-0.80	-4.49	0.01	4.13	4.94	-3.20	3.95	4.25	14.35	-11.54	-26.18	32.10	5.06	-8.09	10.60	-1.15	3.91	2.07
Ang Thong	-5.28	0.79	1.07	-2.85	6.97	-1.19	6.68	-2.99	-31.34	43.95	10.36	-4.04	-9.36	-5.24	13.45	-1.81	-4.65	7.87	0.55	2.95	3.66
Lop Buri	-4.22	2.49	-36.99	36.63	1.72	9.77	1.91	-5.16	-6.88	6.98	0.74	9.80	-15.03	-22.26	39.39	-1.42	-11.06	20.59	-0.38	1.45	-2.32
Sing Buri	-0.69	1.14	-3.58	-14.94	7.60	1.28	7.23	2.86	-17.05	17.50	2.73	0.18	-10.16	-18.37	26.48	0.42	-3.22	6.23	2.26	-0.66	3.98
Chai Nat	-4.05	-8.28	-5.11	12.06	3.99	-5.68	12.00	-4.62	-8.05	11.83	-5.16	-2.07	-12.37	4.92	5.36	1.89	-2.01	8.56	-0.82	-3.02	-0.16
Saraburi	8.69	-11.89	-14.07	16.69	-11.40	5.13	1.58	-2.33	-2.01	4.87	0.08	2.93	0.35	-2.70	17.57	0.04	4.84	0.67	3.27	-6.23	1.21
Chon Buri	10.18	30.65	-8.80	-18.53	-6.08	12.27	4.05	16.94	1.60	6.67	-18.84	-1.42	16.14	3.72	-6.76	0.38	6.84	-4.43	-4.43	-16.86	21.14
Rayong	19.35	4.54	-5.16	-11.78	10.13	-8.51	-0.02	0.65	3.98	4.84	-5.18	2.71	6.04	1.84	-5.60	-6.13	16.98	-1.42	0.50	3.16	2.36
Chanthaburi	9.19	-11.36	-7.57	2.72	-1.10	0.51	-4.30	-2.57	-6.36	2.38	12.07	-3.77	0.38	22.38	-1.73	-2.06	8.00	2.51	-7.90	0.35	0.18
Trat	-12.60	-14.01	15.79	9.08	-0.22	-1.32	-7.06	-0.43	-1.31	7.84	-6.38	1.95	4.89	10.53	-7.40	-0.26	2.39	6.67	-7.88	23.49	-2.27
Chachoengsao	1.22	-11.31	-5.37	13.48	-3.29	3.29	-13.44	4.57	-0.19	6.70	-5.01	4.14	-2.89	11.33	-0.83	3.66	-4.33	8.24	-0.33	-4.10	5.29
Prachin Buri	35.20	-9.70	-24.04	8.39	6.83	4.28	-3.87	4.68	-5.54	-1.68	1.98	16.86	-7.41	6.02	-23.11	1.29	23.46	17.60	-4.56	-4.82	2.38
Nakhon Nayok	8.11	-11.57	-23.53	34.35	-23.76	2.98	-2.45	0.02	-5.96	7.86	2.00	5.26	2.76	-1.21	7.85	-0.37	-0.81	17.00	-16.82	13.20	-4.66
Sa Kaeo	-10.06	7.83	5.07	-14.69	-4.42	12.68	-5.94	0.02	5.22	-7.43	2.03	12.64	-1.97	8.13	-29.63	10.58	-3.38	-11.14	7.50	6.77	1.56
Ratchaburi	32.03	0.00	-10.78	-14.42	2.71	-0.81	2.18	2.12	11.20	-0.76	3.33	5.19	-10.83	5.59	-3.88	1.90	-4.52	7.78	-0.71	0.54	1.82
Kanchanaburi	-20.62	-1.02	-0.92	18.43	10.71	2.70	-11.89	12.26	3.85	8.58	0.44	1.03	5.06	5.08	-4.01	1.52	-9.62	9.58	5.16	-1.93	-0.70
Suphan Buri	9.68	-11.99	0.64	-6.01	15.02	-2.82	1.73	-0.95	-1.78	3.42	5.89	-4.02	-9.47	13.57	-4.95	1.72	0.94	3.35	2.67	-2.94	3.39
Nakhon Pathom	0.00	-2.36	2.41	-14.92	1.03	4.39	-2.18	2.07	-8.92	7.73	3.65	5.33	-3.32	-12.36	22.51	0.40	-4.15	4.33	-0.11	-1.34	1.47
Samut Sakhon	-4.29	-0.97	1.64	-6.78	8.66	2.81	-6.31	1.38	3.37	-0.55	3.09	9.30	-3.06	-1.11	-1.99	2.51	-4.15	9.57	2.95	-3.77	1.65

Table A.7

Full result of technical efficiency change of the main rice (Cont.)

Technical efficiency change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Prachuap Khiri Khan	-10.86	-8.32	-3.50	5.39	-9.92	1.96	0.88	0.82	-0.11	-0.26	10.91	2.71	10.64	1.35	-0.39	1.10	-0.72	-0.94	-0.73	-0.39	13.89
Samut Songkhram	9.13	-1.68	-11.80	-16.72	28.18	-11.79	-3.04	-2.62	1.77	13.29	3.43	5.29	-15.32	21.99	-14.11	10.62	-3.40	8.96	-2.46	1.74	-1.08
Phetchaburi	10.62	4.57	-3.72	-12.80	-1.89	-1.82	3.26	0.68	3.23	-1.73	7.98	0.19	1.62	23.00	-0.98	0.29	-5.69	9.21	-4.03	-1.41	4.92
Central	0.04	-0.05	-0.07	0.02	0.01	0.01	0.00	0.00	-0.05	0.06	0.02	0.03	-0.07	-0.03	0.04	0.02	-0.04	0.08	0.00	-0.01	0.02
Nakhon Ratchasima	5.42	-10.89	16.23	-26.29	-13.47	13.18	5.58	-4.68	-0.63	1.31	0.36	2.73	-10.93	47.70	-37.57	11.32	5.74	7.79	2.40	0.59	-13.62
Buri Ram	3.93	19.77	15.61	-37.29	5.12	-8.78	1.67	8.38	-3.79	1.11	-12.46	-0.71	20.65	-5.00	-23.21	6.38	8.40	16.59	-3.85	-6.70	-34.29
Surin	-34.47	15.08	12.02	-20.53	10.10	2.17	-6.47	11.95	-3.04	2.37	-3.24	0.18	6.39	-7.93	-13.68	14.22	4.71	8.27	-5.32	-1.16	-17.26
Si Sa Ket	-29.43	4.65	10.47	-4.85	5.28	-1.38	2.06	-7.08	-1.11	4.35	-2.56	1.51	6.12	2.29	-22.46	0.89	3.82	12.15	-6.65	-7.84	0.06
Ubon Ratchathani	-17.52	28.24	-5.00	7.00	-9.10	1.00	7.41	-10.00	-1.95	0.55	-0.21	6.61	-9.45	-2.60	-11.36	-4.45	-5.14	17.70	-3.63	-4.80	0.04
Yasothon	6.74	5.95	-0.02	8.17	-9.06	-4.98	-15.03	8.14	-1.68	9.23	-5.57	1.88	14.24	0.98	-20.19	7.74	10.45	3.16	-3.77	-7.51	10.22
Chaiyaphum	0.75	-7.26	27.78	-18.06	-5.71	1.90	-10.05	1.86	8.13	0.85	0.67	7.30	-0.54	7.43	12.62	-3.98	-1.15	5.31	1.50	-0.77	-7.65
Amnat Charoen	-0.43	6.84	-31.12	34.57	4.61	-2.31	-8.29	-3.83	-9.83	7.84	1.32	-9.58	13.18	-1.33	-19.69	21.10	0.77	-0.97	-1.31	0.60	4.09
Buang Kan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-25.17	13.98	-10.79	-1.92	18.73	-6.74	-11.65
Nong Bua Lam Phu	-16.49	-0.13	1.78	-3.62	3.09	8.46	-23.79	9.73	-3.43	5.19	-0.92	0.56	16.32	8.65	-30.32	15.07	3.11	0.29	1.53	9.77	-6.93
Khon Kaen	9.75	4.37	29.40	-13.71	-13.88	-16.02	7.11	6.52	-6.23	-1.31	-0.56	5.00	-0.81	-4.45	-20.03	1.35	5.18	4.78	12.88	-7.08	-5.35
Udon Thani	-2.85	8.08	4.47	-24.26	8.59	17.93	-22.32	10.89	-4.55	7.45	3.78	3.01	12.20	7.22	-28.58	8.41	11.52	10.29	-1.69	-7.98	-2.25
Loei	34.94	-5.91	6.28	-13.31	4.75	-27.05	-0.95	13.25	-19.51	28.18	-4.13	2.01	-7.67	30.73	-15.09	7.39	2.41	-4.79	1.67	1.52	-3.37
Nong Khai	-8.77	-2.17	-1.10	-6.25	-1.51	-1.95	-1.66	8.98	4.15	4.87	-12.29	-8.85	16.25	-5.98	-0.99	1.50	0.83	4.92	2.81	-9.20	-7.06
Maha Sarakham	-19.28	16.64	15.39	-9.90	-12.36	-6.85	-10.91	-6.06	7.60	4.45	-4.13	4.62	8.59	1.70	-25.90	9.89	6.81	4.31	-1.60	-12.15	-2.23
Roi Et	-23.50	14.00	1.05	-4.37	6.47	-25.06	0.50	-1.08	-5.57	3.81	4.78	3.62	5.52	-8.28	-27.12	29.18	10.19	6.71	-0.95	-13.43	-9.42
Kalasin	-20.90	-1.99	26.02	-26.67	27.68	-23.70	-6.44	2.69	-0.67	2.92	0.33	-1.42	12.07	-13.87	-22.74	20.69	8.68	7.86	-5.76	-17.09	11.87
Sakon Nakhon	-13.09	5.23	-10.06	5.31	22.82	-6.31	-7.52	-2.67	5.16	-7.31	23.45	6.13	-10.38	-2.09	-19.77	15.98	-1.95	5.10	16.08	-21.94	8.02
Nakhon Phanom	15.87	-3.41	-15.23	-8.79	12.10	-1.01	-0.18	-16.92	14.52	6.82	12.14	0.25	9.20	-2.92	13.27	-0.49	-3.94	-0.10	5.72	-12.10	-10.58

Table A.7

Full result of technical efficiency change of the main rice (Cont.)

Technical efficiency change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mukdahan	39.08	-30.66	-7.99	21.50	28.96	-19.75	-15.24	-8.65	-3.70	11.97	18.91	-5.69	-6.01	20.40	-31.70	38.00	8.37	-0.82	5.47	-6.25	2.71
Northeastern	-0.12	0.07	0.07	-0.13	0.01	-0.05	-0.04	0.00	-0.01	0.03	0.00	0.02	0.04	0.01	-0.21	0.08	0.04	0.08	0.00	-0.07	-0.07
Chiang Mai	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lamphun	-0.56	-1.85	10.08	0.00	-1.09	-3.66	3.76	-3.21	-2.64	4.62	2.59	0.00	-3.33	3.44	-6.96	4.50	2.86	-1.04	1.05	0.00	0.00
Lampang	1.76	-5.64	-4.20	8.43	-4.98	-6.46	1.27	0.26	1.99	3.59	3.58	-1.75	-1.87	9.89	-7.59	3.59	-4.30	-0.42	2.51	2.46	-1.11
Uttaradit	-31.59	-2.23	0.47	30.78	-2.06	2.84	0.55	2.84	-7.03	0.76	2.36	-0.49	0.63	6.49	-7.43	1.82	-0.75	-15.53	20.81	2.09	-5.20
Phrae	0.00	0.00	0.00	-8.15	8.88	-11.53	4.52	8.15	-5.27	5.56	0.00	0.00	-2.74	2.82	-0.05	-3.48	-13.79	3.49	1.72	-2.01	4.57
Nan	-3.63	-5.84	2.99	-12.26	12.46	-9.39	6.25	13.38	-9.80	13.59	-3.97	-4.93	5.66	-3.20	6.05	-2.82	1.18	3.50	-0.09	-1.01	-1.71
Phayao	-0.33	7.60	-0.85	-24.05	6.22	8.39	-1.13	5.57	-1.85	5.69	0.32	6.19	-2.21	1.82	-11.66	3.04	0.03	-9.19	-1.37	10.24	2.14
Chiang Rai	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mae Hong Son	0.00	-22.24	28.61	0.00	0.00	0.00	-0.02	-11.23	8.49	1.94	1.88	0.00	-4.24	4.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nakhon Sawan	-13.36	12.69	11.19	1.03	5.24	-0.95	-7.00	5.33	-8.42	6.46	7.64	4.36	-12.59	-19.65	36.21	3.65	-0.99	14.08	-20.00	15.33	5.89
Uthai Thani	13.73	-11.06	11.21	-21.44	-4.35	0.50	16.65	-14.44	2.32	-1.64	13.32	0.07	-13.36	17.26	4.59	0.17	-1.61	13.85	-6.12	5.10	5.28
Kamphaeng Phet	15.11	-1.48	-8.75	13.15	-4.04	6.55	-13.15	-2.83	3.62	-0.63	5.12	-0.04	4.06	6.53	4.65	3.91	-4.21	6.34	-1.33	1.01	3.54
Tak	-19.55	8.74	17.88	9.12	-9.77	-7.50	-7.38	3.22	-1.26	9.69	-5.62	0.73	21.84	-8.26	-4.86	1.13	3.50	0.34	-0.06	8.70	0.61
Sukhothai	4.75	6.70	-22.68	-11.32	15.31	3.42	-9.91	-2.86	-3.77	6.50	-1.12	1.88	3.91	-4.43	4.16	3.93	0.75	-12.59	19.33	-11.96	3.97
Phitsanulok	-11.72	-22.29	21.34	-4.50	12.01	6.49	3.70	-2.96	-16.94	13.53	1.59	5.82	7.07	-23.11	24.68	3.40	-0.55	0.81	1.54	-3.58	0.89
Phichit	-3.15	-39.16	39.07	21.07	-8.59	-0.67	3.72	-5.66	-11.10	8.08	10.83	3.04	3.55	-18.69	14.53	3.08	-1.88	16.52	-3.92	-2.74	9.52
Phetchabun	0.00	0.00	-8.62	9.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-10.95	-1.95	3.59	3.30	7.01	-0.24	0.25	0.00
Northern	-0.04	-0.07	0.03	0.01	0.01	0.01	-0.02	0.00	-0.05	0.04	0.04	0.02	-0.01	-0.08	0.07	0.03	-0.01	0.04	-0.03	0.01	0.03
Nakhon Si Thammarat	-2.62	-6.97	2.64	-12.17	11.35	1.62	-11.89	-0.49	5.17	7.49	-1.92	8.44	-5.49	8.35	6.83	0.07	0.92	18.22	-20.07	19.66	-2.77
Krabi	30.41	-10.68	-11.46	4.41	-4.17	15.89	0.06	7.96	6.50	0.00	0.00	0.00	0.00	0.00	0.00	-0.50	-6.20	-4.98	12.76	-22.33	8.04
Phangnga	58.04	-5.01	-13.03	-38.38	55.35	-0.76	-12.80	-1.74	1.83	2.31	13.01	-0.92	-31.57	-2.42	-2.58	-2.51	1.46	-0.63	3.89	5.00	14.33

Table A.7

Full result of technical efficiency change of the main rice (Cont.)

Technical efficiency change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Phuket	-22.99	30.65	-10.09	-16.04	-15.37	54.30	-14.42	-6.86	26.26	-14.92	10.38	-25.68	44.45	-29.66	7.24	-2.59	-0.20	5.60	4.28	23.84	0.00
Surat Thani	-13.06	4.73	-19.97	17.40	55.70	-26.36	-12.24	3.45	4.10	7.71	-3.65	-1.21	-34.39	26.89	-4.55	7.34	2.08	13.48	-8.65	-2.68	-4.57
Ranong	-1.05	2.92	0.00	-23.74	26.13	-2.17	-1.37	-19.35	-2.31	21.98	-4.30	-4.45	2.84	-3.06	5.53	13.45	2.71	0.00	0.00	0.00	0.00
Chumphon	-7.19	12.28	9.15	-6.00	39.58	7.59	-27.34	-7.01	5.66	12.06	-1.72	-3.36	-16.14	15.72	-10.94	0.02	6.12	-0.63	10.41	5.72	-12.18
Songkhla	-2.56	7.65	-17.77	11.90	12.43	-2.61	0.56	-4.38	4.60	0.92	2.74	0.37	-9.76	13.84	15.16	-7.80	2.39	11.47	-27.23	13.45	16.91
Satun	37.30	-7.79	4.93	-26.59	40.91	-27.96	9.17	2.77	-3.26	-7.68	10.91	-12.69	18.39	-12.78	2.87	3.16	-8.00	12.89	17.33	-29.53	20.85
Trang	-1.54	1.56	-5.43	-34.61	19.07	0.30	-6.32	-6.63	21.88	17.74	-21.55	1.44	8.38	-9.26	-0.22	2.47	-1.95	4.30	6.76	-12.13	6.26
Phatthalung	-6.22	9.87	-23.63	-0.97	15.20	-4.76	5.93	-8.29	9.10	1.88	0.10	-4.52	-18.30	12.86	-4.37	11.31	-8.14	8.39	-11.63	2.57	10.74
Pattani	28.54	-24.71	0.58	12.00	-13.80	2.99	-9.72	-14.31	4.82	17.84	11.05	-6.66	10.52	7.97	-13.39	-0.53	-13.08	-1.40	12.80	2.82	21.41
Yala	18.92	7.08	-11.21	43.17	0.00	-0.58	-19.51	7.91	-2.53	13.30	3.82	-4.78	3.00	2.99	-34.64	50.56	-7.19	9.50	-19.71	4.71	-11.69
Narathiwat	9.57	-18.21	-29.11	55.17	-1.60	23.60	3.98	-7.65	-3.90	8.20	-6.69	-0.51	12.18	0.00	-4.51	4.73	-17.45	21.14	-2.31	-24.42	13.95
Southern	0.01	-0.02	-0.11	-0.01	0.12	-0.02	-0.05	-0.04	0.05	0.06	0.00	0.00	-0.06	0.08	0.01	0.00	-0.03	0.12	-0.16	0.07	0.09
Whole country	-0.06	-0.01	0.01	-0.06	0.01	-0.02	-0.02	0.00	-0.03	0.04	0.01	0.02	-0.01	-0.02	-0.09	0.05	0.01	0.07	-0.01	-0.03	-0.02

Table A.8

Full result of technical change of the main rice

Technical change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bangkok Metropolis	-1.17	0.80	1.82	10.94	2.35	5.14	-1.52	3.99	-1.57	-1.27	-0.58	0.24	2.61	-17.27	17.27	-2.48	10.74	-18.66	13.03	-4.35	5.38
Samut Prakan	5.57	3.73	5.36	16.34	-5.03	5.76	-6.57	3.95	2.74	-1.10	-8.02	-5.49	0.67	7.92	20.86	-9.58	7.02	-21.06	3.86	-2.69	-5.19
Nonthaburi	1.40	-3.72	4.08	16.97	-9.86	5.17	-3.53	1.34	-2.87	1.19	-0.80	2.22	-1.02	-11.19	14.30	-0.71	3.53	-10.16	3.98	2.05	-1.34
Pathum Thani	2.98	16.83	-2.18	4.45	1.66	8.43	-8.66	3.51	-5.59	1.53	3.05	0.64	-0.99	-14.36	15.67	-1.28	3.64	-11.26	2.70	2.86	0.98
Phra Nakhon Si Ayutthaya	4.74	6.17	1.83	8.20	4.24	4.64	-1.68	3.25	-1.12	-2.62	-2.33	0.67	-1.67	1.24	16.18	-1.88	7.22	-13.80	4.00	-0.15	-2.03
Ang Thong	2.13	-0.20	-0.49	20.31	-9.69	4.02	-3.11	1.98	-1.69	1.14	-1.73	2.45	-0.59	-3.08	5.87	0.45	2.90	-7.56	2.91	1.63	-0.91
Lop Buri	2.87	3.44	5.60	9.27	0.88	1.73	-0.75	2.16	1.24	-1.68	-3.30	-5.10	-0.15	0.50	13.36	-1.70	4.25	-9.94	6.03	-4.58	-4.73
Sing Buri	1.82	3.52	3.11	15.04	-7.48	5.15	-3.51	2.08	-2.12	-0.65	-1.89	-3.67	0.05	-3.18	6.03	0.29	2.49	-6.15	0.76	3.64	0.76
Chai Nat	-0.40	4.23	3.47	9.78	-1.89	6.19	-6.22	4.22	-1.70	-0.71	0.18	1.96	0.13	-10.87	12.69	0.20	3.03	-9.95	1.94	4.88	-0.02
Saraburi	1.70	2.34	5.08	12.57	-5.95	6.63	-4.18	3.86	-2.47	-0.83	-0.40	-0.26	-0.02	-8.85	13.92	-0.99	5.85	-11.14	3.49	5.03	-0.90
Chon Buri	12.91	-13.22	9.68	14.94	0.67	1.82	-1.96	-14.18	4.43	-4.70	3.50	-5.64	1.85	0.32	12.40	-2.01	-0.72	-9.92	2.09	-3.85	-4.40
Rayong	-2.72	2.30	2.09	14.47	-5.37	9.12	-3.47	0.62	-3.27	-1.26	-2.76	-2.59	0.31	-0.68	16.34	-1.82	-0.71	-8.41	0.54	-1.47	-3.40
Chanthaburi	2.67	3.53	3.64	13.50	-2.18	8.96	-4.15	0.95	-2.72	-2.84	-0.34	-1.80	4.24	-2.01	13.24	-2.03	-2.50	-9.82	0.74	-3.65	-3.99
Trat	2.11	-0.85	3.36	11.80	-2.70	8.73	-1.11	3.46	-0.81	-1.09	-1.42	-1.06	1.10	-1.45	15.39	-1.41	-2.47	-10.74	0.32	-2.01	-3.25
Chachoengsao	-3.97	6.95	2.18	9.66	2.49	6.16	-5.60	4.22	-1.11	-3.73	-0.83	-5.32	-0.13	-3.28	13.51	-1.08	6.88	-13.25	4.28	1.88	-3.37
Prachin Buri	3.61	2.20	6.29	5.26	1.30	0.85	-0.34	1.94	2.75	-2.29	-8.87	-8.58	0.41	0.77	14.96	-2.58	1.17	-7.10	3.94	-4.87	-4.74
Nakhon Nayok	1.67	3.08	6.83	3.77	1.88	4.98	-3.09	6.66	-1.37	-3.68	-2.78	-2.51	-0.91	-2.06	15.53	-1.82	6.63	-18.66	12.76	-9.21	-1.76
Sa Kaeo	3.04	1.56	2.80	11.19	1.21	0.31	0.26	-0.02	1.10	-0.97	-3.98	-5.67	-0.52	-1.43	14.18	-1.62	1.93	-9.58	4.21	-4.40	-4.87
Ratchaburi	2.37	0.59	0.65	17.17	-8.85	7.22	-2.40	1.57	-1.75	0.33	-2.88	-3.63	0.40	-2.47	4.47	0.31	2.68	-6.25	1.74	-0.09	0.67
Kanchanaburi	4.10	0.69	5.09	13.84	-5.16	9.21	-3.96	3.68	-1.63	-1.22	-4.00	-2.92	1.02	1.15	8.48	0.01	2.27	-6.96	1.40	1.27	-0.89
Suphan Buri	1.16	-0.30	-0.35	19.34	-7.10	5.10	-5.05	3.23	-3.18	1.09	-1.93	0.31	-1.21	-6.55	6.54	0.34	2.81	-7.14	1.56	0.70	-0.61
Nakhon Pathom	3.27	-0.62	-0.58	20.00	-6.87	3.59	-2.23	0.28	-1.49	1.45	-0.85	-0.40	0.34	-6.20	11.46	0.47	2.79	-7.60	-0.03	1.52	-0.50
Samut Sakhon	5.37	0.43	-1.83	16.28	-6.17	3.93	-3.51	1.82	-1.37	-0.35	-2.43	-5.28	0.35	3.48	9.95	0.11	2.72	-6.96	12.73	-8.58	-4.26

Table A.8

Full result of technical change of the main rice (Cont.)

Technical change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Prachuap Khiri Khan	12.47	-7.49	3.94	18.84	-5.84	7.38	-2.66	0.82	0.70	-1.96	-4.55	-4.30	0.98	1.24	9.87	-1.84	0.61	-5.32	2.46	-3.17	-2.06
Samut Songkhram	4.70	0.40	3.41	19.64	-5.59	6.10	-4.70	3.13	-2.37	0.01	-1.70	-2.76	0.55	-0.69	3.54	0.36	2.52	-6.75	2.39	-2.14	-3.16
Phetchaburi	2.69	-0.35	2.45	17.06	-7.52	5.46	-2.29	1.51	-1.36	0.20	-2.16	-0.77	0.13	0.23	3.86	0.29	2.35	-6.81	2.70	-0.86	-2.39
Central	0.02	0.03	0.02	0.12	-0.03	0.05	-0.04	0.03	-0.01	-0.01	-0.02	-0.02	0.00	-0.04	0.11	-0.01	0.04	-0.10	0.03	0.00	-0.02
Nakhon Ratchasima	1.62	0.53	1.94	11.65	-3.06	3.34	-0.22	0.99	0.81	-0.25	-2.67	-5.83	0.49	-0.29	16.96	-1.59	-1.72	-6.79	2.56	-4.60	-4.50
Buri Ram	1.97	2.23	0.40	14.30	-4.10	7.78	-3.44	4.67	-1.12	-2.44	-2.25	-4.14	-0.21	-0.89	16.09	-1.64	-1.58	-6.81	3.33	-4.08	-4.09
Surin	2.97	1.68	0.64	13.11	-4.22	5.64	-1.26	3.97	-1.22	-2.62	-1.58	-3.60	-0.03	0.85	9.79	-1.46	-1.32	-6.83	4.06	-4.47	-3.90
Si Sa Ket	0.10	1.57	1.14	12.17	-3.05	8.41	-0.77	4.51	-0.71	-2.06	-2.37	-0.99	-0.69	-0.76	17.88	-1.67	-3.64	-10.61	0.36	-2.88	-4.17
Ubon Ratchathani	0.27	0.86	-0.28	16.54	-6.43	8.22	3.18	5.24	-0.54	-1.96	-3.75	0.54	0.58	-0.58	21.48	-1.70	-6.84	-9.71	-1.58	-2.80	-3.33
Yasothon	-0.13	1.30	0.89	13.31	-4.17	8.83	0.89	0.72	-1.50	-1.65	3.54	-7.86	-0.88	1.42	9.07	0.56	-4.38	-5.35	-1.37	-3.67	-4.20
Chaiyaphum	6.50	0.42	2.21	10.60	-2.06	8.28	-1.35	-1.91	0.28	-4.58	3.64	-7.34	-0.86	0.89	6.88	0.43	-4.24	-4.72	-0.46	-4.28	-2.81
Amnat Charoen	-4.62	2.70	-0.52	13.67	-6.94	8.78	0.98	4.40	-0.64	-1.92	-3.05	-0.52	-1.19	2.03	6.88	0.49	-4.20	-4.82	-2.36	-3.03	-4.88
Bueng Kan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.79	-1.21	-3.33	-4.67	-4.25	-1.25	-2.99
Nong Bua Lam Phu	10.56	-5.50	11.30	10.86	-3.93	7.58	2.12	-7.55	-1.26	-4.09	0.67	-8.54	-0.86	3.57	3.81	0.34	-4.28	-4.87	-0.94	-3.91	-2.28
Khon Kaen	1.42	0.62	0.68	10.14	-4.55	7.98	-0.07	3.73	-0.73	-1.50	-0.20	-7.16	-1.22	1.54	9.48	0.63	-4.39	-4.92	-1.28	-3.54	-3.84
Udon Thani	0.60	-1.98	1.49	11.19	-2.47	8.90	1.85	-4.36	-1.64	-4.32	2.94	-5.63	-0.72	4.46	5.04	0.09	-3.84	-4.75	-2.55	-1.91	-3.74
Loei	10.16	-11.70	9.10	8.79	-11.19	20.27	-10.70	-16.02	11.40	-17.71	5.24	-1.95	12.02	-14.41	5.64	-3.47	-1.04	-2.80	2.04	-4.35	3.22
Nong Khai	5.66	-10.00	8.66	11.85	0.01	4.56	-2.52	-14.06	3.63	-8.60	4.88	-3.27	-1.05	-0.54	11.30	-1.28	-3.73	-4.75	-2.56	-2.16	-4.43
Maha Sarakham	-5.14	1.03	-1.00	12.11	-3.57	8.66	0.28	3.83	-0.60	-1.83	-2.01	-4.70	-1.34	-0.15	18.64	-2.04	-3.32	-7.40	1.37	-4.40	-4.32
Roi Et	-0.36	1.68	0.74	13.13	-3.79	7.49	-1.54	4.97	-0.09	-2.46	-2.59	-5.65	0.71	-0.15	16.13	-1.48	-1.61	-7.14	2.04	-4.42	-4.09
Kalasin	-8.26	-0.42	0.93	9.62	-4.63	7.69	2.29	4.38	-0.49	-1.66	-3.68	0.56	-3.34	1.36	17.86	-0.10	-5.17	-5.24	-3.68	-1.69	-4.24
Sakon Nakhon	-5.96	-2.51	1.38	12.16	-5.59	7.57	3.64	5.36	-1.62	-3.22	-8.54	0.37	2.62	-0.37	12.03	-1.19	-3.56	-5.89	-3.91	-2.49	-4.47
Nakhon Phanom	-0.74	-3.65	4.10	10.55	-4.67	7.89	-0.75	4.13	0.62	-8.53	-0.93	-2.27	2.94	1.55	6.64	-1.33	-3.53	-4.86	-1.82	-3.86	-2.74

Table A.8

Full result of technical change of the main rice (Cont.)

Technical change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mukdahan	-8.58	1.90	6.16	9.86	-3.66	8.03	0.41	1.62	0.10	-7.24	2.69	-1.34	5.41	-3.85	7.53	-3.14	-0.97	-6.16	-5.65	3.16	-2.57
Northeastern	0.00	0.00	0.02	0.12	-0.04	0.08	0.00	0.02	0.00	-0.03	-0.02	-0.04	0.00	0.00	0.13	-0.01	-0.03	-0.07	0.00	-0.03	-0.04
Chiang Mai	-12.59	12.07	-1.23	10.59	-7.86	16.28	-8.21	-5.66	5.12	-11.98	-3.19	0.48	3.19	-3.08	4.65	-0.47	-1.06	-1.41	-3.70	1.57	-5.38
Lamphun	-10.56	4.76	3.58	7.50	-0.06	5.12	-7.66	7.16	-3.50	-3.29	-2.97	3.85	-2.32	-6.21	5.94	-1.35	2.20	-5.42	-0.18	-1.52	1.33
Lampang	-9.60	7.71	4.41	9.76	-0.19	8.06	-3.73	1.45	-3.58	-3.26	-3.20	0.49	3.92	-6.65	2.66	-1.00	1.89	-2.12	0.41	-2.86	2.84
Uttaradit	6.59	-0.24	3.35	15.94	-6.71	6.51	-2.40	1.05	-1.08	-0.52	-2.27	-1.66	0.16	3.05	8.47	-0.42	1.86	-5.81	4.25	-5.70	-3.41
Phrae	-1.78	1.89	0.39	10.73	-4.30	12.22	-3.14	-10.44	4.72	-11.96	-0.27	3.22	-0.02	-2.75	0.30	-0.42	0.22	-2.99	-0.33	0.10	-1.14
Nan	-2.42	1.99	-0.42	12.92	-5.28	12.25	-5.65	-14.15	5.08	-12.90	2.18	2.00	-0.46	-9.36	4.53	-1.89	1.33	-2.50	1.22	-2.02	2.18
Phayao	0.82	-2.36	4.14	11.22	-4.11	8.96	-2.00	-1.78	0.82	-6.31	3.55	-2.81	0.17	-1.61	10.04	-0.52	-1.79	-3.99	-2.61	-2.49	-3.74
Chiang Rai	5.63	-7.85	7.47	8.71	-3.03	7.50	2.14	-3.47	-1.44	-2.67	-2.12	-3.58	1.59	-2.82	16.24	-0.74	-6.19	-7.29	-3.51	-3.59	-2.16
Mae Hong Son	-19.77	-9.82	-1.36	30.85	-15.67	23.22	-27.25	-15.98	6.78	-16.29	11.01	0.09	13.41	-15.53	9.08	-2.29	-4.09	-4.58	3.98	-5.43	4.67
Nakhon Sawan	5.72	4.67	8.57	5.27	0.11	3.58	-0.45	4.15	1.50	-2.68	-9.21	-9.26	0.37	-2.05	16.60	-2.14	6.35	-16.74	12.05	-8.97	-1.11
Uthai Thani	19.03	-9.02	2.63	13.05	-3.70	5.01	-1.80	3.80	2.03	-1.73	-5.84	-8.52	0.13	1.31	10.34	0.25	2.39	-8.02	5.99	-5.78	-4.73
Kamphaeng Phet	4.77	0.42	2.99	17.39	-0.37	1.61	-0.37	2.04	0.56	0.76	-5.66	-5.67	0.16	1.85	14.35	-2.55	2.69	-8.99	5.81	-5.04	-5.64
Tak	5.44	1.34	2.33	11.06	-4.31	10.02	-3.11	-6.31	4.96	-11.44	2.99	-4.09	3.64	-5.63	7.02	0.16	-4.37	-5.21	1.68	-5.42	0.24
Sukhothai	17.36	-10.76	4.97	18.57	-2.96	0.73	-2.80	-1.68	3.03	-3.54	-5.19	-5.31	0.86	4.31	11.56	-1.22	0.98	-7.01	5.12	-5.49	-3.89
Phitsanulok	6.98	0.85	5.29	16.70	-8.80	1.12	-2.51	-0.24	2.89	-3.09	-7.19	-6.14	1.72	4.71	9.03	-2.42	0.97	-7.79	5.87	-5.51	-4.38
Phichit	6.29	2.56	6.06	2.63	1.04	2.80	-1.15	4.89	2.78	-2.47	-9.21	-9.16	2.19	4.49	17.12	-2.44	5.28	-14.96	9.56	-7.53	-1.14
Phetchabun	21.70	-14.74	3.13	16.93	11.27	-10.14	0.58	-11.43	0.46	2.31	9.35	-16.72	0.43	-3.29	9.44	-1.31	-2.14	-5.51	2.11	-2.84	-5.16
Northern	0.06	-0.02	0.05	0.11	-0.02	0.04	-0.02	-0.01	0.01	-0.03	-0.04	-0.07	0.01	0.00	0.12	-0.02	0.01	-0.09	0.05	-0.05	-0.03
Nakhon Si Thammarat	-0.44	-0.22	2.16	17.32	-7.51	9.17	-4.38	0.78	-2.03	-0.71	-3.79	-3.41	2.06	-0.67	13.20	-0.60	0.19	-7.40	3.07	-4.76	-4.24
Krabi	-10.64	15.66	0.59	9.23	4.37	-14.67	9.16	-12.06	-0.55	2.34	-4.50	-1.68	5.05	-4.98	-5.90	-7.11	4.45	-0.42	-1.68	-1.44	14.23
Phangnga	-7.62	18.07	-1.08	9.19	-2.02	6.66	-2.40	0.44	-1.63	-2.01	-6.04	2.77	0.77	-5.58	4.64	-0.62	0.23	-2.05	-1.00	1.79	-4.38

Table A.8

Full result of technical change of the main rice (Cont.)

Technical change rate of the main rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Phuket	-13.29	15.77	-2.54	10.10	3.15	-14.20	13.30	-11.00	-0.59	1.55	-6.14	1.83	33.95	-24.62	2.03	-0.41	-0.59	-3.45	-0.48	6.34	-1.56
Surat Thani	-6.28	3.82	3.36	13.59	-4.95	7.16	-5.02	-7.92	3.09	-7.39	-2.15	-0.94	0.20	1.70	3.77	-0.92	0.64	-3.95	1.81	-3.89	-3.93
Ranong	-4.65	14.04	7.89	-2.22	-6.12	10.44	-3.98	-4.41	6.65	-10.00	-3.38	7.26	5.11	-8.85	-3.51	-6.70	7.91	1.13	12.49	-9.41	19.86
Chumphon	-3.28	3.38	3.06	9.18	-0.68	1.87	-5.97	4.50	-4.16	-1.93	-3.43	-0.91	2.37	-0.73	6.40	-0.65	-1.04	-3.11	0.03	0.55	-1.61
Songkhla	-0.89	0.68	2.57	16.68	-6.57	7.98	-3.89	2.79	-3.11	-0.73	-1.65	-1.09	0.87	1.60	6.27	-0.41	1.50	-4.44	3.33	-3.37	-2.65
Satun	-9.07	6.17	2.56	8.18	-0.93	-0.31	-7.03	5.15	-2.09	-2.45	-6.04	1.49	2.56	-4.39	8.92	-0.93	-1.71	-6.84	-6.66	7.29	-4.10
Trang	-10.82	20.52	-2.89	9.80	1.68	-0.42	-3.84	1.80	-1.36	0.62	-4.85	6.23	-2.42	-4.86	8.05	-0.67	0.18	-4.70	-7.46	5.96	-4.46
Phatthalung	0.24	0.05	0.98	13.12	-3.94	9.26	-4.79	3.06	-2.25	-0.65	-1.29	0.45	1.80	-0.36	5.52	-0.43	0.56	-3.29	1.66	-0.25	-1.44
Pattani	-11.46	11.14	3.38	8.66	2.17	-7.11	-2.08	4.69	-1.75	-4.09	-6.76	1.20	2.51	-2.21	5.60	-0.72	-2.47	-5.52	-5.23	-3.52	-1.58
Yala	-12.48	13.72	0.43	15.99	7.14	-26.45	8.04	-5.53	-1.05	0.52	-2.06	-1.76	2.30	-0.82	1.44	-0.27	-1.97	0.36	-9.32	7.33	6.17
Narathiwat	-11.66	12.90	3.47	10.86	-0.54	-6.71	9.15	-9.97	-1.04	-1.45	-2.81	4.67	4.07	2.09	-6.40	1.00	-0.23	6.21	-7.78	5.62	-2.08
Southern	-0.04	0.04	0.02	0.14	-0.04	0.04	-0.03	0.01	-0.02	-0.01	-0.03	-0.01	0.02	0.00	0.07	0.00	0.00	-0.05	0.01	-0.02	-0.03
Whole country	0.02	0.00	0.03	0.12	-0.03	0.06	-0.02	0.01	0.00	-0.02	-0.02	-0.04	0.00	-0.01	0.12	-0.01	0.00	-0.08	0.02	-0.03	-0.03

(b) Results of the second rice

Table A.9

Average technical efficiency of the second rice

Province	Efficiency score of the second rice						
	1997	2002	2007	2012	2017	2018	1997
	-	-	-	-			-
	2001	2006	2011	2016			2018
Bangkok Metropolis	0.8406	0.8980	0.9966	0.9760	1.0000	1.0000	0.9322
Samut Prakan	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Nonthaburi	0.9837	0.9736	0.9489	0.9469	0.9170	0.9488	0.9603
Pathum Thani	0.9567	0.9282	0.9503	0.9873	1.0000	1.0000	0.9594
Phra Nakhon Si Ayutthaya	0.9233	0.9810	0.9993	0.9581	0.9956	0.9725	0.9667
Ang Thong	0.8896	0.8745	0.8745	0.8723	0.8581	0.9135	0.8784
Lop Buri	0.8422	0.8956	0.9666	0.8572	0.8422	0.8819	0.8866
Sing Buri	0.9613	0.9585	0.9156	0.8534	0.8708	0.8995	0.9178
Chai Nat	0.9907	1.0000	0.9485	0.9319	0.9249	0.9277	0.9636
Saraburi	0.7887	0.8915	0.9350	0.8570	0.8702	0.8688	0.8667
Chon Buri	0.7200	0.6562	0.7284	0.9944	1.0000	1.0000	0.7837
Rayong	0.5943	0.6603	0.6945	0.7176	0.7134	0.7376	0.6703
Chanthaburi	-	-	-	-	-	-	-
Trat	0.5557	0.4935	0.5802	0.6598	0.7529	0.7713	0.5859
Chachoengsao	0.8615	0.9166	0.9241	0.9545	0.9667	0.9944	0.9194
Prachin Buri	0.6868	0.7909	0.8507	0.8899	0.9182	1.0000	0.8140
Nakhon Nayok	0.6692	0.6904	0.8212	0.8990	0.9609	0.9817	0.7811
Sa Kaeo	0.6330	0.6792	0.6989	0.6827	0.7315	0.7477	0.6811
Ratchaburi	0.8341	0.8732	0.8844	0.9588	0.9303	0.9580	0.8916
Kanchanaburi	0.8665	0.9323	0.9177	0.9689	0.9644	0.9724	0.9249
Suphan Buri	0.9590	0.9521	0.9154	0.9569	0.9262	0.9434	0.9447
Nakhon Pathom	0.9636	0.9802	0.9942	1.0000	1.0000	1.0000	0.9858
Samut Sakhon	0.9604	0.8527	0.8855	0.9255	0.9331	0.9160	0.9069
Samut Songkhram	0.8907	0.9625	0.9159	0.9416	0.6285	0.9292	0.9111
Phetchaburi	0.8871	0.8345	0.8365	0.9907	0.9484	0.9738	0.8917
Prachuap Khiri Khan	0.5567	0.6624	0.6566	0.7358	0.7812	0.8132	0.6619
Central	0.9254	0.9363	0.9338	0.9474	0.9414	0.9506	0.9366
Nakhon Ratchasima	0.7735	0.7405	0.7952	0.7912	0.8143	0.8862	0.7813
Buri Ram	0.4840	0.5305	0.6267	0.6613	0.6591	0.7372	0.5816
Surin	0.4954	0.6015	0.6248	0.5902	0.5588	0.6276	0.5772
Si Sa Ket	0.5333	0.5833	0.6192	0.6675	0.6843	0.7394	0.6082
Ubon Ratchathani	0.5761	0.6827	0.8745	0.7050	0.7347	0.7501	0.7053
Yasothon	0.5889	0.6225	0.6756	0.7112	0.7168	0.7557	0.6554
Chaiyaphum	0.6701	0.6528	0.7257	0.7389	0.7446	0.8150	0.7031
Amnat Charoen	0.4977	0.7551	0.8358	0.7430	0.6915	0.6883	0.6918
Bueng Kan	-	-	-	0.8400	0.7349	0.7454	0.8101
Nong Bua Lam Phu	0.6821	0.8125	0.8728	0.7938	0.7377	0.7921	0.7851

Table A.9

Average technical efficiency of the second rice (Cont.)

Province	Efficiency score of the second rice						
	1997	2002	2007	2012	2017	2018	1997
	-	-	-	-			-
	2001	2006	2011	2016			2018
Khon Kaen	0.7264	0.6971	0.7146	0.6988	0.7448	0.8029	0.7148
Udon Thani	0.6700	0.7196	0.7370	0.7289	0.6924	0.6932	0.7115
Loei	0.8636	0.9398	1.0000	0.8001	0.8879	0.7116	0.8878
Nong Khai	0.6456	0.6572	0.7372	0.7333	0.6705	0.7137	0.6920
Maha Sarakham	0.6842	0.7518	0.7477	0.7846	0.7792	0.8096	0.7458
Roi Et	0.6635	0.7066	0.7383	0.7041	0.7424	0.7789	0.7077
Kalasin	0.7475	0.6812	0.7525	0.7919	0.7987	0.8281	0.7484
Sakon Nakhon	0.5823	0.5128	0.6886	0.6903	0.6936	0.7223	0.6218
Nakhon Phanom	0.6805	0.7350	0.7671	0.6837	0.6433	0.6906	0.7110
Mukdahan	0.5150	0.9722	1.0000	0.7877	0.6839	0.7219	0.7758
Northeastern	0.7076	0.6981	0.7475	0.7326	0.7406	0.7860	0.7249
Chiang Mai	0.9925	0.9847	0.9925	0.9890	0.9962	0.9920	0.9901
Lamphun	0.9741	0.9862	1.0000	1.0000	1.0000	1.0000	0.9909
Lampang	0.7502	0.8740	0.9468	0.8477	0.8426	0.8443	0.8510
Uttaradit	0.8722	0.9551	0.8897	0.9008	0.8485	0.8726	0.8999
Phrae	0.7765	0.8031	0.7961	0.8048	0.7956	0.8074	0.7966
Nan	0.8182	0.8772	0.9131	0.7975	0.7688	0.7720	0.8427
Phayao	0.8388	0.9044	0.9418	0.9253	0.9036	0.8878	0.9012
Chiang Rai	0.9881	1.0000	1.0000	1.0000	1.0000	1.0000	0.9973
Mae Hong Son	0.6832	0.7380	0.7978	0.9744	1.0000	1.0000	0.8199
Nakhon Sawan	0.7800	0.9441	0.8975	0.8713	0.8290	0.9345	0.8719
Uthai Thani	0.8086	0.8124	0.8120	0.8504	0.8083	0.8867	0.8230
Kamphaeng Phet	0.9506	0.8992	0.8614	0.8945	0.8405	0.8964	0.8978
Tak	0.8691	0.9817	0.9468	0.8306	0.7918	0.8383	0.8965
Sukhothai	0.8746	0.8687	0.8723	0.8299	0.8049	0.8386	0.8575
Phitsanulok	0.9177	0.8598	0.8675	0.8957	0.8258	0.8825	0.8820
Phichit	0.9822	0.9471	0.9512	0.9011	0.8129	0.8745	0.9352
Phetchabun	0.6534	0.6959	0.6510	0.7622	0.8342	0.8317	0.7012
Northern	0.9082	0.9124	0.8971	0.8965	0.8463	0.8977	0.9006
Nakhon Si Thammarat	0.5528	0.5973	0.6258	0.7020	0.7098	0.6996	0.6246
Krabi	-	-	-	-	-	-	-
Phangnga	-	-	-	-	-	-	-
Phuket	-	-	-	-	-	-	-
Surat Thani	0.6692	0.6601	0.6941	0.7603	0.8320	0.8478	0.7069
Ranong	-	-	-	-	-	-	-
Chumphon	0.6515	0.7104	0.7760	0.7268	0.7641	0.7188	0.7171
Songkhla	0.6470	0.6325	0.7055	0.7824	0.7805	0.7947	0.6978
Satun	0.6337	0.7228	0.9864	0.9041	0.8460	0.5994	0.8035
Trang	-	-	-	-	-	-	-

Table A.9

Average technical efficiency of the second rice (Cont.)

Efficiency score of the second rice							
Province	1997	2002	2007	2012	2017	2018	1997
	-	-	-	-			-
	2001	2006	2011	2016			2018
Phatthalung	0.6659	0.6014	0.6754	0.7546	0.7814	0.7705	0.6810
Pattani	0.7618	0.7140	0.8732	0.9135	0.9793	1.0000	0.8282
Yala	0.6858	0.5118	0.8547	0.9171	1.0000	0.8106	0.7511
Narathiwat	0.8154	0.6518	0.7663	0.8319	0.9632	0.8236	0.7738
Southern	0.6358	0.6127	0.6786	0.7483	0.7573	0.7677	0.6751
Whole country	0.8998	0.9077	0.8917	0.8948	0.8713	0.9049	0.8975

Table A.10

Average TFP change of the second rice

Province	TFP change rate of the second rice (%)					
	1998	2003	2008	2013	2018	1998
	-	-	-	-	-	-
	2002	2007	2012	2017		2018
Bangkok Metropolis	-0.27	0.23	-1.99	0.48	-0.78	-0.41
Samut Prakan	-1.58	1.01	0.51	-1.18	2.72	-0.17
Nonthaburi	-1.68	-0.04	-0.36	-2.09	2.56	-0.88
Pathum Thani	4.68	-2.00	0.57	0.35	3.89	1.01
Phra Nakhon Si Ayutthaya	-1.21	1.81	-0.16	-1.72	1.26	-0.25
Ang Thong	1.28	-0.85	0.89	-2.55	6.59	0.00
Lop Buri	0.20	3.43	0.28	-2.75	5.48	0.51
Sing Buri	-2.25	2.52	-1.23	-1.33	3.90	-0.38
Chai Nat	2.04	0.67	0.28	-1.08	4.02	0.63
Saraburi	1.58	0.22	0.00	-0.43	1.82	0.41
Chon Buri	3.43	6.28	6.75	0.02	-0.09	3.88
Rayong	0.14	3.13	0.21	-0.24	3.18	0.91
Chanthaburi	-	-	-	-	-	-
Trat	-4.43	5.55	-0.11	3.04	3.02	1.32
Chachoengsao	-1.38	-1.91	0.53	0.58	2.34	-0.41
Prachin Buri	-4.46	5.36	-0.52	1.09	13.78	0.91
Nakhon Nayok	-4.29	3.48	1.64	1.70	2.32	0.67
Sa Kaeo	6.27	6.53	-2.80	1.82	1.81	2.48
Ratchaburi	-1.91	0.82	1.31	-0.93	4.50	0.03
Kanchanaburi	1.59	0.01	-0.04	0.36	2.44	0.57
Suphan Buri	-2.77	1.13	-0.17	-1.35	0.50	-0.74
Nakhon Pathom	-1.45	1.07	-0.41	-0.99	-0.92	-0.47
Samut Sakhon	-3.00	0.68	1.07	-0.18	-2.27	-0.46
Samut Songkhram	0.23	1.26	-0.75	-7.95	46.97	0.03
Phetchaburi	-3.32	0.40	2.53	-0.85	2.48	-0.20
Prachuap Khiri Khan	6.25	-3.01	1.10	1.37	5.50	1.57

Table A.10

Average TFP change of the second rice (Cont.)

Province	TFP change rate of the second rice (%)					
	1998	2003	2008	2013	2018	1998
	-	-	-	-	-	-
	2002	2007	2012	2017		2018
Central	-1.48	0.61	-0.37	-1.45	2.49	-0.53
Nakhon Ratchasima	-2.24	5.20	-1.33	-0.08	8.87	0.74
Buri Ram	1.00	-6.12	2.23	-1.85	14.11	-0.56
Surin	-5.74	0.58	-2.02	-2.07	15.35	-1.56
Si Sa Ket	-4.17	0.59	-0.36	0.76	8.48	-0.39
Ubon Ratchathani	-4.93	5.54	-2.42	-2.63	2.67	-1.01
Yasothon	-1.19	2.38	0.72	-0.50	4.81	0.55
Chaiyaphum	-8.09	3.46	-0.05	-0.96	10.53	-0.96
Amnat Charoen	1.85	-5.47	-3.44	-3.49	-0.09	-2.24
Bueng Kan	-	-	-	-4.28	3.08	-3.09
Nong Bua Lam Phu	-0.60	4.41	-1.28	-3.02	10.61	0.33
Khon Kaen	-8.61	-0.73	1.41	-1.17	8.04	-1.88
Udon Thani	10.15	0.04	-1.20	-0.44	2.47	2.06
Loei	-9.50	4.45	-1.53	-2.22	-18.45	-3.16
Nong Khai	-9.52	3.93	1.55	-4.15	7.36	-1.75
Maha Sarakham	2.69	-0.53	1.35	-1.24	3.43	0.69
Roi Et	5.04	-1.24	-1.78	0.35	5.22	0.78
Kalasin	-3.52	3.87	0.92	-0.23	4.91	0.44
Sakon Nakhon	2.75	-2.57	1.43	-0.69	5.11	0.44
Nakhon Phanom	-8.06	-2.54	-0.83	-2.04	7.10	-2.93
Mukdahan	-0.11	-7.60	-1.21	-7.96	7.87	-3.33
Northeastern	-5.55	1.75	-0.17	-1.54	5.75	-1.09
Chiang Mai	2.84	-3.32	-1.34	-1.89	3.89	-0.73
Lamphun	-1.39	-1.88	-0.94	-1.76	4.92	-1.20
Lampang	-4.93	1.06	-0.52	-2.97	2.62	-1.66
Uttaradit	0.05	-0.26	-1.10	-1.25	2.97	-0.47
Phrae	-2.95	-0.31	-0.24	-1.45	3.22	-0.94
Nan	3.68	2.57	-3.30	-2.47	2.28	0.18
Phayao	4.40	-2.51	-1.27	-2.50	0.27	-0.47
Chiang Rai	-1.91	1.22	-1.96	-0.87	3.07	-0.70
Mae Hong Son	10.31	-14.50	10.37	-3.98	3.64	1.93
Nakhon Sawan	-0.58	1.70	0.81	-3.19	12.73	0.25
Uthai Thani	-4.46	3.96	1.28	-2.19	9.75	0.06
Kamphaeng Phet	-0.32	-1.01	2.51	-3.40	5.47	-0.30
Tak	2.01	-2.33	2.12	-5.37	8.69	-0.50
Sukhothai	0.41	-0.80	-0.28	-1.79	4.46	-0.38
Phitsanulok	-2.42	0.73	3.34	-4.20	6.02	-0.37
Phichit	-1.49	0.02	1.47	-3.89	5.74	-0.68
Phetchabun	-4.93	-1.47	1.05	0.93	2.43	-0.97

Table A.10

Average TFP change of the second rice (Cont.)

Province	TFP change rate of the second rice (%)					
	1998	2003	2008	2013	2018	1998
	2002	2007	2012	2017		2018
Northern	-1.59	0.29	0.92	-2.90	6.10	-0.51
Nakhon Si Thammarat	4.79	0.02	0.16	1.47	-1.80	1.43
Krabi	-	-	-	-	-	-
Phangnga	-	-	-	-	-	-
Phuket	-	-	-	-	-	-
Surat Thani	-7.44	9.13	-0.71	0.40	2.77	0.30
Ranong	-	-	-	-	-	-
Chumphon	-0.04	1.41	-0.24	-1.43	-3.93	-0.26
Songkhla	-0.58	1.03	3.42	-0.46	1.48	0.87
Satun	1.30	5.26	0.34	-5.92	-27.29	-2.41
Trang	-	-	-	-	-	-
Phatthalung	2.21	1.78	0.79	1.01	-0.52	1.35
Pattani	-0.72	4.08	0.17	2.98	9.43	1.60
Yala	-17.87	7.68	-1.30	11.41	-21.09	0.36
Narathiwat	-15.14	6.78	2.24	2.18	-13.01	-1.95
Southern	0.35	1.87	1.09	0.83	-0.19	0.98
Whole country	-1.72	0.54	0.04	-2.14	4.33	-0.59

Table A.11

Average technical efficiency change of the second rice

Province	Technical efficiency change rate of the second rice (%)					
	1998	2003	2008	2013	2018	1998
	2002	2007	2012	2017		2018
Bangkok Metropolis	0.57	-0.16	-2.09	2.30	0.00	0.14
Samut Prakan	0.00	0.00	0.00	0.00	0.00	0.00
Nonthaburi	0.00	0.00	-0.10	-1.62	3.47	-0.25
Pathum Thani	1.48	-1.21	1.23	0.00	0.00	0.35
Phra Nakhon Si Ayutthaya	-1.69	1.92	0.00	-0.09	-2.32	-0.09
Ang Thong	3.31	-1.22	1.22	-2.52	6.46	0.46
Lop Buri	0.88	3.07	0.38	-2.87	4.71	0.54
Sing Buri	-2.23	2.00	-0.91	-1.57	3.29	-0.50
Chai Nat	0.00	0.00	0.00	-1.55	0.30	-0.36
Saraburi	1.06	-0.32	0.10	-1.11	-0.16	-0.08
Chon Buri	1.67	7.48	5.74	0.02	0.00	3.51
Rayong	0.81	1.30	0.83	-0.03	3.39	0.85
Chanthaburi	-	-	-	-	-	-
Trat	-3.70	5.36	0.18	3.81	2.44	1.67
Chachoengsao	-0.22	-2.07	0.64	1.01	2.86	-0.03

Table A.11

Average technical efficiency change of the second rice (Cont.)

Province	Technical efficiency change rate of the second rice (%)					
	1998	2003	2008	2013	2018	1998
	-	-	-	-		-
	2002	2007	2012	2017		2018
Prachin Buri	-3.76	3.67	-0.47	2.86	8.91	0.91
Nakhon Nayok	-3.58	3.61	1.85	1.99	2.16	0.99
Sa Kaeo	4.00	5.65	-2.43	1.92	2.21	2.05
Ratchaburi	-1.08	0.80	1.32	-0.88	2.98	0.17
Kanchanaburi	3.81	-0.10	-0.06	0.32	0.82	0.97
Suphan Buri	-0.99	1.09	0.24	-1.18	1.86	-0.12
Nakhon Pathom	0.00	0.00	0.00	0.00	0.00	0.00
Samut Sakhon	-1.72	0.41	0.66	-0.20	-1.84	-0.30
Samut Songkhram	0.50	1.80	-0.79	-7.86	47.85	0.27
Phetchaburi	-2.91	0.21	2.55	-0.84	2.68	-0.13
Prachuap Khiri Khan	7.91	-2.90	1.64	1.27	4.10	2.01
Central	-0.87	0.42	-0.16	-0.94	1.40	-0.30
Nakhon Ratchasima	-4.10	5.12	-0.16	0.04	8.83	0.57
Buri Ram	1.18	-2.23	3.74	-1.03	11.84	0.91
Surin	-5.71	1.64	-1.14	-1.01	12.32	-0.97
Si Sa Ket	-3.47	2.54	0.40	1.48	8.05	0.57
Ubon Ratchathani	-2.89	8.15	-1.32	-1.08	2.10	0.69
Yasothon	-1.29	2.52	1.42	0.24	5.44	0.93
Chaiyaphum	-4.44	5.50	0.48	-0.17	9.45	0.70
Amnat Charoen	1.99	4.94	-2.78	-1.56	-0.45	0.10
Buang Kan	-	-	-	-3.57	1.43	-2.76
Nong Bua Lam Phu	1.52	5.23	-1.94	-2.72	7.38	0.79
Khon Kaen	-8.20	1.42	2.19	-0.91	7.80	-1.04
Udon Thani	11.18	1.26	-1.55	-0.42	0.11	2.38
Loei	-6.02	6.40	-0.14	-2.22	-19.85	-1.61
Nong Khai	-8.07	3.45	1.36	-2.81	6.43	-1.25
Maha Sarakham	2.48	-0.12	1.31	-1.16	3.90	0.77
Roi Et	5.42	-1.15	-1.62	0.36	4.92	0.91
Kalasin	-3.26	3.85	1.08	-0.22	3.68	0.49
Sakon Nakhon	2.09	1.26	1.73	-0.35	4.14	1.32
Nakhon Phanom	-4.90	-0.57	-0.92	-2.27	7.36	-1.75
Mukdahan	2.92	0.00	-0.31	-7.03	5.55	-0.95
Northeastern	-5.57	2.52	0.12	-1.11	5.15	-0.77
Chiang Mai	0.30	0.00	0.00	-0.08	-0.42	0.03
Lamphun	-1.38	1.40	0.00	0.00	0.00	0.00
Lampang	-2.50	3.89	-0.09	-0.90	0.20	0.08
Uttaradit	0.30	-0.61	-0.51	-1.15	2.84	-0.34
Phrae	-5.35	1.06	0.25	-1.47	1.48	-1.06
Nan	2.40	5.94	-2.59	-1.56	0.41	0.97

Table A.11

Average technical efficiency change of the second rice (Cont.)

Technical efficiency change rate of the second rice (%)						
Province	1998 -	2003 -	2008 -	2013 -	2018	1998 -
	2002	2007	2012	2017		2018
Phayao	0.61	1.11	1.25	-1.43	-1.74	0.28
Chiang Rai	0.00	0.00	0.00	0.00	0.00	0.00
Mae Hong Son	9.04	-4.68	8.04	0.00	0.00	3.56
Nakhon Sawan	0.45	1.02	0.43	-2.51	12.73	0.42
Uthai Thani	-3.36	3.53	1.06	-2.05	9.70	0.21
Kamphaeng Phet	0.69	-1.82	1.86	-2.53	6.66	-0.14
Tak	4.45	-0.84	1.76	-4.56	5.87	0.41
Sukhothai	0.73	-0.94	-0.07	-1.62	4.18	-0.26
Phitsanulok	-1.23	0.20	2.60	-3.76	6.87	-0.23
Phichit	0.32	-0.90	0.92	-3.68	7.58	-0.46
Phetchabun	-3.77	-1.41	1.60	1.94	-0.30	-0.43
Northern	-0.37	-0.37	0.84	-2.34	6.06	-0.26
Nakhon Si Thammarat	5.57	-0.16	0.29	1.52	-1.44	1.63
Krabi	-	-	-	-	-	-
Phangnga	-	-	-	-	-	-
Phuket	-	-	-	-	-	-
Surat Thani	-8.37	10.04	-0.02	2.04	1.89	0.76
Ranong	-	-	-	-	-	-
Chumphon	0.36	2.04	-0.22	-0.08	-5.93	0.20
Songkhla	0.18	0.73	3.36	-0.41	1.83	1.00
Satun	-5.92	15.01	0.02	-2.56	-29.15	-1.38
Trang	-	-	-	-	-	-
Phatthalung	2.10	1.31	1.28	2.05	-1.40	1.53
Pattani	0.48	4.10	-0.34	11.86	2.12	2.89
Yala	-29.78	16.58	-0.60	11.22	-18.94	1.44
Narathiwat	-11.31	8.60	3.11	3.02	-14.49	-0.20
Southern	0.98	1.81	1.28	1.51	-0.49	1.31
Whole country	-0.93	0.27	0.20	-1.59	3.74	-0.32

Table A.12

Average technical change of the second rice

Technical change rate of the second rice (%)						
Province	1998 -	2003 -	2008 -	2013 -	2018	1998 -
	2002	2007	2012	2017		2018
Bangkok Metropolis	-0.84	0.39	0.11	-1.78	-0.78	-0.55
Samut Prakan	-1.58	1.01	0.51	-1.18	2.72	-0.17
Nonthaburi	-1.68	-0.04	-0.26	-0.48	-0.88	-0.63
Pathum Thani	3.15	-0.80	-0.65	0.35	3.89	0.66

Table A.12

Average technical change of the second rice (Cont.)

Province	Technical change rate of the second rice (%)					
	1998	2003	2008	2013	2018	1998
	-	-	-	-	-	-
	2002	2007	2012	2017		2018
Phra Nakhon Si Ayutthaya	0.49	-0.11	-0.16	-1.63	3.66	-0.17
Ang Thong	-1.97	0.38	-0.33	-0.04	0.12	-0.47
Lop Buri	-0.67	0.35	-0.10	0.13	0.73	-0.04
Sing Buri	-0.02	0.50	-0.33	0.24	0.59	0.12
Chai Nat	2.04	0.67	0.28	0.47	3.70	0.99
Saraburi	0.51	0.54	-0.10	0.69	1.98	0.49
Chon Buri	1.73	-1.12	0.96	-0.01	-0.09	0.36
Rayong	-0.66	1.81	-0.61	-0.21	-0.20	0.06
Chanthaburi	-	-	-	-	-	-
Trat	-0.76	0.18	-0.29	-0.74	0.56	-0.34
Chachoengsao	-1.15	0.17	-0.12	-0.42	-0.50	-0.39
Prachin Buri	-0.73	1.63	-0.04	-1.71	4.47	0.00
Nakhon Nayok	-0.74	-0.13	-0.20	-0.28	0.16	-0.32
Sa Kaeo	2.19	0.84	-0.37	-0.10	-0.39	0.42
Ratchaburi	-0.83	0.02	-0.01	-0.05	1.48	-0.14
Kanchanaburi	-2.14	0.11	0.02	0.05	1.60	-0.40
Suphan Buri	-1.79	0.04	-0.41	-0.18	-1.33	-0.62
Nakhon Pathom	-1.45	1.07	-0.41	-0.99	-0.92	-0.47
Samut Sakhon	-1.30	0.27	0.41	0.02	-0.44	-0.17
Samut Songkhram	-0.27	-0.53	0.04	-0.09	-0.59	-0.23
Phetchaburi	-0.43	0.19	-0.02	-0.01	-0.19	-0.07
Prachuap Khiri Khan	-1.54	-0.11	-0.53	0.10	1.35	-0.44
Central	-0.62	0.19	-0.20	-0.52	1.08	-0.22
Nakhon Ratchasima	1.94	0.08	-1.17	-0.12	0.03	0.17
Buri Ram	-0.18	-3.98	-1.45	-0.83	2.03	-1.45
Surin	-0.04	-1.05	-0.89	-1.07	2.70	-0.60
Si Sa Ket	-0.72	-1.90	-0.76	-0.71	0.40	-0.96
Ubon Ratchathani	-2.10	-2.41	-1.11	-1.57	0.57	-1.69
Yasothon	0.10	-0.13	-0.70	-0.74	-0.59	-0.38
Chaiyaphum	-3.82	-1.94	-0.53	-0.79	0.98	-1.65
Amnat Charoen	-0.13	-9.92	-0.69	-1.96	0.37	-2.34
Buang Kan	-	-	-	-0.73	1.63	-0.34
Nong Bua Lam Phu	-2.09	-0.78	0.67	-0.30	3.01	-0.46
Khon Kaen	-0.45	-2.12	-0.76	-0.27	0.23	-0.85
Udon Thani	-0.93	-1.21	0.35	-0.02	2.36	-0.32
Loei	-3.70	-1.84	-1.39	-0.01	1.75	-1.58
Nong Khai	-1.58	0.46	0.19	-1.39	0.87	-0.51
Maha Sarakham	0.20	-0.41	0.04	-0.09	-0.46	-0.08
Roi Et	-0.36	-0.08	-0.16	-0.01	0.28	-0.13
Kalasin	-0.27	0.02	-0.16	-0.01	1.19	-0.04

Table A.12

Average technical change of the second rice (Cont.)

Province	Technical change rate of the second rice (%)					
	1998	2003	2008	2013	2018	1998
	-	-	-	-	-	-
	2002	2007	2012	2017		2018
Sakon Nakhon	0.64	-3.78	-0.30	-0.34	0.94	-0.87
Nakhon Phanom	-3.32	-1.98	0.09	0.24	-0.24	-1.21
Mukdahan	-2.94	-7.60	-0.90	-1.00	2.19	-2.40
Northeastern	0.01	-0.75	-0.29	-0.44	0.58	-0.32
Chiang Mai	2.53	-3.32	-1.34	-1.81	4.33	-0.76
Lamphun	-0.01	-3.23	-0.94	-1.76	4.92	-1.20
Lampang	-2.50	-2.72	-0.43	-2.09	2.42	-1.73
Uttaradit	-0.25	0.36	-0.59	-0.10	0.12	-0.13
Phrae	2.53	-1.36	-0.48	0.02	1.71	0.13
Nan	1.25	-3.18	-0.73	-0.93	1.86	-0.78
Phayao	3.77	-3.58	-2.48	-1.08	2.04	-0.75
Chiang Rai	-1.91	1.22	-1.96	-0.87	3.07	-0.70
Mae Hong Son	1.17	-10.30	2.16	-3.98	3.64	-1.57
Nakhon Sawan	-1.03	0.67	0.38	-0.69	0.00	-0.16
Uthai Thani	-1.14	0.41	0.22	-0.14	0.04	-0.15
Kamphaeng Phet	-1.00	0.82	0.63	-0.89	-1.12	-0.16
Tak	-2.33	-1.50	0.36	-0.84	2.66	-0.91
Sukhothai	-0.32	0.14	-0.21	-0.17	0.27	-0.12
Phitsanulok	-1.21	0.53	0.73	-0.46	-0.80	-0.14
Phichit	-1.80	0.92	0.54	-0.22	-1.71	-0.22
Phetchabun	-1.21	-0.06	-0.54	-0.99	2.74	-0.54
Northern	-1.22	0.66	0.08	-0.57	0.04	-0.25
Nakhon Si Thammarat	-0.75	0.18	-0.13	-0.05	-0.37	-0.20
Krabi	-	-	-	-	-	-
Phangnga	-	-	-	-	-	-
Phuket	-	-	-	-	-	-
Surat Thani	1.02	-0.83	-0.69	-1.60	0.86	-0.46
Ranong	-	-	-	-	-	-
Chumphon	-0.39	-0.61	-0.02	-1.34	2.12	-0.47
Songkhla	-0.76	0.30	0.06	-0.05	-0.34	-0.13
Satun	7.68	-8.48	0.32	-3.45	2.63	-1.04
Trang	-	-	-	-	-	-
Phatthalung	0.12	0.47	-0.49	-1.02	0.89	-0.18
Pattani	-1.20	-0.03	0.52	-7.94	7.16	-1.25
Yala	16.97	-7.63	-0.71	0.17	-2.66	-1.06
Narathiwat	-4.31	-1.68	-0.85	-0.82	1.72	-1.75
Southern	-0.62	0.06	-0.19	-0.67	0.30	-0.33
Whole country	-0.79	0.27	-0.16	-0.56	0.56	-0.27

Table A.13

Full result of technical efficiency score of the second rice

Efficiency score of the second rice																						
Province	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bangkok Metropolis	0.972	0.809	0.722	0.836	0.885	1.000	0.806	0.844	0.895	0.960	0.992	1.000	0.991	1.000	1.000	0.893	1.000	0.992	1.000	1.000	1.000	1.000
Samut Prakan	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Nonthaburi	1.000	1.000	1.000	0.929	0.991	1.000	0.955	0.942	0.993	0.979	1.000	0.988	0.960	0.904	0.898	0.995	0.978	0.923	0.952	0.890	0.917	0.949
Pathum Thani	0.929	0.976	1.000	1.000	0.884	1.000	0.896	0.909	0.906	0.934	0.941	0.919	1.000	0.967	0.927	1.000	1.000	1.000	1.000	0.938	1.000	1.000
Phra Nakhon Si Ayutthaya	0.990	0.886	0.936	0.944	0.865	0.909	1.000	1.000	0.999	1.000	1.000	1.000	0.996	1.000	1.000	1.000	0.954	0.953	0.953	0.932	0.996	0.972
Ang Thong	0.829	0.894	0.889	0.940	0.900	0.975	0.811	0.846	0.866	0.883	0.917	0.941	0.921	0.761	0.846	0.975	0.918	0.865	0.850	0.768	0.858	0.914
Lop Buri	0.787	0.767	0.863	0.849	0.958	0.822	0.902	0.910	0.921	0.926	0.956	1.000	1.000	0.914	0.965	0.974	0.994	0.792	0.797	0.757	0.842	0.882
Sing Buri	1.000	0.938	0.972	1.000	0.900	0.893	0.968	0.951	0.994	0.989	0.987	0.979	0.965	0.807	0.855	0.942	0.932	0.826	0.814	0.767	0.871	0.899
Chai Nat	1.000	1.000	1.000	1.000	0.954	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.990	0.810	0.957	1.000	0.943	0.901	0.873	0.949	0.925	0.928
Saraburi	0.883	0.648	0.822	0.861	0.755	0.930	0.876	0.848	0.922	0.884	0.916	0.904	0.960	0.921	0.976	0.920	0.884	0.812	0.851	0.822	0.870	0.869
Chon Buri	0.485	0.578	1.000	1.000	0.691	0.527	0.605	0.709	0.747	0.720	0.756	0.731	0.730	0.821	0.619	0.999	0.973	1.000	1.000	1.000	1.000	1.000
Rayong	0.618	0.639	0.682	0.470	0.586	0.643	0.663	0.664	0.651	0.682	0.686	0.711	0.723	0.676	0.678	0.715	0.685	0.721	0.720	0.749	0.713	0.738
Chanthaburi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trat	-	0.554	0.628	0.599	0.458	0.477	0.499	0.520	0.469	0.505	0.619	0.618	0.542	0.624	0.508	0.625	0.696	0.656	0.674	0.651	0.753	0.771
Chachoengsao	1.000	0.967	0.720	0.853	0.799	0.989	0.968	0.958	0.822	0.859	0.891	0.902	0.912	0.954	0.963	0.919	0.969	1.000	0.990	0.898	0.967	0.994
Prachin Buri	0.826	0.548	0.628	0.834	0.645	0.682	0.727	0.734	1.000	0.850	0.817	0.877	0.884	0.833	0.846	0.798	0.946	0.924	0.881	0.908	0.918	1.000
Nakhon Nayok	0.798	0.510	0.669	0.690	0.715	0.665	0.674	0.680	0.720	0.715	0.795	0.801	0.850	0.816	0.846	0.871	0.910	0.938	0.859	0.919	0.961	0.982
Sa Kaeo	0.813	-	0.508	0.655	0.593	0.572	0.731	0.740	0.648	0.721	0.752	0.765	0.750	0.652	0.592	0.665	0.678	0.698	0.717	0.658	0.732	0.748
Ratchaburi	0.924	0.819	0.768	0.787	0.883	0.875	0.849	0.864	0.903	0.876	0.910	0.898	0.871	0.876	0.867	0.972	0.976	0.991	0.920	0.937	0.930	0.958
Kanchanaburi	0.794	0.833	0.880	0.888	0.945	0.957	0.908	0.906	0.968	0.923	0.952	0.931	0.921	0.880	0.906	0.949	0.969	0.991	0.938	0.999	0.964	0.972
Suphan Buri	0.967	0.963	1.000	0.955	0.913	0.920	0.978	0.948	0.957	0.958	0.971	0.984	0.963	0.772	0.905	0.983	0.960	0.922	0.958	0.963	0.926	0.943
Nakhon Pathom	1.000	0.992	1.000	0.908	0.923	1.000	0.956	0.947	1.000	1.000	1.000	1.000	1.000	1.000	0.971	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Samut Sakhon	0.975	0.972	1.000	0.923	0.934	0.894	0.774	0.788	0.941	0.879	0.912	0.904	0.867	0.876	0.869	0.943	0.922	0.971	0.888	0.906	0.933	0.916

Table A.13

Full result of technical efficiency score of the second rice (Cont.)

Efficiency score of the second rice																						
Province	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Samut Songkhram	0.879	0.657	1.000	1.000	0.971	0.901	0.948	1.000	1.000	0.967	0.985	0.969	0.908	0.882	0.843	0.947	0.969	1.000	0.836	0.964	0.629	0.929
Phetchaburi	1.000	0.860	0.841	0.905	0.839	0.863	0.801	0.800	0.867	0.844	0.872	0.868	0.835	0.826	0.785	0.989	0.996	0.997	0.972	1.000	0.948	0.974
Prachuap Khiri Khan	0.535	0.632	0.485	0.526	0.620	0.783	0.695	0.633	0.610	0.607	0.676	0.665	0.655	0.657	0.631	0.733	0.711	0.752	0.865	0.636	0.781	0.813
Central	0.954	0.921	0.934	0.926	0.893	0.936	0.933	0.926	0.946	0.940	0.955	0.963	0.955	0.875	0.925	0.967	0.958	0.933	0.943	0.936	0.941	0.951
Nakhon Ratchasima	0.787	0.782	0.704	0.854	0.748	0.638	0.757	0.781	0.757	0.779	0.819	0.797	0.842	0.763	0.757	0.813	0.718	0.783	0.763	0.889	0.814	0.886
Buri Ram	0.610	0.399	0.668	0.468	0.348	0.647	0.558	0.498	0.481	0.487	0.578	0.621	0.676	0.638	0.625	0.694	0.640	0.669	0.675	0.630	0.659	0.737
Surin	0.770	0.378	0.376	0.473	0.577	0.574	0.618	0.624	0.577	0.616	0.623	0.649	0.576	0.651	0.629	0.588	0.600	0.611	0.599	0.555	0.559	0.628
Si Sa Ket	0.656	0.379	0.543	0.543	0.588	0.550	0.606	0.589	0.584	0.588	0.623	0.634	0.587	0.620	0.633	0.636	0.673	0.671	0.655	0.704	0.684	0.739
Ubon Ratchathani	0.649	0.627	0.617	0.522	0.485	0.560	0.649	0.799	0.776	0.658	0.829	0.879	0.893	0.880	0.894	0.775	0.732	0.707	0.657	0.660	0.735	0.750
Yasothon	0.622	0.667	0.554	0.535	0.576	0.583	0.624	0.686	0.617	0.608	0.660	0.680	0.707	0.652	0.680	0.708	0.690	0.736	0.714	0.709	0.717	0.756
Chaiyaphum	0.704	0.492	0.700	0.683	0.816	0.561	0.728	0.715	0.640	0.634	0.733	0.748	0.758	0.693	0.699	0.751	0.739	0.752	0.736	0.717	0.745	0.815
Amnat Charoen	0.601	0.450	0.517	0.471	0.463	0.663	0.641	0.825	-	0.927	0.861	0.865	0.670	0.928	0.881	0.748	0.723	0.716	0.740	0.791	0.691	0.688
Bueng Kan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.882	0.770	0.945	0.851	0.766	0.735	0.745
Nong Bua Lam Phu	0.671	0.758	0.645	0.608	0.740	0.724	0.681	0.837	0.934	0.918	0.934	0.849	0.883	0.815	0.888	0.847	0.822	0.781	0.789	0.734	0.738	0.792
Khon Kaen	1.000	0.613	0.768	0.758	0.568	0.652	0.801	0.700	0.669	0.673	0.700	0.710	0.773	0.674	0.720	0.780	0.595	0.728	0.698	0.707	0.745	0.803
Udon Thani	0.423	0.669	0.772	0.907	0.682	0.718	0.756	0.783	0.658	0.689	0.765	0.729	0.713	0.731	0.749	0.707	0.777	0.750	0.710	0.703	0.692	0.693
Loei	1.000	0.763	1.000	0.878	0.717	0.733	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.993	0.949	0.761	0.523	0.873	0.888	0.712
Nong Khai	0.929	0.585	0.719	0.488	0.588	0.610	0.684	0.671	0.680	0.645	0.723	0.724	0.723	0.767	0.750	0.773	0.745	0.744	0.720	0.687	0.671	0.714
Maha Sarakham	0.689	0.701	0.666	0.650	0.718	0.779	0.755	0.734	0.747	0.744	0.774	0.769	0.768	0.675	0.757	0.826	0.726	0.811	0.778	0.787	0.779	0.810
Roi Et	0.644	0.699	0.571	0.620	0.807	0.838	0.625	0.654	0.713	0.720	0.791	0.765	0.766	0.666	0.710	0.729	0.663	0.704	0.707	0.719	0.742	0.779
Kalasin	0.748	0.764	0.727	0.755	0.744	0.633	0.678	0.717	0.744	0.640	0.765	0.769	0.799	0.684	0.751	0.807	0.769	0.793	0.796	0.794	0.799	0.828
Sakon Nakhon	0.549	0.674	0.622	0.444	0.655	0.608	0.624	0.421	0.413	0.536	0.648	0.703	0.672	0.705	0.718	0.706	0.722	0.714	0.690	0.624	0.694	0.722
Nakhon Phanom	1.000	0.559	0.694	0.723	0.520	0.778	0.771	0.732	0.720	0.678	0.756	0.767	0.682	0.825	0.814	0.722	0.699	0.665	0.693	0.643	0.643	0.691

Table A.13

Full result of technical efficiency score of the second rice (Cont.)

Efficiency score of the second rice																						
Province	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mukdahan	0.866	0.443	0.501	0.481	0.392	1.000	0.894	1.000	-	1.000	1.000	1.000	1.000	1.000	1.000	0.985	1.000	0.697	0.689	0.641	0.684	0.722
Northeastern	0.777	0.681	0.683	0.706	0.695	0.669	0.717	0.717	0.717	0.672	0.761	0.761	0.778	0.704	0.736	0.763	0.701	0.744	0.722	0.735	0.741	0.786
Chiang Mai	0.985	1.000	0.978	1.000	1.000	1.000	0.926	1.000	1.000	1.000	1.000	0.994	0.969	1.000	1.000	1.000	1.000	1.000	1.000	0.946	0.996	0.992
Lamphun	1.000	0.894	1.000	1.000	0.982	0.933	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Lampang	0.831	0.765	0.797	0.702	0.668	0.732	0.995	0.922	0.840	0.904	0.886	0.958	1.000	0.954	0.940	0.882	0.900	0.840	0.818	0.804	0.843	0.844
Uttaradit	0.937	0.893	0.946	0.670	0.953	0.951	0.950	0.973	0.966	0.935	0.922	0.968	0.910	0.825	0.831	0.899	0.922	0.906	0.897	0.880	0.848	0.873
Phrae	-	1.000	0.781	0.646	0.720	0.803	0.774	0.970	0.679	0.816	0.846	0.894	0.764	0.746	0.742	0.857	0.832	0.744	0.823	0.774	0.796	0.807
Nan	0.631	0.725	0.907	0.884	1.000	0.710	0.960	0.818	0.985	0.944	0.948	0.980	0.954	0.843	0.850	0.832	0.813	0.794	0.772	0.779	0.769	0.772
Phayao	0.838	0.727	0.827	1.000	0.824	0.864	1.000	0.900	0.895	0.870	0.913	0.902	1.000	1.000	0.900	0.971	0.900	0.915	0.916	0.926	0.904	0.888
Chiang Rai	1.000	1.000	1.000	1.000	0.942	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Mae Hong Son	-	0.519	0.670	0.627	1.000	0.733	0.773	0.666	-	0.786	-	0.734	0.776	0.850	0.836	1.000	0.878	1.000	1.000	1.000	1.000	1.000
Nakhon Sawan	0.856	0.688	0.672	0.773	0.943	0.876	0.980	0.975	0.917	0.977	0.921	0.971	0.900	0.851	0.850	0.941	0.905	0.882	0.849	0.788	0.829	0.934
Uthai Thani	0.848	0.812	0.742	0.816	0.829	0.715	0.839	0.817	0.831	0.868	0.850	0.857	0.831	0.759	0.767	0.897	0.868	0.821	0.838	0.831	0.808	0.887
Kamphaeng Phet	0.923	0.967	0.958	0.988	0.920	0.955	0.875	0.884	0.916	0.868	0.871	0.912	0.901	0.838	0.790	0.956	0.945	0.917	0.847	0.816	0.840	0.896
Tak	0.769	0.981	1.000	0.804	0.817	0.956	0.992	1.000	0.961	1.000	0.916	0.948	0.981	0.943	0.946	1.000	0.873	0.867	0.790	0.662	0.792	0.838
Sukhothai	0.886	0.823	0.892	0.892	0.883	0.919	0.852	0.873	0.857	0.845	0.876	0.900	0.857	0.868	0.861	0.873	0.860	0.803	0.821	0.795	0.805	0.839
Phitsanulok	0.927	0.906	0.966	0.876	0.917	0.871	0.819	0.820	0.884	0.909	0.880	0.913	0.869	0.842	0.837	1.000	0.989	0.859	0.853	0.795	0.826	0.883
Phichit	0.964	1.000	1.000	1.000	0.948	0.980	0.972	0.944	0.927	0.915	0.936	1.000	0.969	0.946	0.907	0.980	0.921	0.899	0.872	0.839	0.813	0.875
Phetchabun	0.910	0.681	0.590	0.428	0.761	0.751	0.679	0.735	0.635	0.686	0.700	0.700	0.629	0.658	0.577	0.758	0.747	0.748	0.736	0.825	0.834	0.832
Northern	0.918	0.887	0.917	0.892	0.927	0.917	0.910	0.909	0.910	0.916	0.905	0.945	0.907	0.873	0.859	0.948	0.928	0.887	0.875	0.848	0.846	0.898
Nakhon Si Thammarat	0.499	0.596	0.601	0.539	0.536	0.654	0.552	0.577	0.575	0.634	0.649	0.644	0.648	0.593	0.598	0.658	0.704	0.734	0.697	0.720	0.710	0.700
Krabi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phangnga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A.13

Full result of technical efficiency score of the second rice (Cont.)

Efficiency score of the second rice																						
Province	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Phuket	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surat Thani	0.723	0.706	0.774	0.529	0.643	0.467	0.776	0.762	0.618	0.734	0.753	0.749	0.770	0.741	0.500	0.752	0.825	0.638	0.763	0.841	0.832	0.848
Ranong	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chumphon	0.689	0.507	0.664	0.624	0.810	0.701	0.810	0.888	0.492	0.729	0.776	0.786	0.749	0.799	0.772	0.767	0.812	0.596	0.730	0.748	0.764	0.719
Songkhla	0.645	0.661	0.646	0.640	0.643	0.651	0.613	0.608	0.652	0.638	0.675	0.735	0.718	0.702	0.698	0.797	0.788	0.761	0.769	0.798	0.780	0.795
Satun	0.482	-	0.685	0.728	0.671	0.570	0.722	0.773	-	0.858	0.962	1.000	0.987	0.990	0.993	0.963	1.000	0.877	0.872	0.820	0.846	0.599
Trang	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phatthalung	0.560	0.794	0.735	0.680	0.589	0.621	0.578	0.598	0.625	0.586	0.663	0.667	0.685	0.681	0.683	0.706	0.766	0.756	0.747	0.801	0.781	0.770
Pattani	0.622	0.675	1.000	0.974	0.627	0.637	-	0.733	0.727	0.765	0.827	0.844	0.874	0.921	0.904	0.813	0.998	-	0.859	1.000	0.979	1.000
Yala	0.542	-	0.920	0.646	-	0.474	0.493	0.543	-	0.541	0.749	0.791	0.949	0.897	0.904	0.727	0.973	1.000	1.000	-	1.000	0.811
Narathiwat	0.859	0.846	0.883	0.798	0.705	0.471	0.735	0.742	0.575	0.797	0.712	0.738	0.763	0.833	0.791	0.830	0.858	0.591	0.947	1.000	0.963	0.824
Southern	0.610	0.679	0.675	0.634	0.586	0.635	0.581	0.609	0.598	0.642	0.673	0.695	0.696	0.674	0.656	0.715	0.760	0.750	0.741	0.777	0.757	0.768
Whole country	0.927	0.893	0.906	0.892	0.882	0.911	0.904	0.899	0.913	0.913	0.918	0.933	0.912	0.838	0.861	0.924	0.918	0.886	0.879	0.869	0.871	0.905

Table A.14

Full result of TFP change of the second rice

TFP change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bangkok Metropolis	-21.36	-12.22	14.26	18.56	5.47	-13.23	4.23	-3.57	13.84	1.89	7.08	1.53	-12.17	4.91	-9.70	14.43	-2.68	1.33	-8.01	-1.34	-0.78
Samut Prakan	-11.86	2.90	-2.93	29.56	-19.04	10.87	-4.47	-5.59	12.70	-6.68	3.05	1.99	-5.66	8.25	-4.41	-1.70	-6.86	3.95	-2.77	1.85	2.72
Nonthaburi	-5.23	-2.07	-8.69	11.05	-2.36	-1.05	-0.48	-0.67	3.31	-1.25	1.02	-1.60	-10.78	5.62	4.84	-2.35	-6.00	-0.50	-8.36	7.51	2.56
Pathum Thani	-1.68	5.11	3.66	2.72	14.25	-14.29	3.20	-5.87	9.65	-0.99	-0.34	7.04	-11.69	-0.63	9.90	5.13	-3.57	-1.26	-10.35	13.38	3.89
Phra Nakhon Si Ayutthaya	-14.72	7.21	3.68	-1.46	0.75	6.35	-0.06	-5.26	8.30	0.31	11.30	-4.25	-13.37	5.76	1.63	-3.68	-4.27	-2.91	-5.52	8.41	1.26
Ang Thong	2.70	-1.82	5.32	-2.96	3.39	-13.57	5.43	-2.50	6.89	0.89	4.71	-1.47	-21.67	18.00	9.60	-5.92	-6.30	-2.75	-13.03	17.85	6.59
Lop Buri	-2.99	10.62	0.75	16.26	-19.65	13.92	1.56	-3.70	5.28	0.90	10.47	1.82	-20.20	9.94	2.74	3.55	-21.18	-1.02	-8.14	17.22	5.48
Sing Buri	-5.04	2.37	5.93	-7.31	-6.49	15.18	-0.78	-2.53	4.31	-2.55	1.16	-1.85	-21.74	14.27	5.83	0.90	-12.63	-2.41	-9.02	19.48	3.90
Chai Nat	4.13	0.35	3.81	2.77	-0.78	0.27	2.32	-2.83	5.98	-2.15	5.06	-2.98	-23.97	22.88	6.49	-2.12	-5.87	-4.40	3.67	3.70	4.02
Saraburi	-25.41	25.24	7.83	-8.71	17.61	-4.48	-2.05	3.35	3.04	1.50	3.99	4.97	-15.09	10.80	-2.63	0.00	-9.87	3.80	-6.62	12.01	1.82
Chon Buri	16.24	55.95	16.20	-27.56	-22.44	10.46	16.10	3.66	4.31	-2.23	-2.89	3.32	9.83	-20.66	58.55	-3.74	-0.09	5.55	-3.13	1.77	-0.09
Rayong	2.45	7.02	-30.72	24.06	6.87	7.26	1.12	-3.07	16.47	-4.75	3.97	4.99	-9.14	3.25	-1.30	-4.75	2.99	0.12	-0.22	0.81	3.18
Chanthaburi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trat	-	-1.29	2.93	-21.32	4.37	9.02	3.71	-11.86	13.24	16.10	2.04	-9.33	12.45	-16.44	14.42	10.36	-10.68	4.64	-7.17	21.31	3.02
Chachoengsao	-10.62	-26.97	19.32	7.63	11.29	0.78	-0.89	-18.81	9.53	2.25	2.83	2.25	-2.43	3.64	-3.44	8.67	2.41	-4.40	-10.84	8.52	2.34
Prachin Buri	-36.59	10.47	29.95	-13.21	0.74	16.70	-1.33	31.92	-9.64	-5.43	10.80	1.67	-14.53	5.35	-3.94	19.25	-3.57	-6.92	-0.89	-0.47	13.78
Nakhon Nayok	-40.46	29.83	4.24	14.27	-12.79	3.96	1.87	-0.51	4.12	8.13	2.96	7.64	-12.96	7.66	4.45	6.28	2.35	-9.29	4.72	5.32	2.32
Sa Kaeo	-	-	41.06	-5.50	-9.96	34.31	0.82	-14.21	19.39	-1.08	2.10	1.66	-15.14	-6.24	5.07	2.24	0.83	3.17	-11.87	16.76	1.81
Ratchaburi	-11.49	-6.53	1.90	12.40	-4.15	-0.42	2.77	-0.89	2.32	0.39	1.23	-0.99	-4.76	5.46	5.99	-0.25	0.99	-7.96	-1.19	4.19	4.50
Kanchanaburi	0.11	4.47	-0.07	6.45	-2.74	-1.38	0.78	0.44	1.07	-0.83	0.21	2.05	-6.53	5.39	-0.96	1.66	1.52	-6.11	3.20	1.83	2.44
Suphan Buri	-6.27	2.26	-6.16	-0.88	-2.51	8.80	-2.16	-4.35	5.09	-1.16	3.61	-2.62	-24.94	21.75	7.53	-2.92	-4.52	2.01	-1.40	0.20	0.50
Nakhon Pathom	-6.90	-3.13	-9.74	12.18	1.80	0.28	0.04	0.54	5.47	-0.85	1.69	1.52	-6.85	-0.41	2.29	0.15	-3.67	-2.12	-1.42	2.22	-0.92
Samut Sakhon	-8.13	1.63	-6.12	5.82	-7.43	-9.62	2.48	9.39	2.38	-0.28	1.71	-1.60	-2.92	6.94	1.53	-1.27	2.86	-8.18	-2.03	8.46	-2.27

Table A.14

Full result of TFP change of the second rice (Cont.)

TFP change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Samut Songkhram	-29.17	54.43	6.77	-3.05	-10.67	9.04	5.60	-6.39	0.92	-2.15	0.84	-3.37	-4.93	-2.09	6.16	1.56	2.09	-16.46	11.44	-31.52	46.97
Phetchaburi	-11.93	-1.99	7.67	-7.46	-1.78	-3.38	0.92	3.29	1.99	-0.67	1.95	-0.74	-3.28	-2.64	18.91	0.10	-0.33	-2.75	-0.88	-0.36	2.48
Prachuap Khiri Khan	13.03	-26.99	15.96	17.26	20.66	-13.92	-10.58	-1.51	6.29	6.54	-0.39	1.51	-2.29	-1.42	8.44	-3.28	3.36	16.84	-28.36	27.90	5.50
Central	-0.07	-0.01	0.00	0.02	-0.01	0.01	0.00	-0.03	0.05	-0.01	0.04	-0.01	-0.16	0.09	0.04	0.00	-0.05	-0.02	-0.05	0.05	0.02
Nakhon Ratchasima	-3.44	-15.11	35.23	-2.18	-17.66	23.16	-0.47	-4.43	7.33	2.48	-2.55	5.50	-14.09	4.59	1.24	-11.87	6.39	-1.63	12.00	-3.60	8.87
Buri Ram	-34.44	62.74	-27.22	-22.65	74.95	-21.89	-20.14	-3.24	5.63	14.41	4.45	10.14	-9.29	0.62	6.33	-9.27	1.86	2.02	-10.46	7.90	14.11
Surin	-49.34	-9.09	32.34	22.07	-0.02	4.54	-1.09	-8.35	11.87	-2.93	3.36	-10.03	9.18	-1.15	-10.02	-0.80	-1.38	-0.62	-10.87	3.94	15.35
Si Sa Ket	-43.88	27.03	11.59	8.48	-6.34	-0.40	-4.32	-0.21	5.95	2.24	-0.36	-5.42	1.97	4.72	-2.42	2.39	-1.62	-1.80	2.63	2.28	8.48
Ubon Ratchathani	-12.34	-13.38	-13.03	2.61	14.64	5.61	13.57	0.74	-10.27	20.78	3.23	-0.03	-4.69	4.18	-13.64	-10.88	-4.15	-6.51	-4.72	15.01	2.67
Yasothon	9.56	-23.61	4.80	8.12	-0.70	5.94	6.93	-7.94	3.41	4.32	1.23	6.35	-10.44	7.21	0.26	-4.39	2.82	-2.80	-4.18	6.50	4.81
Chaiyaphum	-40.32	40.50	0.80	28.08	-39.42	14.44	-1.44	-9.72	5.00	10.86	-0.33	3.14	-10.86	4.34	4.31	-4.64	-0.99	-0.46	-6.35	8.28	10.53
Amnat Charoen	-23.31	4.19	-7.16	3.72	42.45	-17.61	8.61	-	-	-5.61	1.29	-26.55	32.44	-1.72	-13.33	-9.82	-1.75	3.68	-1.53	-7.43	-0.09
Bueng Kan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-17.03	27.44	-12.40	-13.79	0.62	3.08
Nong Bua Lam Phu	-12.92	-20.72	24.12	26.85	-10.71	-14.37	24.30	12.06	7.50	-3.23	-8.17	6.46	-9.81	12.45	-5.45	-6.93	-4.78	3.10	-9.94	4.25	10.61
Khon Kaen	-40.14	18.07	4.48	-20.47	8.54	18.94	-16.44	-8.63	6.77	-0.57	1.68	11.85	-15.31	9.79	1.43	-23.83	18.06	-3.27	-2.65	11.30	8.04
Udon Thani	50.75	4.21	43.88	-25.18	-4.12	-6.40	4.16	-15.86	14.06	7.11	-2.51	-2.16	0.16	5.79	-6.87	5.58	-0.12	-3.88	-4.79	1.35	2.47
Loei	-51.50	16.62	40.03	-26.78	4.71	8.29	6.74	12.17	-7.14	3.23	4.72	-8.23	-3.81	4.66	-4.29	-17.51	-1.61	-31.23	53.80	4.10	-18.45
Nong Khai	-37.77	23.02	-34.01	22.94	-2.37	8.31	-0.36	2.01	3.64	6.28	1.57	1.37	3.32	0.95	0.57	-8.40	-3.65	-2.24	-8.10	2.01	7.36
Maha Sarakham	6.75	-3.95	-2.76	10.28	3.86	2.13	-3.86	-3.91	3.27	-0.08	1.84	3.03	-13.99	14.80	3.19	-12.78	10.85	-4.72	-2.12	4.18	3.43
Roi Et	15.89	-14.95	1.56	28.93	-0.91	-21.06	1.42	5.93	4.43	6.11	-1.43	3.20	-15.27	9.40	-3.03	-9.49	5.53	-0.37	-0.61	7.58	5.22
Kalasin	3.73	-3.00	3.37	-1.49	-18.41	11.72	4.34	-2.18	-8.26	15.60	2.86	6.74	-16.57	12.64	1.46	-5.27	2.57	-0.45	-2.81	5.16	4.91
Sakon Nakhon	14.85	-19.56	-10.60	47.94	-6.28	-16.91	-33.84	-1.24	38.60	16.69	7.34	-2.73	1.88	5.77	-4.57	-2.19	0.60	-1.88	-14.43	16.96	5.11
Nakhon Phanom	-55.44	6.44	36.88	-29.19	42.93	-15.86	-2.85	-1.14	0.09	8.71	2.55	-10.14	16.79	2.36	-12.94	-6.63	-2.89	6.29	-11.09	5.26	7.10

Table A.14

Full result of TFP change of the second rice (Cont.)

TFP change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mukdahan	-49.61	-8.53	2.02	-15.58	150.52	-28.52	7.69	-	-	2.47	1.39	-7.94	-4.12	4.75	0.37	-8.37	-23.51	-0.80	-15.63	12.60	7.87
Northeastern	-0.15	-0.01	-0.02	-0.01	-0.08	0.06	-0.02	-0.03	0.00	0.09	0.01	0.04	-0.12	0.07	-0.01	-0.10	0.03	-0.02	-0.04	0.05	0.06
Chiang Mai	16.48	-19.44	17.56	8.91	-4.23	-23.62	9.37	-1.76	6.62	-3.48	-5.67	-3.28	0.34	1.17	0.94	-4.69	-1.19	0.73	-14.22	11.72	3.89
Lamphun	-2.77	21.35	-16.43	-7.38	2.11	6.31	-15.76	13.68	-7.42	-3.50	5.67	-2.77	-11.57	5.40	-0.40	-5.64	-3.34	0.04	-8.33	9.43	4.92
Lampang	-16.54	-10.09	-5.74	-2.55	12.65	10.88	-3.10	-8.53	13.01	-5.10	4.10	5.27	-9.30	1.01	-2.96	-7.20	-5.42	-2.50	-9.23	10.71	2.62
Uttaradit	-10.68	4.22	-23.14	50.03	-6.60	6.90	-0.65	-5.33	3.59	-5.22	8.18	-5.36	-14.13	5.46	2.06	2.28	-3.47	-1.02	-5.73	1.92	2.97
Phrae	-	-29.35	-5.05	18.28	11.80	-9.48	22.82	-28.82	26.86	-1.94	6.38	-12.47	-5.07	2.66	8.90	-3.38	-11.58	9.94	-8.99	8.74	3.22
Nan	26.14	6.54	3.57	16.75	-26.28	9.53	-11.04	19.90	-0.72	-2.12	0.49	-1.72	-15.09	3.67	-2.73	-7.65	-3.14	-3.34	-2.31	4.47	2.28
Phayao	-3.59	2.71	72.76	-33.36	8.79	-6.91	-6.88	-0.23	1.10	0.71	-4.88	5.37	-6.31	-5.42	5.63	-11.41	0.80	-0.07	-2.90	1.70	0.27
Chiang Rai	0.35	-4.64	-2.87	-0.85	-1.47	1.01	0.11	-1.76	1.12	5.77	0.37	-5.82	-4.08	5.47	-5.31	-5.53	1.16	2.33	-5.44	3.53	3.07
Mae Hong Son	-	1.84	3.62	99.43	-29.65	-16.80	-12.13	-	-	-	-	3.48	3.43	2.43	35.34	-28.03	34.86	-7.35	-12.68	3.98	3.64
Nakhon Sawan	-24.51	-5.68	14.37	36.69	-12.77	14.16	-0.74	-8.52	12.22	-6.48	8.14	-4.94	-14.34	4.37	13.31	-3.96	-4.81	-5.61	-8.55	7.76	12.73
Uthai Thani	-8.93	-9.20	11.67	3.82	-16.99	21.33	-1.62	-3.15	10.96	-5.33	3.53	-2.10	-13.62	6.90	13.88	-3.58	-6.91	1.48	-4.06	2.44	9.75
Kamphaeng Phet	-0.53	-3.62	2.22	5.36	-4.67	-2.56	-0.94	-4.08	4.70	-1.96	8.99	0.04	-16.44	-1.02	25.53	-2.78	-5.33	-7.80	-6.71	6.24	5.47
Tak	18.48	-2.09	-15.16	3.74	8.22	-7.90	2.26	-4.05	12.52	-12.59	4.32	1.90	-6.10	3.60	7.43	-16.08	-3.89	-5.33	-19.79	23.93	8.69
Sukhothai	-9.60	6.25	5.56	1.83	-1.15	-2.58	0.62	-7.19	5.94	-0.34	4.79	-3.12	-7.44	5.81	-0.84	-1.57	-8.16	1.90	-6.77	6.38	4.46
Phitsanulok	-7.93	3.18	-8.11	11.19	-8.85	-2.25	0.70	1.36	11.72	-6.96	6.48	-3.48	-12.30	6.31	23.03	-3.42	-13.80	-2.31	-8.58	8.50	6.02
Phichit	-3.62	-3.11	-0.82	6.97	-6.37	6.14	-4.24	-7.80	6.94	-0.12	12.70	-1.50	-13.09	0.99	10.41	-6.76	-3.61	-4.27	-5.71	1.08	5.74
Phetchabun	-29.38	-19.36	-17.86	91.31	-13.22	-9.70	6.20	-13.32	15.99	-3.68	1.38	-6.99	-2.06	-6.98	22.67	-1.73	-4.60	0.32	7.46	3.66	2.43
Northern	-0.09	-0.02	-0.01	0.14	-0.08	0.03	-0.01	-0.05	0.08	-0.04	0.08	-0.03	-0.13	0.03	0.11	-0.04	-0.06	-0.03	-0.07	0.05	0.06
Nakhon Si Thammarat	15.03	-0.62	-5.18	-0.62	17.27	-11.88	3.22	-1.66	13.81	-1.68	1.66	3.79	-10.40	3.34	3.15	7.21	0.99	-3.05	-0.57	3.05	-1.80
Krabi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phangnga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A.14

Full result of TFP change of the second rice (Cont.)

TFP change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Phuket	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surat Thani	-4.45	-0.62	-25.59	29.72	-25.85	56.67	-0.78	-19.20	24.25	-0.83	-3.02	4.32	-6.76	-31.11	48.51	3.55	-22.09	19.80	3.24	2.24	2.77
Ranong	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chumphon	-30.87	13.82	7.07	37.00	-13.52	11.18	8.04	-43.34	56.07	0.99	1.33	-3.42	4.20	0.17	-3.24	-0.22	-26.38	22.49	-3.74	7.46	-3.93
Songkhla	-2.67	-4.59	7.50	0.48	-3.14	-1.06	-1.22	4.60	1.28	1.65	11.60	-0.33	-9.48	5.95	10.89	-0.65	-5.44	0.04	0.52	3.41	1.48
Satun	-	-	11.03	10.02	-14.90	-5.95	9.96	-	-	12.78	3.16	-8.34	-3.41	3.70	7.38	-14.98	-3.86	2.84	-16.17	4.59	-27.29
Trang	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phatthalung	43.66	-10.98	-3.15	-10.87	1.07	-0.66	-1.22	4.47	-1.57	8.26	0.75	5.16	-3.50	2.78	-1.04	5.97	-3.66	-1.04	2.37	1.69	-0.52
Pattani	8.96	20.30	-2.98	-25.12	1.27	-	-	0.37	7.51	4.46	1.19	-0.29	-0.44	1.57	-1.16	2.98	-	-	2.90	3.05	9.43
Yala	-	-	-17.87	-	-	-19.59	15.35	-	-	34.63	3.53	10.95	-8.50	4.78	-14.96	16.56	18.14	0.41	-	-	-21.09
Narathiwat	-12.47	-9.96	-13.91	-4.24	-32.27	27.57	6.13	-22.21	48.54	-11.26	5.12	-1.55	6.45	-1.15	2.57	-9.12	-12.83	51.74	-6.76	-0.62	-13.01
Southern	0.06	-0.04	-0.01	-0.03	0.04	-0.03	0.01	-0.01	0.11	0.01	0.03	0.02	-0.08	0.03	0.05	0.04	-0.03	-0.01	0.01	0.03	0.00
Whole country	-0.08	-0.01	-0.01	0.06	-0.04	0.02	0.00	-0.04	0.06	-0.01	0.05	-0.01	-0.14	0.07	0.06	-0.03	-0.05	-0.02	-0.06	0.05	0.04

Table A.15

Full result of technical efficiency change of the second rice

Technical efficiency change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bangkok Metropolis	-16.79	-10.77	15.78	5.95	12.96	-19.44	4.74	6.10	7.23	3.36	0.79	-0.92	0.93	0.00	-10.73	12.02	-0.80	0.81	0.00	0.00	0.00
Samut Prakan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nonthaburi	0.00	0.00	-7.09	6.69	0.88	-4.55	-1.33	5.48	-1.40	2.09	-1.23	-2.78	-5.88	-0.69	10.86	-1.73	-5.55	3.13	-6.60	3.08	3.47
Pathum Thani	5.05	2.47	0.00	-11.59	13.11	-10.43	1.47	-0.33	3.16	0.68	-2.32	8.81	-3.33	-4.10	7.86	0.00	0.00	0.00	-6.17	6.58	0.00
Phra Nakhon Si Ayutthaya	-10.52	5.61	0.89	-8.35	5.09	9.97	0.00	-0.08	0.08	0.00	0.00	-0.37	0.37	0.00	0.00	-4.57	-0.17	0.01	-2.19	6.84	-2.32
Ang Thong	7.88	-0.58	5.74	-4.28	8.42	-16.90	4.36	2.35	1.98	3.89	2.56	-2.10	-17.36	11.11	15.27	-5.85	-5.72	-1.81	-9.59	11.71	6.46
Lop Buri	-2.54	12.56	-1.69	12.90	-14.20	9.77	0.89	1.19	0.53	3.25	4.58	0.00	-8.59	5.59	0.94	2.02	-20.36	0.73	-5.06	11.24	4.71
Sing Buri	-6.20	3.63	2.88	-9.96	-0.77	8.39	-1.78	4.48	-0.50	-0.24	-0.75	-1.47	-16.31	5.91	10.20	-1.11	-11.34	-1.54	-5.74	13.56	3.29
Chai Nat	0.00	0.00	0.00	-4.59	4.81	0.00	0.00	0.00	0.00	0.00	0.00	-0.99	-18.15	18.07	4.50	-5.74	-4.45	-3.12	8.77	-2.54	0.30
Saraburi	-26.61	26.85	4.74	-12.30	23.28	-5.85	-3.24	8.79	-4.12	3.58	-1.28	6.18	-4.00	5.90	-5.69	-3.93	-8.17	4.87	-3.46	5.86	-0.16
Chon Buri	19.13	73.13	0.00	-30.89	-23.79	14.85	17.26	5.38	-3.65	4.90	-3.29	-0.05	12.42	-24.56	61.24	-2.53	2.73	0.00	0.00	0.00	0.00
Rayong	3.48	6.73	-31.14	24.76	9.70	3.11	0.11	-1.94	4.73	0.61	3.70	1.65	-6.52	0.38	5.35	-4.10	5.21	-0.16	4.06	-4.75	3.39
Chanthaburi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trat	-	13.29	-4.62	-23.52	4.09	4.62	4.37	-9.90	7.64	22.62	-0.18	-12.24	15.18	-18.64	22.95	11.39	-5.64	2.63	-3.40	15.69	2.44
Chachoengsao	-3.26	-25.59	18.47	-6.32	23.77	-2.14	-1.02	-14.20	4.55	3.66	1.34	1.10	4.59	0.92	-4.53	5.42	3.17	-0.95	-9.37	7.70	2.86
Prachin Buri	-33.73	14.70	32.72	-22.66	5.80	6.62	0.91	36.25	-15.01	-3.89	7.34	0.78	-5.78	1.56	-5.67	18.60	-2.33	-4.62	3.04	1.11	8.91
Nakhon Nayok	-36.11	31.07	3.16	3.63	-6.89	1.31	0.85	5.85	-0.68	11.18	0.79	6.15	-4.03	3.66	2.96	4.55	3.08	-8.51	7.05	4.55	2.16
Sa Kaeo	-	-	28.82	-9.39	-3.65	27.87	1.21	-12.40	11.33	4.29	1.71	-1.95	-13.13	-9.18	12.37	1.86	3.00	2.66	-8.18	11.19	2.21
Ratchaburi	-11.34	-6.25	2.46	12.27	-0.94	-2.98	1.74	4.60	-3.03	3.93	-1.35	-3.02	0.54	-0.95	12.08	0.38	1.58	-7.21	1.83	-0.68	2.98
Kanchanaburi	4.93	5.68	0.89	6.34	1.34	-5.10	-0.23	6.86	-4.72	3.20	-2.19	-1.11	-4.48	2.92	4.83	2.10	2.25	-5.35	6.46	-3.42	0.82
Suphan Buri	-0.42	3.90	-4.46	-4.48	0.78	6.34	-3.04	0.94	0.13	1.30	1.36	-2.17	-19.85	17.34	8.53	-2.34	-3.89	3.84	0.59	-3.85	1.86
Nakhon Pathom	-0.76	0.76	-9.25	1.66	8.39	-4.44	-0.91	5.61	0.00	0.00	0.00	0.00	0.00	-2.87	2.95	0.00	0.00	0.00	0.00	0.00	0.00
Samut Sakhon	-0.31	2.88	-7.70	1.19	-4.27	-13.43	1.80	19.47	-6.67	3.85	-0.89	-4.09	1.01	-0.83	8.52	-2.24	5.37	-8.52	1.96	3.01	-1.84

Table A.15

Full result of technical efficiency change of the second rice (Cont.)

Technical efficiency change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Samut Songkhram	-25.29	52.31	0.00	-2.86	-7.26	5.23	5.48	0.00	-3.28	1.82	-1.57	-6.36	-2.85	-4.38	12.26	2.37	3.19	-16.36	15.30	-34.83	47.85
Phetchaburi	-13.96	-2.21	7.52	-7.28	2.87	-7.18	-0.09	8.39	-2.73	3.37	-0.49	-3.81	-1.11	-4.91	26.02	0.65	0.13	-2.50	2.88	-5.16	2.68
Prachuap Khiri Khan	17.98	-23.23	8.50	17.90	26.32	-11.27	-8.96	-3.67	-0.42	11.41	-1.69	-1.49	0.30	-3.93	16.22	-3.07	5.75	15.09	-26.51	22.86	4.10
Central	-0.04	0.00	-0.01	-0.04	0.04	0.00	-0.01	0.02	0.00	0.02	0.00	-0.01	-0.09	0.05	0.04	-0.01	-0.03	-0.01	-0.02	0.02	0.01
Nakhon Ratchasima	-0.68	-9.97	21.37	-12.38	-14.71	18.53	3.21	-3.02	2.90	5.15	-2.71	5.67	-9.44	-0.71	7.29	-11.64	9.00	-2.55	16.59	-8.45	8.83
Buri Ram	-34.58	67.49	-29.91	-25.63	85.62	-13.80	-10.73	-3.33	1.12	18.76	7.43	8.95	-5.68	-2.03	11.07	-7.81	4.54	0.96	-6.68	4.58	11.84
Surin	-50.97	-0.44	25.94	21.91	-0.55	7.75	0.96	-7.55	6.72	1.08	4.24	-11.25	13.03	-3.39	-6.52	1.98	1.96	-1.99	-7.36	0.68	12.32
Si Sa Ket	-42.14	43.06	0.01	8.27	-6.48	10.32	-2.82	-0.89	0.71	5.94	1.74	-7.36	5.49	2.12	0.47	5.90	-0.30	-2.44	7.49	-2.80	8.05
Ubon Ratchathani	-3.41	-1.57	-15.36	-7.06	15.48	15.90	22.98	-2.86	-15.20	25.99	6.01	1.61	-1.47	1.65	-13.28	-5.57	-3.40	-7.19	0.59	11.23	2.10
Yasothon	7.29	-17.04	-3.30	7.61	1.16	7.03	9.99	-10.07	-1.49	8.60	3.00	4.04	-7.75	4.19	4.20	-2.60	6.65	-3.01	-0.60	1.05	5.44
Chaiyaphum	-30.15	42.32	-2.38	19.47	-31.28	29.79	-1.75	-10.55	-0.89	15.61	1.99	1.40	-8.65	0.85	7.48	-1.56	1.77	-2.15	-2.59	3.85	9.45
Amnat Charoen	-25.16	14.92	-8.83	-1.69	43.15	-3.35	28.70	-	-	-7.08	0.43	-22.49	38.54	-5.16	-15.07	-3.39	-0.91	3.28	6.98	-12.60	-0.45
Bueng Kan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-12.64	22.64	-9.94	-9.92	-4.10	1.43
Nong Bua Lam Phu	12.87	-14.92	-5.64	21.65	-2.16	-5.89	22.85	11.63	-1.78	1.80	-9.15	4.01	-7.68	8.92	-4.60	-2.98	-4.96	1.09	-6.97	0.44	7.38
Khon Kaen	-38.74	25.36	-1.34	-25.09	14.87	22.85	-12.59	-4.45	0.68	3.88	1.45	8.88	-12.78	6.86	8.23	-23.64	22.28	-4.05	1.17	5.41	7.80
Udon Thani	58.38	15.29	17.51	-24.86	5.38	5.32	3.56	-15.97	4.65	11.02	-4.71	-2.19	2.52	2.48	-5.56	9.90	-3.47	-5.43	-0.95	-1.48	0.11
Loei	-23.67	31.02	-12.22	-18.35	2.29	36.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.68	-4.45	-19.77	-31.25	66.75	1.72	-19.85
Nong Khai	-37.00	22.90	-32.14	20.53	3.70	12.15	-1.93	1.30	-5.14	12.11	0.21	-0.23	6.20	-2.21	3.03	-3.65	-0.10	-3.25	-4.52	-2.45	6.43
Maha Sarakham	1.71	-4.94	-2.44	10.53	8.43	-3.03	-2.74	1.76	-0.40	3.98	-0.60	-0.16	-12.11	12.11	9.12	-12.07	11.62	-4.05	1.17	-0.97	3.90
Roi Et	8.62	-18.42	8.75	30.05	3.90	-25.43	4.68	9.02	0.89	9.92	-3.34	0.22	-13.06	6.61	2.66	-9.08	6.18	0.39	1.74	3.24	4.92
Kalasin	2.18	-4.86	3.94	-1.51	-14.87	7.04	5.81	3.71	-14.03	19.61	0.57	3.79	-14.36	9.77	7.56	-4.76	3.18	0.31	-0.25	0.60	3.68
Sakon Nakhon	22.95	-7.80	-28.57	47.45	-7.12	2.52	-32.42	-1.92	29.74	20.76	8.55	-4.47	5.02	1.77	-1.67	2.28	-1.04	-3.36	-9.64	11.19	4.14
Nakhon Phanom	-44.11	24.21	4.15	-28.07	49.54	-0.83	-5.09	-1.60	-5.88	11.49	1.42	-10.98	20.87	-1.33	-11.34	-3.14	-4.81	4.11	-7.24	0.12	7.36

Table A.15

Full result of technical efficiency change of the second rice (Cont.)

Technical efficiency change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mukdahan	-48.86	13.02	-3.82	-18.59	155.15	-10.65	11.92	-	-	0.00	0.00	0.00	0.00	0.00	-1.54	1.57	-30.25	-1.25	-6.95	6.71	5.55
Northeastern	-0.13	0.01	-0.07	-0.04	-0.04	0.06	0.00	0.00	-0.06	0.13	0.00	0.02	-0.09	0.04	0.04	-0.08	0.05	-0.02	0.00	0.01	0.05
Chiang Mai	1.53	-2.22	2.27	0.00	0.00	-7.40	8.00	0.00	0.00	0.00	-0.62	-2.49	3.19	0.00	0.00	0.00	0.00	0.00	-5.38	5.28	-0.42
Lamphun	-10.64	11.90	0.00	-1.84	-4.96	7.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lampang	-7.93	4.24	-12.01	-4.72	9.50	35.93	-7.31	-8.88	7.55	-2.00	8.16	4.38	-4.58	-1.52	-6.18	2.03	-6.64	-2.62	-1.73	4.85	0.20
Uttaradit	-4.74	5.94	-29.15	42.26	-0.21	-0.10	2.46	-0.75	-3.22	-1.36	4.95	-5.96	-9.37	0.74	8.18	2.52	-1.69	-1.03	-1.85	-3.62	2.84
Phrae	-	-21.91	-17.21	11.41	11.45	-3.56	25.30	-30.02	20.28	3.63	5.62	-14.54	-2.33	-0.45	15.38	-2.92	-10.59	10.72	-5.95	2.75	1.48
Nan	14.91	25.07	-2.51	13.13	-28.96	35.15	-14.76	20.39	-4.16	0.40	3.34	-2.66	-11.59	0.83	-2.18	-2.29	-2.34	-2.73	0.96	-1.35	0.41
Phayao	-13.19	13.75	20.89	-17.57	4.77	15.79	-10.02	-0.55	-2.78	4.92	-1.21	10.90	0.00	-9.96	7.85	-7.30	1.70	0.02	1.11	-2.40	-1.74
Chiang Rai	0.00	0.00	0.00	-5.79	6.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mae Hong Son	-	29.14	-6.32	59.40	-26.70	5.53	-13.90	-	-	-	-	5.69	9.60	-1.63	19.55	-12.17	13.86	0.00	0.00	0.00	0.00
Nakhon Sawan	-19.60	-2.40	15.06	21.98	-7.12	11.91	-0.49	-6.03	6.59	-5.69	5.37	-7.35	-5.37	-0.11	10.72	-3.91	-2.54	-3.69	-7.24	5.25	12.73
Uthai Thani	-4.24	-8.60	9.89	1.63	-13.76	17.40	-2.60	1.68	4.43	-2.03	0.82	-3.06	-8.67	1.08	16.85	-3.14	-5.50	2.09	-0.83	-2.71	9.70
Kamphaeng Phet	4.72	-0.92	3.14	-6.87	3.84	-8.41	1.05	3.67	-5.26	0.36	4.71	-1.26	-6.98	-5.67	20.89	-1.14	-2.89	-7.69	-3.59	2.94	6.66
Tak	27.55	1.93	-19.59	1.61	17.01	3.77	0.79	-3.86	4.02	-8.35	3.47	3.46	-3.89	0.35	5.69	-12.74	-0.69	-8.83	-16.21	19.63	5.87
Sukhothai	-7.10	8.41	-0.04	-0.99	4.04	-7.22	2.40	-1.78	-1.47	3.75	2.68	-4.75	1.27	-0.79	1.42	-1.54	-6.59	2.16	-3.09	1.21	4.18
Phitsanulok	-2.24	6.59	-9.30	4.73	-5.02	-6.04	0.17	7.81	2.87	-3.24	3.72	-4.82	-3.08	-0.55	19.44	-1.08	-13.15	-0.74	-6.74	3.82	6.87
Phichit	3.72	0.00	0.00	-5.19	3.32	-0.79	-2.90	-1.74	-1.34	2.36	6.80	-3.07	-2.43	-4.07	8.07	-6.02	-2.40	-3.04	-3.80	-3.08	7.58
Phetchabun	-25.24	-13.28	-27.46	77.85	-1.33	-9.56	8.14	-13.60	8.10	2.00	0.05	-10.21	4.61	-12.24	31.31	-1.39	0.16	-1.69	12.15	1.09	-0.30
Northern	-0.04	0.02	-0.02	0.04	-0.01	-0.01	0.00	0.00	0.01	-0.01	0.04	-0.04	-0.04	-0.02	0.10	-0.02	-0.05	-0.02	-0.04	0.01	0.06
Nakhon Si Thammarat	19.54	0.85	-10.27	-0.73	22.13	-15.61	4.59	-0.33	10.20	2.32	-0.77	0.58	-8.44	0.92	10.00	6.89	4.33	-5.10	3.35	-1.41	-1.44
Krabi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phangnga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A.15

Full result of technical efficiency change of the second rice (Cont.)

Technical efficiency change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Phuket	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surat Thani	-2.38	9.75	-31.67	21.45	-27.37	66.34	-1.90	-18.82	18.77	2.56	-0.61	2.92	-3.78	-32.48	50.30	9.63	-22.67	19.71	10.16	-1.07	1.89
Ranong	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chumphon	-26.33	30.81	-5.97	29.77	-13.43	15.47	9.68	-44.57	48.11	6.38	1.31	-4.73	6.78	-3.45	-0.58	5.81	-26.62	22.54	2.52	2.10	-5.93
Songkhla	2.46	-2.35	-0.92	0.55	1.26	-5.83	-0.81	7.21	-2.12	5.78	8.81	-2.26	-2.21	-0.66	14.17	-1.08	-3.47	1.11	3.72	-2.18	1.83
Satun	-	-	6.36	-7.81	-15.07	26.65	7.11	-	-	12.16	3.95	-1.31	0.36	0.28	-3.04	3.85	-12.27	-0.56	-6.03	3.20	-29.15
Trang	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phatthalung	41.88	-7.39	-7.55	-13.30	5.33	-6.81	3.42	4.52	-6.32	13.11	0.60	2.71	-0.51	0.26	3.41	8.46	-1.29	-1.15	7.18	-2.43	-1.40
Pattani	8.60	48.04	-2.64	-35.57	1.57	-	-	-0.76	5.20	8.06	2.11	3.54	5.32	-1.86	-10.06	22.77	-	-	16.43	-2.07	2.12
Yala	-	-	-29.78	-	-	4.05	10.01	-	-	38.42	5.59	20.03	-5.51	0.81	-19.62	33.90	2.75	0.00	-	-	-18.94
Narathiwat	-1.57	4.45	-9.69	-11.67	-33.10	55.89	1.05	-22.61	38.63	-10.62	3.70	3.37	9.12	-5.07	4.97	3.39	-31.14	60.22	5.62	-3.68	-14.49
Southern	0.10	0.00	-0.07	-0.05	0.08	-0.07	0.03	0.00	0.07	0.05	0.02	0.00	-0.03	-0.01	0.09	0.06	0.00	-0.01	0.05	-0.02	0.00
Whole country	-0.04	0.01	-0.02	-0.01	0.02	0.00	0.00	0.01	0.00	0.01	0.02	-0.02	-0.07	0.02	0.07	-0.02	-0.03	-0.01	-0.02	0.02	0.04

Table A.16

Full result of technical change of the second rice

Technical change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bangkok Metropolis	-5.48	-1.63	-1.31	11.90	-6.62	7.71	-0.48	-9.11	6.16	-1.43	6.24	2.47	-12.97	4.91	1.15	2.15	-1.89	0.51	-8.01	-1.34	-0.78
Samut Prakan	-11.86	2.90	-2.93	29.56	-19.04	10.87	-4.47	-5.59	12.70	-6.68	3.05	1.99	-5.66	8.25	-4.41	-1.70	-6.86	3.95	-2.77	1.85	2.72
Nonthaburi	-5.23	-2.07	-1.73	4.09	-3.22	3.67	0.86	-5.83	4.78	-3.27	2.27	1.22	-5.21	6.35	-5.43	-0.63	-0.48	-3.52	-1.89	4.30	-0.88
Pathum Thani	-6.40	2.58	3.66	16.18	1.01	-4.32	1.71	-5.55	6.29	-1.67	2.02	-1.62	-8.66	3.62	1.89	5.13	-3.57	-1.26	-4.45	6.38	3.89
Phra Nakhon Si Ayutthaya	-4.69	1.51	2.76	7.52	-4.13	-3.29	-0.06	-5.19	8.21	0.31	11.30	-3.89	-13.69	5.76	1.63	0.94	-4.11	-2.92	-3.40	1.48	3.66
Ang Thong	-4.80	-1.25	-0.39	1.38	-4.64	4.01	1.03	-4.74	4.81	-2.88	2.10	0.65	-5.22	6.20	-4.92	-0.07	-0.62	-0.96	-3.80	5.49	0.12
Lop Buri	-0.46	-1.72	2.48	2.97	-6.35	3.78	0.66	-4.83	4.72	-2.27	5.63	1.82	-12.70	4.12	1.79	1.50	-1.03	-1.74	-3.24	5.38	0.73
Sing Buri	1.24	-1.22	2.97	2.95	-5.77	6.26	1.01	-6.71	4.83	-2.32	1.93	-0.38	-6.49	7.90	-3.97	2.03	-1.46	-0.89	-3.48	5.21	0.59
Chai Nat	4.13	0.35	3.81	7.71	-5.33	0.27	2.32	-2.83	5.98	-2.15	5.06	-2.02	-7.11	4.07	1.90	3.85	-1.48	-1.32	-4.69	6.41	3.70
Saraburi	1.64	-1.26	2.95	4.09	-4.60	1.45	1.23	-5.00	7.46	-2.01	5.34	-1.14	-11.55	4.62	3.25	4.09	-1.85	-1.02	-3.27	5.80	1.98
Chon Buri	-2.43	-9.92	16.20	4.82	1.78	-3.83	-0.99	-1.63	8.26	-6.80	0.41	3.38	-2.30	5.17	-1.67	-1.24	-2.74	5.55	-3.13	1.77	-0.09
Rayong	-0.99	0.28	0.60	-0.56	-2.58	4.02	1.01	-1.14	11.21	-5.33	0.25	3.29	-2.81	2.86	-6.32	-0.68	-2.11	0.28	-4.11	5.84	-0.20
Chanthaburi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trat	-	-12.87	7.92	2.88	0.27	4.21	-0.64	-2.18	5.21	-5.32	2.22	3.32	-2.37	2.71	-6.94	-0.93	-5.34	1.96	-3.91	4.86	0.56
Chachoengsao	-7.61	-1.85	0.72	14.89	-10.09	2.98	0.14	-5.38	4.76	-1.36	1.47	1.13	-6.72	2.70	1.14	3.08	-0.73	-3.48	-1.62	0.77	-0.50
Prachin Buri	-4.32	-3.69	-2.09	12.22	-4.78	9.45	-2.22	-3.18	6.32	-1.60	3.23	0.88	-9.29	3.73	1.83	0.55	-1.27	-2.42	-3.81	-1.56	4.47
Nakhon Nayok	-6.80	-0.95	1.05	10.27	-6.34	2.62	1.01	-6.01	4.83	-2.74	2.15	1.41	-9.30	3.86	1.45	1.65	-0.70	-0.85	-2.18	0.73	0.16
Sa Kaeo	-	-	9.50	4.29	-6.55	5.04	-0.38	-2.07	7.25	-5.15	0.39	3.68	-2.30	3.24	-6.49	0.37	-2.11	0.50	-4.02	5.01	-0.39
Ratchaburi	-0.16	-0.30	-0.55	0.11	-3.24	2.63	1.01	-5.25	5.52	-3.40	2.62	2.10	-5.27	6.48	-5.43	-0.63	-0.58	-0.81	-2.96	4.90	1.48
Kanchanaburi	-4.60	-1.14	-0.95	0.11	-4.02	3.92	1.01	-6.01	6.07	-3.91	2.45	3.19	-2.14	2.40	-5.53	-0.43	-0.71	-0.81	-3.06	5.43	1.60
Suphan Buri	-5.88	-1.57	-1.78	3.78	-3.27	2.32	0.91	-5.25	4.95	-2.43	2.22	-0.46	-6.34	3.76	-0.92	-0.60	-0.65	-1.76	-1.98	4.21	-1.33
Nakhon Pathom	-6.19	-3.86	-0.55	10.35	-6.08	4.93	0.95	-4.80	5.47	-0.85	1.69	1.52	-6.85	2.53	-0.65	0.15	-3.67	-2.12	-1.42	2.22	-0.92
Samut Sakhon	-7.84	-1.22	1.72	4.57	-3.30	4.40	0.67	-8.44	9.69	-3.97	2.62	2.59	-3.90	7.84	-6.44	0.99	-2.38	0.37	-3.91	5.29	-0.44

Table A.16

Full result of technical change of the second rice (Cont.)

Technical change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Samut Songkhram	-5.19	1.39	6.77	-0.20	-3.68	3.62	0.11	-6.39	4.34	-3.91	2.45	3.19	-2.14	2.40	-5.43	-0.80	-1.07	-0.13	-3.35	5.08	-0.59
Phetchaburi	2.36	0.22	0.14	-0.20	-4.52	4.10	1.01	-4.71	4.85	-3.91	2.45	3.19	-2.19	2.40	-5.65	-0.54	-0.46	-0.26	-3.66	5.06	-0.19
Prachuap Khiri Khan	-4.20	-4.89	6.88	-0.54	-4.48	-2.99	-1.78	2.24	6.73	-4.37	1.33	3.04	-2.59	2.61	-6.69	-0.22	-2.25	1.52	-2.51	4.10	1.35
Central	-0.04	-0.01	0.00	0.06	-0.05	0.02	0.01	-0.05	0.06	-0.02	0.04	0.00	-0.08	0.04	0.00	0.01	-0.02	-0.02	-0.03	0.03	0.01
Nakhon Ratchasima	-2.78	-5.72	11.42	11.64	-3.46	3.90	-3.56	-1.45	4.31	-2.54	0.17	-0.16	-5.14	5.33	-5.64	-0.26	-2.40	0.94	-3.93	5.29	0.03
Buri Ram	0.21	-2.83	3.83	4.01	-5.75	-9.39	-10.54	0.09	4.46	-3.66	-2.78	1.09	-3.83	2.71	-4.27	-1.58	-2.56	1.05	-4.05	3.17	2.03
Surin	3.34	-8.69	5.09	0.13	0.54	-2.97	-2.02	-0.87	4.83	-3.97	-0.84	1.37	-3.41	2.32	-3.75	-2.73	-3.28	1.39	-3.78	3.24	2.70
Si Sa Ket	-3.00	-11.21	11.57	0.19	0.16	-9.72	-1.54	0.68	5.20	-3.50	-2.07	2.10	-3.34	2.55	-2.87	-3.31	-1.32	0.66	-4.52	5.23	0.40
Ubon Ratchathani	-9.24	-12.01	2.75	10.41	-0.73	-8.88	-7.65	3.70	5.82	-4.14	-2.63	-1.62	-3.27	2.49	-0.42	-5.62	-0.78	0.72	-5.28	3.40	0.57
Yasothon	2.12	-7.92	8.38	0.47	-1.84	-1.02	-2.78	2.37	4.97	-3.94	-1.72	2.22	-2.91	2.90	-3.77	-1.84	-3.60	0.21	-3.60	5.40	-0.59
Chaiyaphum	-14.56	-1.28	3.26	7.21	-11.84	-11.83	0.31	0.93	5.94	-4.11	-2.27	1.71	-2.42	3.45	-2.95	-3.12	-2.72	1.73	-3.87	4.26	0.98
Amnat Charoen	2.47	-9.34	1.83	5.50	-0.49	-14.75	-15.61	-	-	1.59	0.86	-5.23	-4.41	3.62	2.04	-6.66	-0.85	0.39	-7.96	5.92	0.37
Buang Kan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-5.03	3.92	-2.73	-4.29	4.92	1.63
Nong Bua Lam Phu	-22.85	-6.82	31.53	4.27	-8.74	-9.01	1.18	0.39	9.45	-4.94	1.08	2.35	-2.30	3.24	-0.89	-4.07	0.18	1.98	-3.19	3.79	3.01
Khon Kaen	-2.29	-5.81	5.90	6.17	-5.51	-3.18	-4.40	-4.38	6.05	-4.28	0.22	2.73	-2.90	2.74	-6.29	-0.24	-3.45	0.81	-3.77	5.59	0.23
Udon Thani	-4.82	-9.61	22.43	-0.43	-9.02	-11.13	0.57	0.12	8.99	-3.52	2.31	0.03	-2.30	3.24	-1.39	-3.94	3.47	1.65	-3.87	2.87	2.36
Loei	-36.46	-10.99	59.52	-10.32	2.36	-20.61	6.74	12.17	-7.14	3.23	4.72	-8.23	-3.81	4.66	-3.64	-13.67	22.64	0.03	-7.76	2.34	1.75
Nong Khai	-1.21	0.09	-2.75	1.99	-5.85	-3.43	1.60	0.71	9.25	-5.20	1.36	1.60	-2.71	3.24	-2.39	-4.93	-3.55	1.04	-3.75	4.57	0.87
Maha Sarakham	4.95	1.04	-0.33	-0.22	-4.21	5.33	-1.15	-5.57	3.69	-3.91	2.45	3.19	-2.14	2.40	-5.43	-0.80	-0.69	-0.70	-3.25	5.20	-0.46
Roi Et	6.70	4.26	-6.61	-0.86	-4.63	5.86	-3.11	-2.83	3.51	-3.46	1.98	2.97	-2.55	2.61	-5.54	-0.45	-0.61	-0.76	-2.31	4.21	0.28
Kalasin	1.52	1.95	-0.55	0.03	-4.16	4.37	-1.39	-5.67	6.71	-3.35	2.28	2.85	-2.58	2.62	-5.68	-0.54	-0.59	-0.76	-2.56	4.53	1.19
Sakon Nakhon	-6.59	-12.75	25.16	0.33	0.89	-18.96	-2.09	0.70	6.83	-3.38	-1.11	1.82	-3.00	3.93	-2.94	-4.37	1.66	1.53	-5.30	5.19	0.94
Nakhon Phanom	-20.28	-14.31	31.42	-1.55	-4.42	-15.16	2.36	0.47	6.34	-2.50	1.12	0.94	-3.38	3.73	-1.80	-3.60	2.01	2.10	-4.14	5.13	-0.24

Table A.16

Full result of technical change of the second rice (Cont.)

Technical change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Mukdahan	-1.46	-19.06	6.07	3.70	-1.82	-20.00	-3.78	-	-	2.47	1.39	-7.94	-4.12	4.75	1.94	-9.78	9.67	0.46	-9.32	5.52	2.19
Northeastern	-0.01	-0.02	0.05	0.03	-0.04	0.00	-0.02	-0.03	0.06	-0.04	0.01	0.02	-0.03	0.03	-0.04	-0.02	-0.02	0.00	-0.04	0.04	0.01
Chiang Mai	14.73	-17.61	14.95	8.91	-4.23	-17.51	1.27	-1.76	6.62	-3.48	-5.09	-0.81	-2.76	1.17	0.94	-4.69	-1.19	0.73	-9.34	6.11	4.33
Lamphun	8.80	8.44	-16.43	-5.65	7.44	-0.83	-15.76	13.68	-7.42	-3.50	5.67	-2.77	-11.57	5.40	-0.40	-5.64	-3.34	0.04	-8.33	9.43	4.92
Lampang	-9.35	-13.75	7.13	2.27	2.87	-18.43	4.54	0.39	5.08	-3.17	-3.75	0.85	-4.95	2.57	3.43	-9.05	1.31	0.13	-7.63	5.59	2.42
Uttaradit	-6.24	-1.62	8.47	5.47	-6.41	7.00	-3.03	-4.62	7.04	-3.91	3.08	0.64	-5.25	4.69	-5.66	-0.23	-1.81	0.01	-3.96	5.75	0.12
Phrae	-	-9.53	14.69	6.16	0.32	-6.14	-1.98	1.72	5.47	-5.37	0.72	2.43	-2.80	3.12	-5.62	-0.47	-1.10	-0.70	-3.23	5.83	1.71
Nan	9.78	-14.81	6.24	3.20	3.77	-18.96	4.36	-0.40	3.58	-2.52	-2.75	0.96	-3.95	2.81	-0.56	-5.49	-0.82	-0.63	-3.24	5.90	1.86
Phayao	11.06	-9.71	42.90	-19.15	3.84	-19.61	3.49	0.32	3.99	-4.01	-3.71	-4.99	-6.31	5.04	-2.05	-4.43	-0.89	-0.08	-3.96	4.21	2.04
Chiang Rai	0.35	-4.64	-2.87	5.24	-7.17	1.01	0.11	-1.76	1.12	5.77	0.37	-5.82	-4.08	5.47	-5.31	-5.53	1.16	2.33	-5.44	3.53	3.07
Mae Hong Son	-	-21.14	10.61	25.11	-4.02	-21.16	2.06	-	-	-	-	-2.09	-5.63	4.13	13.20	-18.05	18.44	-7.35	-12.68	3.98	3.64
Nakhon Sawan	-6.11	-3.36	-0.60	12.07	-6.08	2.01	-0.25	-2.65	5.28	-0.84	2.63	2.60	-9.48	4.49	2.33	-0.04	-2.33	-2.00	-1.42	2.39	0.00
Uthai Thani	-4.89	-0.65	1.62	2.15	-3.74	3.34	1.01	-4.75	6.25	-3.37	2.68	0.99	-5.42	5.76	-2.54	-0.45	-1.49	-0.59	-3.26	5.30	0.04
Kamphaeng Phet	-5.02	-2.72	-0.89	13.13	-8.19	6.39	-1.97	-7.47	10.51	-2.31	4.08	1.31	-10.17	4.93	3.84	-1.65	-2.52	-0.12	-3.24	3.21	-1.12
Tak	-7.11	-3.95	5.50	2.09	-7.51	-11.24	1.46	-0.20	8.18	-4.63	0.82	-1.51	-2.30	3.24	1.65	-3.83	-3.22	3.84	-4.28	3.60	2.66
Sukhothai	-2.69	-1.99	5.60	2.85	-4.99	5.00	-1.74	-5.51	7.52	-3.95	2.06	1.71	-8.60	6.65	-2.23	-0.02	-1.68	-0.25	-3.80	5.10	0.27
Phitsanulok	-5.82	-3.20	1.32	6.16	-4.03	4.04	0.53	-5.98	8.61	-3.84	2.65	1.41	-9.52	6.90	3.00	-2.37	-0.74	-1.58	-1.97	4.50	-0.80
Phichit	-7.07	-3.11	-0.82	12.83	-9.37	6.98	-1.38	-6.17	8.39	-2.42	5.52	1.61	-10.92	5.28	2.17	-0.79	-1.24	-1.27	-1.99	4.30	-1.71
Phetchabun	-5.54	-7.01	13.23	7.57	-12.04	-0.15	-1.79	0.32	7.30	-5.57	1.33	3.59	-6.37	6.00	-6.58	-0.35	-4.75	2.05	-4.18	2.54	2.74
Northern	-0.06	-0.03	0.01	0.10	-0.07	0.04	-0.01	-0.05	0.08	-0.02	0.03	0.01	-0.09	0.05	0.00	-0.02	-0.01	-0.01	-0.03	0.04	0.00
Nakhon Si Thammarat	-3.77	-1.46	5.67	0.11	-3.98	4.41	-1.31	-1.33	3.28	-3.91	2.45	3.19	-2.14	2.40	-6.23	0.30	-3.21	2.15	-3.80	4.53	-0.37
Krabi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phangnga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A.16

Full result of technical change of the second rice (Cont.)

Technical change rate of the second rice (%)																					
Province	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Phuket	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surat Thani	-2.13	-9.45	8.89	6.81	2.09	-5.82	1.14	-0.47	4.62	-3.31	-2.43	1.36	-3.09	2.03	-1.19	-5.54	0.74	0.08	-6.28	3.35	0.86
Ranong	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chumphon	-6.16	-12.99	13.87	5.57	-0.11	-3.72	-1.50	2.22	5.37	-5.07	0.02	1.37	-2.42	3.76	-2.68	-5.70	0.32	-0.04	-6.11	5.25	2.12
Songkhla	-5.01	-2.29	8.50	-0.07	-4.35	5.06	-0.41	-2.44	3.47	-3.91	2.57	1.98	-7.44	6.65	-2.87	0.44	-2.04	-1.06	-3.08	5.71	-0.34
Satun	-	-	4.39	19.35	0.20	-25.74	2.66	-	-	0.56	-0.77	-7.12	-3.75	3.41	10.74	-18.13	9.59	3.42	-10.78	1.35	2.63
Trang	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phatthalung	1.26	-3.88	4.76	2.80	-4.05	6.60	-4.49	-0.04	5.07	-4.29	0.15	2.39	-3.01	2.52	-4.30	-2.30	-2.41	0.11	-4.49	4.22	0.89
Pattani	0.33	-18.74	-0.35	16.21	-0.30	-	-	1.14	2.20	-3.33	-0.90	-3.69	-5.47	3.49	9.90	-16.12	-	-	-11.62	5.24	7.16
Yala	-	-	16.97	-	-	-22.72	4.85	-	-	-2.74	-1.95	-7.57	-3.17	3.94	5.80	-12.95	14.98	0.41	-	-	-2.66
Narathiwat	-11.07	-13.79	-4.68	8.42	1.24	-18.17	5.02	0.51	7.15	-0.72	1.37	-4.76	-2.44	4.13	-2.29	-12.10	26.59	-5.29	-11.72	3.18	1.72
Southern	-0.03	-0.04	0.06	0.02	-0.03	0.04	-0.02	-0.01	0.04	-0.04	0.02	0.02	-0.04	0.04	-0.04	-0.01	-0.03	0.00	-0.04	0.05	0.00
Whole country	-0.04	-0.02	0.01	0.07	-0.05	0.03	0.00	-0.05	0.06	-0.02	0.03	0.00	-0.08	0.05	-0.01	0.00	-0.02	-0.01	-0.03	0.03	0.01

APPENDIX B

NOTE ON THE DATA PREPARATION

This section shows the issues of the data in detail as well as the solution.

(a) Missing and imputed values

There are missing data used in the first step of the analysis. Some of the missing data are imputed, using other available variables as the regressor for imputing. The criteria used for imputing data is if there is only one missing variable of the observation, then the missing value is imputed. And if there are more than one missing variable in the observation, the values are left as missing. The list of missing variables is shown in Table B.1 and the list of imputed variables is shown in Table B.2.

Table B.1

Missing variables

Provinces	Rice produced	Land	Household	Seed used	Fertilizer used
Main rice					
Saraburi			1998		
Bueng Kan	1997-2010	1997-2010	1997-2010	1997-2010	1997-2010
Kalasin			1998		
Lamphun					2010
Second rice					
Chon Buri			1999		
Rayong			2006		
Chanthaburi	1997-2009, 2014-2018	1997-2009, 2014-2018	1997-2009, 2014-2018	1997-2009, 2014-2018	1997-2009, 2014-2018
Trat	1997	1997	1997, 1998	1997	1997
Sa Kaeo	1998	1998	1998	1998	1998
Amnat Charoen	2005	2005	2005	2005	2005
Bueng Kan	1997-2011	1997-2011	1997-2011	1997-2011	1997-2011
Mukdahan	2005	2005	2005	2005	2005

Table B.1

Missing variables (Cont.)

Provinces	Rice produced	Land	Household	Seed used	Fertilizer used
Phrae	1997	1997	1997, 2002	1997	1997
Mae Hong Son	1997, 2005, 2007	1997, 2005, 2007	1997, 2002, 2005, 2007	1997, 2005, 2007	1997, 2005, 2007
Krabi	1997-1999, 2001-2018	1997-1999, 2001-2018	1997-1999, 2001-2018	1997-1999, 2001-2018	1997-1999, 2001-2018
Phang-nga	1997-2007, 2010-2018	1997-2007, 2010-2018	1997-2007, 2010-2018	1997-2007, 2010-2018	1997-2007, 2010-2018
Phuket	1997-2018	1997-2018	1997-2018	1997-2018	1997-2018
Surat Thani			2004		
Ranong	1997-2018	1997-2018	1997-2018	1997-2018	1997-2018
Satun	1998, 2005	1998, 2005	1998, 2005	1998, 2005	1998, 2005
Trang	1997-1999, 2003-2011, 2013	1997-1999, 2003-2011, 2013	1997-1999, 2003-2011, 2013	1997-1999, 2003-2011, 2013	1997-1999, 2003-2011, 2013
Pattani	2003, 2014	2003, 2014	2003, 2014	2003, 2014	2003, 2014
Yala	1998, 2001, 2005, 2016	1998, 2001, 2005, 2016	1998, 2001, 2005, 2016	1998, 2001, 2005, 2016	1998, 2001, 2005, 2016

Table B.2

Imputed value

Year	Province	Imputed variable
Main rice		
2541	Saraburi	Household (18,720)
2541	Kalasin	Household (91,217)
2553	Lamphun	Fertilizer (3,108)
Second rice		
2541	Trat	Household (154)
2542	Chon Buri	Household (257)
2544	Trang	Household (45)
2545	Phrae	Household (285)
2545	Mae Hong Son	Household (23)
2545	Trang	Household (20)
2547	Surat Thani	Household (1,320)
2549	Rayong	Household (658)

The spatial panel regression in the second step requires more restrictions. First, the weighted matrix of neighborhood provinces must be constant for all periods of the study. The issue arises with Bueng Kan province, which separated from Nong Khai in 2011. To solve this issue, the author combined the data of Bueng Kan back to Nong Khai before remeasuring the provincial TFP growth. This results in 76 areas in the part of spatial analysis for the main rice.

The second restriction is the spatial panel data requires balanced panel data. For this reason, observation in the main rice model is subsetting to 1,292, due to the lack of high-yielding varieties shared before the year 2002. The problem is more severe for the second rice data as there are more missing values of the input and output in the first step of the analysis, which causes missing values of TFP growth that use in the second step. So, the investigation must drop 10 more provinces that have missing values, further from 6 provinces that are completely dropped in the first step of performance measurement due to lack of second rice input and output data. As a result, the observation in the spatial analysis of the second rice will contain only 60 provinces. However, the 10 provinces that are dropped have a little magnitude as the share of average inputs and output of the whole country, as shown in Table B.3.

Table B.3

Average input and output of dropped provinces

Province	Paddy	Land	Household	Seed	Fertilizer
Amnat Charoen	1,305.67 (0.018%)	2,911.71 (0.027%)	423.19 (0.086%)	41.80 (0.013%)	117.15 (0.021%)
Mae Hong Son	181.00 (0.003%)	393.68 (0.004%)	87.11 (0.018%)	4.43 (0.001%)	12.80 (0.002%)
Mukdahan	256.10 (0.004%)	643.24 (0.006%)	119.05 (0.024%)	6.33 (0.002%)	21.42 (0.004%)
Narathiwat	318.68 (0.005%)	803.64 (0.008%)	160.86 (0.033%)	9.54 (0.003%)	22.01 (0.004%)
Pattani	7,859.25 (0.111%)	19,487.85 (0.182%)	3,455.60 (0.706%)	188.73 (0.059%)	557.27 (0.101%)
Phrae	9,838.57 (0.139%)	16,577.62 (0.155%)	1,994.71 (0.407%)	422.54 (0.132%)	814.89 (0.148%)
Sa Kaeo	6,636.48 (0.094%)	12,696.00 (0.119%)	794.53 (0.162%)	385.96 (0.121%)	569.57 (0.103%)

Table B.3

Average input and output of dropped provinces (Cont.)

Province	Paddy	Land	Household	Seed	Fertilizer
Satun	205.90 (0.003%)	511.65 (0.005%)	97.75 (0.020%)	4.87 (0.002%)	14.61 (0.003%)
Trat	843.19 (0.012%)	1,916.38 (0.018%)	254.19 (0.052%)	47.33 (0.015%)	83.03 (0.015%)
Yala	165.00 (0.002%)	428.11 (0.004%)	111.00 (0.023%)	4.17 (0.001%)	13.06 (0.002%)
Whole Country	7,070,177.62	10,680,045.99	489,682.19	319,995.25	551,010.83

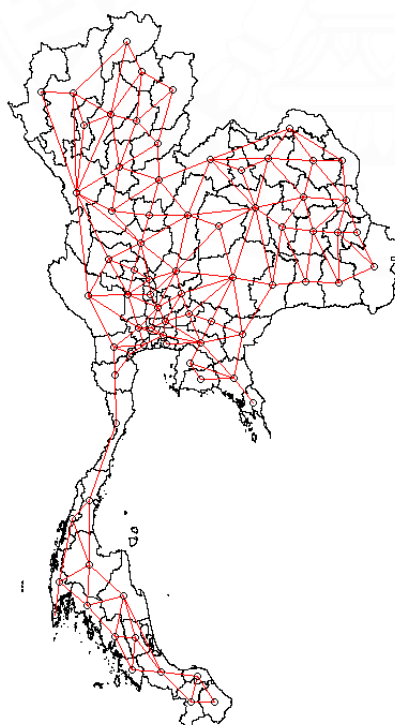
Note. The percentage share of the total average of the whole country is in parenthesis.

The weighted matrix of neighborhood provinces for the main and second rice can be shown on the map in Figure B.1.

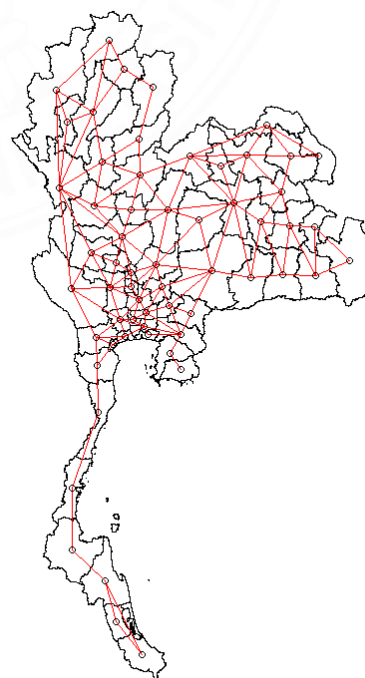
Figure B.1

Coordinate map of spatial weighted matrix

Coordinate map of 76 provinces



Coordinate map of 60 provinces



(b) Dropped irrigation data

There are some irrigation data that are not included in the irrigation area for the second step of the analysis due to the lack of information about the finish date of the projects. All these dropped data are small-project irrigation. There are 495 projects with this issue. However, only 173 projects that have the value of irrigation area while the rest is not. The summary of the dropped irrigation data is shown in the Table B.4.

Table B.4

The summary of the small-irrigation projects that are dropped

Province	Number of dropped project	Irrigation area of the dropped project (rai)
Amnat Charoen	1	0
Ang Thong	1	0
Buri Ram	2	0
Chachoengsao	1	0
Chai Nat	7	0
Chaiyaphum	27	0
Chiang Mai	8	8,900 (0.1%)
Chon Buri	6	0
Kalasin	1	0
Kamphaeng Phet	4	0
Khon Kaen	15	0
Krabi	5	0
Lamphun	14	14,540 (0.164%)
Lop Buri	2	0
Mukdahan	2	700 (0.007%)
Nakhon Phanom	36	0
Nakhon Ratchasima	138	131,730 (1.486%)
Nakhon Si Thammarat	1	0
Narathiwat	18	0

Table B.4

The summary of the small-irrigation projects that are dropped (Cont.)

Province	Number of dropped project	Irrigation area of the dropped project (rai)
Nonthaburi	4	0
Pathum Thani	2	0
Phangnga	13	0
Phatthalung	1	0
Phetchaburi	4	2,400 (0.027%)
Phichit	3	0
Ratchaburi	2	1,500 (0.017%)
Rayong	65	0
Roi Et	1	0
Saraburi	22	0
Si Sa Ket	9	2,670 (0.03%)
Sing Buri	3	0
Songkhla	10	0
Suphan Buri	3	0
Surat Thani	1	0
Surin	54	57,420 (0.648%)
Trang	1	0
Udon Thani	1	0
Uthai Thani	5	0
Uttaradit	1	0
Yasothon	1	0
Total	495	219,860 (2.481%)
Total of usable projects	22,572	8,861,789

Note. The percentage share to the total usable data of the small-irrigation project is in parenthesis.

(c) Lack of details in the high-yielding variety

There are 26 categories or varieties of rice in the main rice and second rice data provided by OAE. These consist of 9 varieties labeled as high-yielding, 12 varieties labeled as normal, and 5 categories that cannot be specified as either. Unspecified category of rice causes issues in generating high-yielding shared variable that is used in the second step of the analysis. This issue of lacking details is more severe in the case of the second rice compared to the main rice. The unspecified category is account for 18.37% for the main rice data while it is account for 54.80% for the second rice data. This may be the reason for the non-statistical significant for high-yielding share variable in TFP determinant models for the second rice. Detail of high-yielding variety is shown in Table B.5.

Table B.5

Rice variety

High-yielding variety	Total shared of the main rice data	Total shared of the second rice data
กข6 (RD6) กข21 (RD21) กข23 (RD23) สุพรรณบุรี 1 (Suphan Buri 1) สุพรรณบุรี 60 (Suphan Buri 60) ชัยนาท 1 (Chai Nat 1) ปทุมธานี 1 (Pathum Thani 1) พิษณุโลก 2 (Phitsanulok 2) พิษณุโลก 60-2 (Phitsanulok 60-2)	36.29%	41.79%
Normal variety	Total shared of the main rice data	Total shared of the second rice data
พันธุ์พื้นเมือง (Local variety) กข7 (RD7) กข10 (RD10) กข15 (RD15) ขาวดอกมะลิ 105 (Khao Dawk Mali 105) ข้าวเจ้าหอมสุพรรณบุรี (Khao' Jow Hawm Suphan Buri) สุพรรณบุรี 90 (Suphan Buri 90) ชัยนาท 2 (Chai Nat 2)	45.34%	3.42%

Table B.5

Rice variety (Cont.)

Normal variety	Total shared of the main rice data	Total shared of the second rice data
ข้าวเจ้าหอมคลองหลวง 1 (Khao' Jow Hawm Khlong Luang 1) ข้าวเจ้าหอมพิชญ์โลก 1 (Khao' Jow Hawm Phitsanulok 1) บาสมาติ (Basmati) ข้าวหอม		
Unspecify category	Total shared of the main rice data	Total shared of the second rice data
กข.ไม่ไวแสง (RD Non-photoperiod Sensitive) กข.ไวแสง (RD Photoperiod Sensitive) ราชการไม่ไวแสง (Ratchakarn Non- photoperiod Sensitive) ราชการไวแสง (Ratchakarn Photoperiod Sensitive) อื่นๆ (Others)	18.37%	54.80%

Note. Author's calculation based on OAE data

APPENDIX C

VARIATION OF THE RESULT ON RICE VARIETY

As mentioned in section C of appendix B about the lacking details in high-yielding variety of rice, high-yielding shared variable, used in the analysis and presented in chapter 5, is generated as follows; all varieties that are labeled as high-yielding variety are included as the shared of high-yielding variety. While some categories that cannot be really specified as either are included only for half of its planted land.

Nevertheless, this section shows the results of the TFP determinant models when using different ratios of unspecified categories when generating high-yielding shared variable.

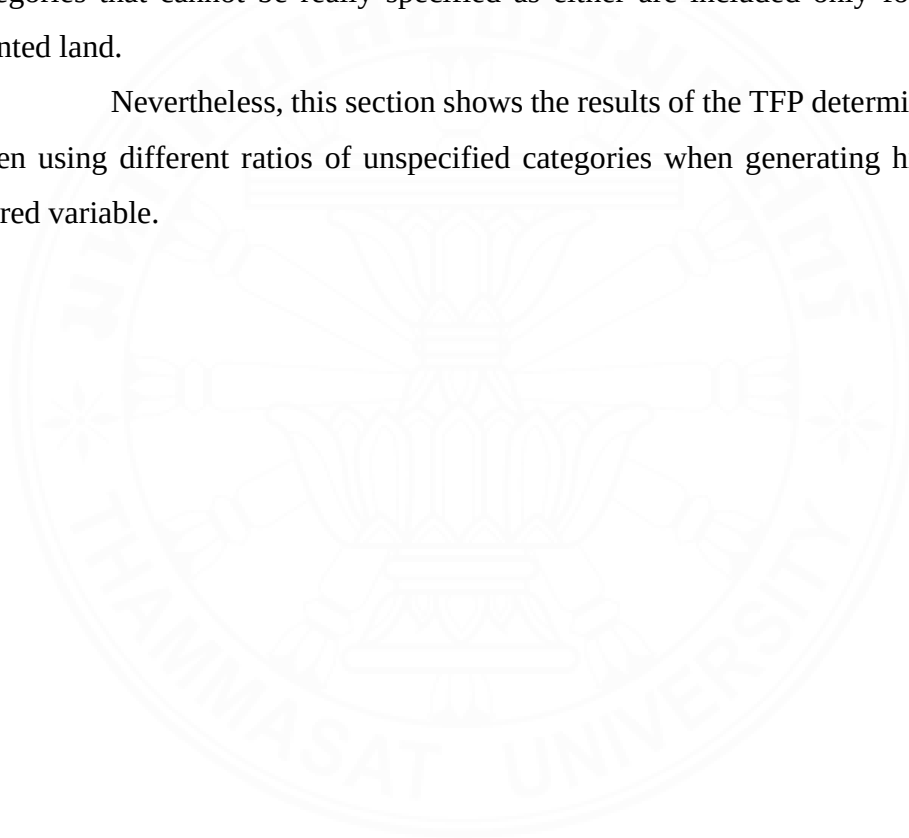


Table C.1

Results of TFP growth determinant models: none of unspecified categories are included when generating high-yielding shared variable

Items	Main rice model					Second rice model				
	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error
High-yielding shared	0.0148 (0.012)	0.0152 (0.0113)	0.0187 (0.0136)	0.0437* (0.0217)	0.046+ (0.0243)	0.005 (0.0117)	-0.0008 (0.0111)	-0.0004 (0.0119)	0.0155 (0.0138)	0.0166 (0.0147)
Irrigation area per planted area	-0.0058 (0.0233)	-0.0028 (0.022)	0.0017 (0.0237)	-0.0341 (0.0333)	-0.0339 (0.036)	0.0045** (0.0015)	0.0118+ (0.0018)	0.0121*** (0.0018)	0.0135*** (0.002)	0.0138*** (0.002)
ln(Surface temperature)	9.8671 (6.9498)	8.5545 (6.5514)	9.6558 (8.1566)	-48.6269* (21.5525)	-60.752+ (31.2724)	-10.3094* (5.2093)	-6.7922 (4.8349)	-7.0738 (5.4205)	-53.8499** (17.4301)	-64.5092** (19.6713)
ln(Total precipitation)	0.7619 (1.6008)	1.1803 (1.509)	1.352 (1.8514)	-1.0566 (2.5881)	-2.9389 (3.5175)	2.177** (0.7023)	3.119*** (0.7305)	3.5325*** (0.858)	3.7744** (1.3849)	4.0008* (1.5668)
Damaged area	-0.599*** (0.0529)	-0.5052*** (0.0499)	-0.5883*** (0.0572)	-0.675*** (0.059)	-0.7612*** (0.0646)	-0.6863*** (0.1036)	-0.9158*** (0.0986)	-0.9463*** (0.1011)	-1.0223*** (0.1031)	-1.0458*** (0.1046)
GPP	-0.0003 (0.0009)	-0.0002 (0.0008)	0.0004 (0.0009)	0.0007 (0.0042)	0.0006 (0.0043)	0.0002 (0.0011)	-0.0001 (0.001)	-0.0001 (0.001)	-0.0007 (0.0038)	-0.0005 (0.0039)
Constant	-27.2063 (20.4024)	-22.1774 (19.2328)	-25.0027 (24.1312)			45.5712** (17.1033)	39.1081* (15.6865)	42.1692* (17.6222)		
Spatial lag parameter (ρ)		0.3425*** (0.0311)		0.33*** (0.0324)			0.1651*** (0.0338)		0.1313*** (0.0358)	
Spatial error parameter (λ)			0.3565*** (0.0316)		0.3453*** (0.0333)			0.172*** (0.0347)		0.1408*** (0.0367)
Log likelihood		-4802.234	-4800.273	-4776.391	-7569.2 ^a		-4912.532	-4912.172	-4887.365	-7596.38
R2	0.0928					0.0456				
Observation	1292	1292	1292	1292	1292	1441	1260	1260	1260	1260

Note: *** Means significant at 0.1%, ** Means significant at 1%, * Means significant at 5%, + Means significant at 10%, ^a Log likelihood function of fixed effects spatial error model is for optimize the models only and not directly comparable with other models as the selection criteria, Standard errors of estimated coefficients are in parenthesis

Table C.2

Results of TFP growth determinant models: 25% of unspecified categories are included when generating high-yielding shared variable

Items	Main rice model					Second rice model				
	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error
High-yielding shared	0.0154 (0.0126)	0.0159 (0.0119)	0.0215 (0.0143)	0.0681** (0.026)	0.0775** (0.0291)	0.0043 (0.0142)	-0.004 (0.0134)	-0.0026 (0.0144)	0.0187 (0.0177)	0.0208 (0.0189)
Irrigation area per planted area	-0.0064 (0.0233)	-0.0035 (0.0219)	0.001 (0.0237)	-0.0435 (0.0337)	-0.0427 (0.0363)	0.0044** (0.0015)	0.0118*** (0.0018)	0.0121*** (0.0018)	0.0135*** (0.002)	0.0138*** (0.002)
ln(Surface temperature)	9.5699 (6.956)	8.2479 (6.5571)	9.1309 (8.1819)	-48.8244* (21.4829)	-60.6557+ (31.2278)	-10.2306+ (5.2899)	-6.436 (4.9219)	-6.8484 (5.4973)	-53.7439** (17.434)	-64.4925** (19.6898)
ln(Total precipitation)	0.8133 (1.6069)	1.23423 (1.5147)	1.4204 (1.855)	-1.1623 (2.586)	-3.0317 (3.5176)	2.1777** (0.7063)	3.1578*** (0.7367)	3.5588*** (0.8636)	3.7761** (1.385)	4.002* (1.568)
Damaged area	-0.5962*** (0.0527)	-0.5022*** (0.0497)	-0.5858*** (0.0571)	-0.6749*** (0.0588)	-0.7613*** (0.0645)	-0.6856*** (0.1037)	-0.9167*** (0.0987)	-0.9468*** (0.1011)	-1.0207*** (0.103)	-1.0447*** (0.1046)
GPP	-0.0003 (0.0009)	-0.0003 (0.0008)	0.0004 (0.0009)	0.0008 (0.0041)	0.0006 (0.0043)	0.0002 (0.0011)	-0.0001 (0.001)	-0.0001 (0.001)	-0.0007 (0.0038)	-0.0005 (0.0039)
Constant	-26.2085 (20.436)	-21.1469 (19.2643)	-23.324 (24.2236)			45.2864** (17.2199)	38.2991* (15.8113)	41.6744* (17.7235)		
Spatial lag parameter (ρ)		0.3426*** (0.0311)		0.33*** (0.0324)			0.165*** (0.034)		0.1317*** (0.0358)	
Spatial error parameter (λ)			0.3573*** (0.0316)		0.3468*** (0.0333)			0.1718*** (0.0348)		0.1416*** (0.0367)
Log likelihood		-4802.238	-4800.097	-4774.998	-7567.453					-7596.409
R2	0.0928					0.0455				
Observation	1292	1292	1292	1292	1292	1441	1260	1260	1260	1260

Note: *** Means significant at 0.1%, ** Means significant at 1%, * Means significant at 5%, + Means significant at 10%, ^a Log likelihood function of fixed effects spatial error model is for optimize the models only and not directly comparable with other models as the selection criteria, Standard errors of estimated coefficients are in parenthesis

Table C.3

Results of TFP growth determinant models: 50% of unspecified categories are included when generating high-yielding shared variable

Items	Main rice model					Second rice model				
	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error
High-yielding shared	0.0141 (0.0124)	0.0146 (0.0117)	0.0217 (0.0142)	0.0963** (0.0298)	0.1156*** (0.0331)	0.0017 (0.0167)	-0.0095 (0.0159)	-0.0065 (0.0171)	0.0198 (0.0231)	0.024 (0.0138)
Irrigation area per planted area	-0.0071 (0.0233)	-0.0042 (0.0219)	0.0002 (0.0237)	-0.0564 (0.0343)	-0.0554 (0.0367)	0.0044** (0.0015)	0.0118*** (0.0018)	0.0121*** (0.0018)	0.0135*** (0.002)	0.0138*** (0.002)
ln(Surface temperature)	9.3304 (6.9702)	7.9988 (6.5707)	8.6765 (8.2154)	-50.7494* (21.4096)	-63.2781* (31.2393)	-9.9396+ (5.3873)	-5.7719 (5.0428)	-6.4208 (5.6046)	-53.33** (17.4303)	-64.2159** (19.7086)
ln(Total precipitation)	0.8261 (1.6117)	1.2486 (1.5193)	1.4549 (1.8576)	-1.3207 (2.5837)	-3.2151 (3.522)	2.1955* (0.7126)	3.2281*** (0.7448)	3.6072*** (0.8708)	3.7853** (1.3851)	4.0095* (1.5697)
Damaged area	-0.5928*** (0.0526)	-0.4988*** (0.0496)	-0.5823*** (0.057)	-0.6716*** (0.0587)	-0.7589*** (0.0644)	-0.6857*** (0.1037)	-0.9196*** (0.0988)	-0.9482*** (0.1012)	-1.0179*** (0.103)	-1.0424*** (0.1045)
GPP	-0.0004 (0.0009)	-0.0003 (0.0009)	0.0004 (0.0009)	0.0005 (0.0041)	0.0004 (0.0043)	0.0002 (0.0011)	-0.0001 (0.001)	-0.0001 (0.001)	-0.0009 (0.0038)	-0.0006 (0.0039)
Constant	-25.4412 (20.4982)	-20.3472 (19.3232)	-21.9057 (24.3403)			44.5218* (17.3333)	36.8656* (15.9739)	40.7855* (17.853)		
Spatial lag parameter (ρ)		0.3425*** (0.0311)		0.3304*** (0.0323)			0.1647*** (0.0339)		0.1322*** (0.0358)	
Spatial error parameter (λ)			0.358*** (0.0316)		0.3501*** (0.0332)			0.1711*** (0.0349)		0.1428*** (0.0367)
Log likelihood		-4802.35	-4800.048	-4773.214	-7564.923 ^a		-4912.356	-4912.102	-4887.637	-7596.534 ^a
R2	0.0926					0.0455				
Observation	1292	1292	1292	1292	1292	1441	1260	1260	1260	1260

Note: *** Means significant at 0.1%, ** Means significant at 1%, * Means significant at 5%, + Means significant at 10%, ^a Log likelihood function of fixed effects spatial error model is for optimize the models only and not directly comparable with other models as the selection criteria, Standard errors of estimated coefficients are in parenthesis

Table C.4

Results of TFP growth determinant models: 75% of unspecified categories are included when generating high-yielding shared variable

Items	Main rice model					Second rice model				
	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error
High-yielding shared	0.0115 (0.0115)	0.012 (0.0108)	0.0195 (0.0132)	0.1083*** (0.0306)	0.1354*** (0.0336)	-0.0029 (0.0179)	-0.016 (0.0174)	-0.0112 (0.0187)	0.0107 (0.0273)	0.0181 (0.0286)
Irrigation area per planted area	-0.0077 (0.0233)	-0.0049 (0.0219)	-0.0006 (0.0237)	-0.0655+ (0.0348)	-0.0653+ (0.037)	0.0044** (0.0015)	0.0118*** (0.0018)	0.0121*** (0.0018)	0.0135*** (0.002)	0.0138*** (0.002)
ln(Surface temperature)	9.2212 (6.9872)	7.8827 (6.5868)	8.4451 (8.2452)	-54.5034* (21.3908)	-69.0243* (31.3474)	-9.4149+ (5.438)	-4.9366 (5.1426)	-5.8632 (5.6954)	-52.4342** (17.403)	-63.4103** (19.6976)
ln(Total precipitation)	0.7993 (1.6139)	1.2222 (1.5214)	1.4454 (1.8583)	-1.4516 (2.583)	-3.423 (3.531)	2.2376** (0.7185)	3.3143*** (0.7508)	3.6682*** (0.8756)	3.8078** (1.3851)	4.0286* (1.5708)
Damaged area	-0.5902*** (0.0526)	-0.496*** (0.0496)	-0.579*** (0.057)	-0.6647*** (0.0586)	-0.7536*** (0.0643)	-0.6874*** (0.1039)	-0.9248*** (0.0991)	-0.9508*** (0.1014)	-1.0151*** (0.103)	-1.0393*** (0.1045)
GPP	-0.0005 (0.0009)	-0.0003 (0.0009)	0.0004 (0.0009)	-0.0004 (0.0041)	-0.0002 (0.0043)	0.0002 (0.0011)	-0.0001 (0.001)	-0.0001 (0.001)	-0.0012 (0.0038)	-0.0009 (0.0039)
Constant	-25.1328 (20.5664)	-20.017 (19.3879)	-21.221 (24.4399)			43.3258* (17.3385)	35.1614* (16.0867)	39.6921* (17.94)		
Spatial lag parameter (ρ)		0.3425*** (0.0311)		0.3315*** (0.0323)			0.164*** (0.0339)		0.1325*** (0.0358)	
Spatial error parameter (λ)			0.3584*** (0.0317)		0.3542*** (0.0331)			0.1699*** (0.0349)		0.1434*** (0.0367)
Log likelihood		-4802.525	-4800.137	-4772.15	-7562.964		-4912.111	-4911.997	-4887.926	-7596.815
R2	0.0924					0.0455				
Observation	1292	1292	1292	1292	1292	1441	1260	1260	1260	1260

Note: *** Means significant at 0.1%, ** Means significant at 1%, * Means significant at 5%, + Means significant at 10%, ^a Log likelihood function of fixed effects spatial error model is for optimize the models only and not directly comparable with other models as the selection criteria, Standard errors of estimated coefficients are in parenthesis

Table C.5

Results of TFP growth determinant models: all unspecified categories are included when generating high-yielding shared variable

Items	Main rice model					Second rice model				
	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error	Pooled OLS	Pooled spatial lag	Pooled spatial error	FE spatial lag	FE spatial error
High-yielding shared	0.0087 (0.0103)	0.0091 (0.0097)	0.0161 (0.0119)	0.094*** (0.0276)	0.122*** (0.0302)	-0.0067 (0.0166)	-0.0188 (0.0166)	-0.0134 (0.0179)	-0.0051 (0.0249)	0.0027 (0.0264)
Irrigation area per planted area	-0.0081 (0.0233)	-0.0053 (0.0219)	-0.0011 (0.0237)	-0.0641 ⁺ (0.0349)	-0.0656 ⁺ (0.037)	0.0044** (0.0015)	0.0118*** (0.0018)	0.0121*** (0.0018)	0.0135*** (0.002)	0.0138*** (0.002)
ln(Surface temperature)	9.2278 (7.0017)	7.8861 (6.6006)	8.4304 (8.2642)	-57.7532** (21.4466)	-74.3614* (31.4967)	-8.9785 ⁺ (5.3868)	-4.514 (5.1335)	-5.5526 (5.6907)	-51.8997** (17.3681)	-62.6971** (19.6408)
ln(Total precipitation)	0.7529 (1.6137)	1.1752 (1.5213)	1.4083 (1.8576)	-1.462 (2.5844)	-3.5212 (3.5396)	2.2801** (0.7195)	3.355*** (0.7487)	3.6998*** (0.873)	3.8235** (1.3849)	4.0436** (1.5688)
Damaged area	-0.5886*** (0.0527)	-0.4945*** (0.0497)	-0.5767*** (0.0571)	-0.6585*** (0.0587)	-0.7486*** (0.0643)	-0.69*** (0.1041)	-0.9294*** (0.0993)	-0.9533*** (0.1015)	-1.0164*** (0.1031)	-1.0391*** (0.1046)
GPP	-0.0004 (0.0009)	-0.0003 (0.0009)	0.0004 (0.0009)	-0.0014 (0.0041)	-0.0008 (0.0043)	0.0003 (0.0011)	-0.0001 (0.001)	-0.0001 (0.001)	-0.0012 (0.0038)	-0.001 (0.0039)
Constant	-25.2128 (20.6209)	-20.0879 (19.4398)	-21.2286 (24.5003)			42.4707* (17.1904)	34.4199* (16.0346)	39.1623* (17.8928)		
Spatial lag parameter (ρ)		0.3424*** (0.0311)		0.3325*** (0.0323)			0.1635*** (0.034)		0.1319*** (0.0358)	
Spatial error parameter (λ)			0.3584*** (0.0317)		0.3567*** (0.033)			0.1688*** (0.0351)		0.142*** (0.0367)
Log likelihood		-4802.696	-4800.297	-4772.628	-7562.938		-4911.893	-4911.898	-4887.982	-7597.009
R2	0.0922					0.0456				
Observation	1292	1292	1292	1292	1292	1441	1260	1260	1260	1260

Note: *** Means significant at 0.1%, ** Means significant at 1%, * Means significant at 5%, ⁺ Means significant at 10%, ^a Log likelihood function of fixed effects spatial error model is for optimize the models only and not directly comparable with other models as the selection criteria, Standard errors of estimated coefficients are in parenthesis

APPENDIX D

OTHER DATA

(a) Appropriateness of rice farming area

Data about the level of appropriateness for rice farming area are obtained from Agri-Map Online database (MOAC, 2022). Rice farming area in each province is divided into 4 categories of appropriateness; high-appropriate (S1), medium-appropriate (S2), low-appropriate (S3), and not appropriate (N) for rice farming according to the attribute of the soil. Provincial appropriateness of rice farming areas from the period 2018-2020 are shown in Table D.1.

Table D.1

Appropriateness of rice farming area

Province	High-appropriate	Medium-appropriate	Low-appropriate	Not appropriate	Total rice farming area
Bangkok Metropolis	113,034.54				113,034.54
Samut Prakan	18,125.73				18,125.73
Nonthaburi	107,029.01				107,029.01
Pathum Thani	314,200.16	5,397.71			319,597.87
Phra Nakhon Si Ayutthaya	995,168.50	11,395.70			1,006,564.20
Ang Thong	356,939.60				356,939.60
Lop Buri	544,906.10	127,393.80	173,258.52	27,910.72	873,469.14
Sing Buri	323,805.50				323,805.50
Chai Nat	686,984.69	92,766.74	56,551.52	5,812.05	842,115.00
Saraburi	327,843.39	75,551.94	16,261.23	1,220.81	420,877.37
Chon Buri	25,506.99	52,495.64	21,664.89	7,438.87	107,106.39
Rayong	11,466.64	12,967.34	5,890.01	1,190.03	31,514.02
Chanthaburi	11,495.80	4,754.81	15,954.06	4,412.97	36,617.64
Trat	16,758.74	3,498.95	8,733.53	1,208.04	30,199.26
Chachoengsao	351,480.67	286,588.88	25,355.63	31,748.72	695,173.90
Prachin Buri	260,401.30	291,001.00	27,414.66	34,776.38	613,593.34

Table D.1

Appropriateness of rice farming area (Cont.)

Province	High-appropriate	Medium-appropriate	Low-appropriate	Not appropriate	Total rice farming area
Nakhon Nayok	294,601.30	117,435.24	6,331.88	878.52	419,246.94
Sa Kaeo	36,734.30	290,378.96	277,087.36	173,190.26	777,390.88
Ratchaburi	253,776.08	8,146.27	55,006.92	5,259.68	322,188.95
Kanchanaburi	197,471.15	26,440.43	189,365.71	13,199.25	426,476.54
Suphan Buri	1,160,215.90	44,573.85	62,851.05	2,888.09	1,270,528.89
Nakhon Pathom	302,573.93		1,100.83		303,674.76
Samut Sakhon	6,169.67			10.71	6,180.38
Samut Songkhram	602.39				602.39
Phetchaburi	301,188.90	33,784.24	54,184.18	4,064.46	393,221.78
Prachuap Khiri Khan	14,572.06	614.12	46,379.95	2,472.88	64,039.01
Central	7,033,053.04 (71.19%)	1,485,185.62 (15.03%)	1,043,391.93 (10.56%)	317,682.44 (3.22%)	9,879,313.03
Nakhon Ratchasima	387,462.21	728,258.89	2,494,700.53	143,337.16	3,753,758.79
Buri Ram	135,214.26	1,707,494.46	1,137,856.23	126,194.10	3,106,759.05
Surin	147,778.60	1,895,235.21	1,112,282.95	255,877.74	3,411,174.50
Si Sa Ket	239,748.72	1,754,231.36	1,074,700.55	291,447.55	3,360,128.18
Ubon Ratchathani	173,601.53	1,499,150.74	1,964,714.92	820,374.45	4,457,841.64
Yasothon	38,539.63	519,773.40	585,966.60	323,961.27	1,468,240.90
Chaiyaphum	105,420.06	485,275.45	751,585.15	46,962.51	1,389,243.17
Amnat Charoen	15,249.28	321,890.70	488,724.30	253,810.93	1,079,675.21
Bueng Kan	92,695.29	308,593.39	38,609.71	105,226.34	545,124.73
Nong Bua Lam Phu	193.66	250,990.61	331,903.09	40,411.37	623,498.73
Khon Kaen	161,386.31	560,451.77	1,357,467.10	300,730.11	2,380,035.29
Udon Thani	177,544.00	1,128,009.69	538,479.98	49,040.47	1,893,074.14
Loei	2,635.03	170,510.06	166,313.15	52,486.75	391,944.99
Nong Khai	126,264.20	402,420.68	53,399.69	71,904.35	653,988.92
Maha Sarakham	159,756.65	844,958.80	604,053.30	460,234.35	2,069,003.10

Table D.1

Appropriateness of rice farming area (Cont.)

Province	High-appropriate	Medium-appropriate	Low-appropriate	Not appropriate	Total rice farming area
Roi Et	134,121.78	1,494,695.40	1,101,988.40	609,381.00	3,340,186.58
Kalasin	299,229.31	294,502.46	668,753.30	185,068.33	1,447,553.40
Sakon Nakhon	318,641.41	880,000.41	503,413.53	690,743.16	2,392,798.51
Nakhon Phanom	372,758.54	528,027.90	320,278.29	352,764.47	1,573,829.20
Mukdahan	11,435.77	120,196.98	327,855.20	13,891.42	473,379.37
Northeastern	3,099,676.24 (7.79%)	15,894,668.36 (39.93%)	15,623,045.97 (39.24%)	5,193,847.83 (13.05%)	39,811,238.40
Chiang Mai	243,832.97	177,103.92	26,621.41	33,543.16	481,101.46
Lamphun	61,558.82	53,718.32	24,989.59	4,991.44	145,258.17
Lampang	96,989.32	166,667.89	184,579.14	122,582.05	570,818.40
Uttaradit	115,523.69	473,082.39	60,881.32	52,954.36	702,441.76
Phrae	195,419.42	94,821.69	34,693.53	34,898.49	359,833.13
Nan	60,918.21	98,991.18	27,050.51	29,316.37	216,276.27
Phayao	113,422.87	530,989.69	40,419.12	21,313.41	706,145.09
Chiang Rai	846,779.19	343,534.29	21,131.64	109,973.42	1,321,418.54
Mae Hong Son	8,539.07	24,902.24	7,149.75	3,922.24	44,513.30
Nakhon Sawan	1,871,498.20	355,395.51	236,290.63	120,923.82	2,584,108.16
Uthai Thani	287,889.87	189,956.27	91,194.10	19,209.68	588,249.92
Kamphaeng Phet	1,077,140.75	170,326.18	42,119.17	22,711.82	1,312,297.92
Tak	32,011.73	42,995.76	133,248.67	23,325.47	231,581.63
Sukhothai	399,360.10	716,348.99	185,911.24	8,434.46	1,310,054.79
Phitsanulok	1,251,431.10	283,907.95	50,763.05	30,417.10	1,616,519.20
Phichit	1,776,190.10	171,259.18	14,905.78	10,267.72	1,972,622.78
Phetchabun	69,344.33	941,348.21	155,344.45	99,172.20	1,265,209.19
Northern	8,507,849.74 (55.14%)	4,835,349.66 (31.34%)	1,337,293.10 (8.67%)	747,957.21 (4.85%)	15,428,449.71
Nakhon Si Thammarat	281,166.94	9,289.58	6,137.07	757.69	297,351.28
Krabi	178.60	953.49	434.01	1,146.18	2,712.28
Phangnga		1,731.21	88.86	602.92	2,422.99

Table D.1

Appropriateness of rice farming area (Cont.)

Province	High-appropriate	Medium-appropriate	Low-appropriate	Not appropriate	Total rice farming area
Phuket	90.22		44.09	3.71	138.02
Surat Thani	3,819.73	593.89	3,795.29	87.70	8,296.61
Ranong	167.47		580.03	197.13	944.63
Chumphon	4,163.15	920.70	1,532.73	127.25	6,743.83
Songkhla	262,706.31	18,012.72	19,226.95	7,525.27	307,471.25
Satun	21,601.02	3,325.82	4,573.20	2,745.50	32,245.54
Trang	9,951.17	257.54	1,824.43	894.13	12,927.27
Phatthalung	137,472.62	41,536.82	11,934.87	3,659.03	194,603.34
Pattani	67,241.46	26,435.66	61,602.60	5,501.19	160,780.91
Yala	7,941.39	19,775.37	25,562.42	909.61	54,188.79
Narathiwat	25,686.34	50,132.84	24,727.91	3,260.94	103,808.03
Southern	822,186.42 (69.40%)	172,965.64 (14.60%)	162,064.46 (13.68%)	27,418.25 (2.31%)	1,184,634.77
Whole country	19,462,765.44 (29.35%)	22,388,169.28 (33.77%)	18,165,795.46 (27.40%)	6,286,905.73 (9.48%)	66,303,635.91

Note. The percentage of share area to the total rice farming area is in parenthesis.

BIOGRAPHY

Name	Nutthapoj Snansiang
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Scholarship	2019: Mitsubishi UFJ Foundation Scholarship 2018-2019: Faculty of Economics, Thammasat University Scholarship

