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Measuring Efficiency, Technical Change and Productivity Trend Using Malmquist Productivity Index Analysis: A Case Study of Rice Production in Thailand

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Abstract:
The purpose of the paper is to measure the efficiency and technical change of production and estimate the rice productivity trend in four regions of Thailand using Malmquist productivity index (MPI) analysis during the crop years 2006/2007 to 2015/2016. Malmquist index analysis show that Thai rice productivity had a good performance and had an upward productivity trend but some areas need to be improved. In addition, our results indicated that Northeastern and Central had the best performance and had a productivity progression for Thai rice production. In other hand, Northern and Southern has the worst efficiency performance and had a productivity regression, which therefore should be increased the quantity of the inputs and outputs. The results from this paper contribute to improving the productivity for sustainable development. Therefore, this paper can provide important information to the Thai government, farmers, the rice research institutes and the development partners to help increase the trend of rice productivity index in some areas of Thailand.

Keywords: *Efficiency, Malmquist productivity index, Productivity trend, Technical change, Thai rice production*

1. Introduction

Rice is one of the most important crops in the world (Khoshnevisan et al., 2014). In Asia, Africa and America almost a billion households depend on the rice production for their main source of employment and livelihood (Nabavi-Pelesaraei, Abdi, Rafiee, & Taromi, 2014; Van Nguyen & Ferrero, 2006). According to the report of Food and Agriculture Organization (2016), in crop year 2015/2016 world rice production was 472.27 million metric tons and China was the world's largest producer of rice and a production volume of more than 100 million metric tons. In 2015/2016, the total rice consumption was around 478.44 million metric tons and global per capita consumption of rice is 54.6 kilograms per year (Food and Agriculture Organization, 2016). Thailand is the seventh largest consumer of rice and has a land area of 9.65 million hectares in 2015/2016 (National Statistical Office, 2016). In addition, Thailand is the sixth largest producer of world rice production approximately 18.75 million metric tons and Thailand is second largest exporter of rice amounted to 10.05 million metric tons in crop year 2015/2016 (Food and Agriculture Organization, 2016; National Statistical Office, 2016). In Thailand, the most of rice growing areas are located in northeast region (57%) followed by northern region (22%), central region (17%), and southern region (4%) and are likely to expand further (Titapiwatanakun, 2012). In 2015, rice production involved 5.4 million Thai farming families, which accounts for more than 17 million people across the country, including laborers, entrepreneurs and government officials (Office of Agricultural Economics, 2016).

According to the economic theory, the basic factors of production, such as, land, capital and labor have been considered as assessment parameters of sustainable development (Longpichai, Perret, & Shivakoti, 2012; Van Passel, Van Huylenbroeck, Lauwers, & Mathijs, 2009). Wijnhoud, Konboon, and Lefroy (2003) proposed that labor resources and capital are significant socio-economic factors in Thailand and affect sustainable development in the long term. Thus, the measurement of production trend is based on output factors and inputs factors. This is consistent with numerous studies (Longpichai et al., 2012; Wijnhoud et al., 2003). Coelli (1996) and Pingali and Xuan (1992) suggested that the output variables and input variables are important to measure the productivity of rice production. Mohammadi et al. (2015) measured the efficiency of 82 rice fields for spring and summer growing seasons in Iran and had one output (quantity of rice) and eight inputs (seed, fertilizer, chemicals, water, electricity, machinery, diesel and labor). The results indicated that the impact of efficiency of the spring more than summer seasons. Krasachat (2003) examined productivity performance of Thai rice production in 1999. The output had one variable (rice quantity) and six input variables (land, labor, capital, fertilizer and other inputs). The results showed that there are significant possibilities to increase the efficiency of rice production in Thailand. Therefore, measuring production trends lead to the advancement of sustainability. Thai rice production are very different in each region. The purpose of this study to measure the changes in rice production efficiency and to estimate the rice productivity trend in different regions of Thailand during the crop years 2006/2007 to 2015/2016 by using Malmquist productivity index (MPI) approach. Few empirical studies have measured the productivity trend of rice production by using MPI technique due to data limitations and the difficulty in determining the inputs and outputs of production.

MPI has mainly been applied to measuring the production efficiency of heterogeneous firms/units operating under different technologies (Malmquist, 1953). Fare, Grosskopf, Norris, and Zhang (1994) modified it to measure the change of productivity over time. Many researchers have suggested that the data envelopment analysis (DEA) model based on the concept of the MPI was developed for evaluating total factor productivity change (TFP), efficiency change (EC), and technical change (TC) (Coelli & Rao, 2005; Liu et al., 2015; Xue, Shen, Wang, & Lu, 2008). Son Nghiem and Coelli (2002) attempted to measure efficiency of rice production in Vietnam for period from 1976 to 1997 using DEA method and MPI approach. The result suggested that there was a strong average total factor productivity change growth and that productivity growth differs between regions. Li and Lin (2016) applied DEA method and MPI approach for improving the measurement of green productivity growth of China's manufacturing sector in 2006 to 2010. The results showed an average total factor productivity change growth at 4.50%, efficiency change at 2.64% and 1.81% technical change over the study period. This literature review of the MPI has shown that this distinctive technique is an appropriate and useful research method for measuring the productivity change over time. The rest of this study is structured as follows. Section 2 introduces the MPI approach and the selection of variables and the source of data. The results and discussion are explained in Section 3. Finally, Section 4 presents the conclusions.

2. Research Methodology

2.1. Malmquist Productivity Index (MPI) Approach

MPI was invented by Malmquist (1953). MPI approach were was introduced by Caves, Christensen, and Diewert (1982)based on the distance functions (Mao & Koo, 1997), that is a very useful approach for measuring the productivity changes which have the advantages for assessing multiple input and output variables at the time period (Arabi, Munisamy, Emrouznejad, & Shadman, 2014; Yang, Wan, & Ma, 2015). This model has been stimulated by Färe, Grosskopf, Lindgren, and Roos (1994), which demonstrated how to use non-parametric linear programming techniques to calculate the MPI. We calculate MPI by the performance of each decision-making units (DMU) at different periods using the technology of a base period. Therefore, it reflects the progress or regress in efficiency performance together with the progress or regress of frontier technology over time under the multiple inputs and multiple outputs of theoretical frameworks (Gregoriou & Zhu, 2005). In this study used input and output variables to measure the rice productivity changes for crop years 2006/2007 –2015/2016 with 77 cities in 4 regions in Thailand. Fare et al. (1994) proposed that MPI can be decomposed into two components based on the constant returns to scale (CRS). The first component is to measure technical change (TC) in production technology and second component measure efficiency change (EC) in a gap between maximum feasible production and the observed production function. Thus, both component indices can effectively identify the cause of productivity change. As specified by Fare et al. (1994) this index is:

$$M(y^{t+1},x^{t+1},y^t,x^t) = \left[\left(\frac{D_i^t(x^{t+1},y^{t+1})}{D_i^{t+1}(x^{t+1},y^{t+1})}\right)\left(\frac{D_i^t(x^t,y^t)}{D_i^{t+1}(x^t,y^t)}\right)\right]^{\frac{1}{2}} \times \frac{D_i^{t+1}(x^{t+1},y^{t+1})}{D_i^t(x^t,y^t)} \qquad (1)$$

= Technical Change (TC) Efficiency Change (EC)

Where M means the productivity changes from the period t to the period $t + 1$ by using the period t technology and period t+ 1 technology as a reference. y^t and x^t are outputs and inputs in the period t.Moreover, y^{t+1} and $x^{t+1}$are outputs and inputs in the period t+1. $D_i^t$is the output distance function in the period t and$\mathrm{D}_i^{t+1}$is the output distance function in the time period t+1.

If TC > 1 indicates advances in technology, TC < 1 means deteriorating technology and TC = 1 means unchanged technology. EC > 1 indicates the increase of efficiency for rice production from period t to $t + 1$; EC < 1 shows the decrease of efficiency from the period t to $t + 1$ and EC = 1 presents rice production efficiency remains stable during the period t to $t + 1$. Furthermore, M> 1 means productivity growth; M< 1 shows productivity decline and M = 1 represents no-change in productivity from period t to t+1.

2.2. Variables and Data Analysis

In this study used the data from secondary data collected from surveys through various governmental agencies in Thailand: Rice Department of Ministry of Agriculture and Cooperatives, Rice Research Institute, Ministry of Labor and Office of Agricultural Economics. We examined four regions; northern, northeastern, central, and southern regions in Thailand, covering 77 cities (77 DMUs) during the crop years 2006/2007 to 2015/2016. Zeng, Hu, and Su (2016) preferred that the selection of the output variables and input variables is a very important component of the analysis of productivity. Consequently, the selection variables are critical in assessing the measurement of productivity. Rice production output used in the study is quantity of rice output and the rice production input includes land, labour, fertilizer, pesticide, tractor and seed. Table 1 shows data descriptions of outputs and inputs in this study. Data analysis was conducted using DEAP Version 2.1 and SPSS Version 23.0. From the descriptive statistics shown in Table 2, an average of rice quantity shows a very high number at 645,638 tons with the maximum quantity of 1,416,140 tons and the minimum quantity of 30 tons. Moreover, the results showed that on average, land was quite big (244,318 ha), labour was 2,894 hr/ha, fertilizer was 31,983 tons, pesticide used was 3,921 tons, tractor was 45 hr/ha and number of seeds were high at 18,379 tons of the rice production sector in Thailand.

Variables		Unit	Definition	Source
Output	Quantity of Rice	tons	Total rice quantity	Sherlund, Barrett, and Adesina (2002); Wijnhoud et al. (2003) and Nabavi-Pelesaraei et al. (2014)
Inputs	Land	hectare (ha)	Total area for rice production	Dhungana, Nuthall, and Nartea (2004); Mailena, Shamsudin, Radam, and Latief (2014) and Tung (2014)
	Labour	hour per ha (hr/ha)	The workers who are 15-60 years old and engaged in rice production	Rahman and Rahman (2009); Khoshnevisan et al. (2014) and Mailena et al. (2014)
	Fertilizer	tons	Total number of the chemical fertilizers used in rice-farming production	Nassiri and Singh (2009); Khoshnevisan et al. (2014) and Mailena et al. (2014)
	Pesticide	tons	Total number of substances that are intently used for mitigating, destroying, repelling and preventing any pest. Pesticides included herbicides, insecticides, fungicide and bactericides.	Khai and Yabe (2011); Khoshnevisan et al. (2014) and Tung (2014)
	Tractor	hour per hectare (hr/ha)	The total power of farm tractors	Nassiri and Singh (2009) and Khoshnevisan et al. (2014)
	Seed	tons	Total number of rice seeds sown in the rice fields, including the total number of in-season and off-season rice seeds	Rahman and Rahman (2009); Mailena et al. (2014) and Mohammadi et al. (2015)

Table 1: Data descriptions of variables items and resource
Source: Author's composition

Variables	Unit	Maximum	Minimum	Mean	Std. dev.
Quantity of Rice	tons	1,416,140	30	645,638	592,804
Land	hectare (ha)	522,645	14,829	244,318	197,839
Labour	hour per ha (hr/ha)	3,690	408	2,894	2,471
Fertilizer	tons	153,093	21	31,983	24,802
Pesticide	tons	58,911	16	3,921	2,274
Tractor	hour per hectare (hr/ha)	63	13	45	17
Seed	tons	125,022	5	18,379	11,902

Table 2: Descriptive statistics of output and input variables during the crop years 2006/2007 to 2015/2016
Source: Author's calculations

3. Results and Discussion

In this study, we used Malmquist Index to estimate changes in productivity trend of rice production during the crop years 2006/2007 to 2015/2016 in Thailand. Based on the MPI, the total factor productivity change can be decomposed into two components, technical change and efficiency change. Both components have directly influenced on the trend of productivity's change. We used DEAP Version 2.1 to analyze these data. Table 3 presents average estimates of Malmquist indices of total factor productivity change decomposed into technical change and efficiency change in Thai rice production. If the value of total factor productivity change is greater than one, it indicates productivity growth as well; less than one implies productivity decline, and equal to one means no change in productivity growth. Therefore, total average including technical change was 1.048, efficiency change was 0.988 and total factor productivity change was 1.035; thus, we find that productivity of Thai rice production has improved in the studied period during the crop years 2006/2007 to 2015/2016, as suggested by the Malmquist total factor productivity change of rice production and the value of total factor productivity change. Northern region had positive growth rates in crop years 2007/2008-2008/2009, 2010/2011-2011/2012 and 2012/2013-2013/2014 and had negative growth rate in crop years 2006/2007-2007/2008, 2008/2009-2009/2010, 2009/2010-2010/2011, 2011/2012-2012/2013, 2013/2014-2014/2015 and 2014/2015-2015/2016; thus, the productivity trend of this region is decreasing. Northeastern region had growth rates of efficiency increased in crop years 2009/2010-2010/2011, 2010/2011-2011/2012, 2012/2013-2013/2014 and 2014/2015-2015/2016 and had growth rates of efficiency decreased in crop years 2006/2007-2007/2008, 2007/2008-2008/2009, 2008/2009-2009/2010, 2011/2012-2012/2013 and 2013/2014-2014/2015. Central region has shown efficiency improvements and technical progress in crop years 2009/2010-2010/2011, 2012/2013-2013/2014 and 2013/2014-2014/2015 and has shown inefficiency and technical recession in crop years 2006/2007-2007/2008, 2007/2008-2008/2009, 2008/2009-2009/2010, 2010/2011-2011/2012, 2011/2012-2012/2013 and 2014/2015-2015/2016. Southern region had a positive productivity trend in crop years 2008/2009-2009/2010, 2010/2011-2011/2012 and 2012/2013-2013/2014 and had a negative productivity trend in crop years 2006/2007-2007/2008, 2007/2008-2008/2009, 2009/2010-2010/2011, 2011/2012-2012/2013, 2013/2014-2014/2015 and 2014/2015-2015/2016. It overall, the northeastern region has the highest productivity growth among the four regions followed by central, northern, and finally the southern regions. Furthermore, an overview of studies found that rice production in Thailand has improved in technical efficiency, technology and productivity growth during the period of this study.

Regions	Crop Years	Technical Change (TC)	Efficiency Change (EC)	Total Factor Productivity Change (TFP)	Estimates of the productivity trend
Northern Region	2006/2007-2007/2008	0.980	0.824	0.808	↓[a]
	2007/2008-2008/2009	1.020	1.012	1.032	↑[b]
	2008/2009-2009/2010	1.000	0.934	0.934	↓
	2009/2010-2010/2011	1.000	0.982	0.982	↓
	2010/2011-2011/2012	1.000	1.179	1.179	↑
	2011/2012-2012/2013	1.000	0.791	0.791	↓
	2012/2013-2013/2014	0.996	1.192	1.187	↑
	2013/2014-2014/2015	0.961	1.014	0.974	↓
	2014/2015-2015/2016	1.045	0.803	0.839	↓
	Mean	1.000	0.970	0.970	↓
Northeastern Region	2006/2007-2007/2008	0.621	0.975	0.606	↓
	2007/2008-2008/2009	0.981	0.999	0.980	↓
	2008/2009-2009/2010	1.052	0.927	0.974	↓
	2009/2010-2010/2011	1.158	1.055	1.221	↑
	2010/2011-2011/2012	1.993	1.640	3.269	↑
	2011/2012-2012/2013	0.977	0.812	0.793	↓
	2012/2013-2013/2014	1.086	1.200	1.304	↑
	2013/2014-2014/2015	0.914	1.004	0.918	↓
	2014/2015-2015/2016	1.892	0.962	1.820	↑
	Mean	1.186	1.064	1.321	↑
Central Region	2006/2007-2007/2008	0.977	0.768	0.750	↓
	2007/2008-2008/2009	1.018	0.943	0.960	↓
	2008/2009-2009/2010	0.900	0.967	0.870	↓
	2009/2010-2010/2011	1.028	0.995	1.023	↑
	2010/2011-2011/2012	0.772	1.204	0.929	↓
	2011/2012-2012/2013	0.892	0.797	0.711	↓
	2012/2013-2013/2014	0.863	1.189	1.026	↑
	2013/2014-2014/2015	1.831	1.754	3.213	↑
	2014/2015-2015/2016	0.786	0.363	0.285	↓
	Mean	1.007	0.998	1.085	↑
Southern Region	2006/2007-2007/2008	1.000	0.579	0.579	↓
	2007/2008-2008/2009	1.000	0.691	0.691	↓
	2008/2009-2009/2010	1.000	1.040	1.040	↑
	2009/2010-2010/2011	1.000	0.955	0.955	↓
	2010/2011-2011/2012	1.000	1.535	1.535	↑
	2011/2012-2012/2013	1.000	0.479	0.479	↓
	2012/2013-2013/2014	1.000	1.313	1.313	↑
	2013/2014-2014/2015	1.000	0.916	0.916	↓
	2014/2015-2015/2016	1.000	0.757	0.757	↓
	Mean	1.000	0.918	0.918	↓
Total Mean		1.048	0.988	1.035	↑

Table 3: Malmquist productivity index summary of annual means

Note: [a] The productivity trend is decreasing; b The productivity trend is increasing.

Source: Author's calculations

4. Conclusions

Rice is a major agricultural crop in Thailand and rice production has an important role in economic and social development of the country. In this study, MPI approach has been applied to measure the efficiency change and to estimate the productivity trend over a ten-year period of rice production in Thailand. Malmquist index of Thai rice production showed an upward trend because of the increasing trends found in both the technical change and the efficiency change. Northern region had a regression in total factor productivity change that was mainly caused by the downward trends in the technical change and efficiency change. Interestingly, Northeastern region found an upward trend in the total factor productivity change. The increasing trend in Northeastern region was mainly due to the improvement in the efficiency change. The total factor productivity change of Central region went up with time-varying trend because of the increasing scores in both the technical change and efficiency change. Moreover, Southern region had a regression in total factor productivity change that was mainly caused by the downward trends in the technical change and efficiency change. The production of rice in Thailand has been varying among four different regions due to the each DMU of each region has different trend of rice production. From the above observation, we recommend the following; the Thai government should focus on policies that are beneficial to supporting facilities, modern machinery and advanced technology training for farmers; thus, they can acquire new knowledge and new machinery to develop their own farms. Finally, this study can provide important information to the farmers, Thai government, the rice research institutes, and the development partners to determine strategies that are useful and practical in raising efficiency performance in each region and to help increase the trend of rice productivity index in some areas of Thailand.

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