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TECHNICAL EFFICIENCY OF OFF-SEASON RICE PRODUCTION IN NORTHERN THAILAND

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Abstract. This research aims to study the technical efficiency was estimated by Data Envelopment Analysis in the panel data by Malmquist Index using collected data of off season rice production in the seventeen provinces in the north of Thailand. The information about off season rice in the crop year 2008/2009 – 2018/2019 to analyze technical efficiency. The results indicated that the average technical efficiency (TE) score of off season rice was high. The average TE was 0.933, the highest TE score was 0.963 in Lamphun province and the lowest TE score was 0.908 in Phetchabun province respectively. In addition, the total factor productivity (TFP) change, an average score of TFP performed a high efficiency (1.001) during the ten years. The scores with less than 1.000 were found in 14 provinces from 17 provinces which implied a need to improve performance and technology. However, this research must be certainly useful for farmers to obtain a better understanding and also for government to implement the policies of this sector.

INTRODUCTION

Rice plays a significant role as an important economic crop in Thailand; it involves 3.55 million households of rice farmers in Thailand [1]. In the global market of rice products, Thailand was the world's largest rice exporter although the amount of rice production in Thailand is relatively small compared to other countries [2]. More than fifty percent of rice production is produced for exporting, making Thailand consistently ranked at the top three of rice exporting countries in the world. Thailand has a market share of approximately 24 percent of world rice exports, with the major competitors being India and Vietnam [3-5]. In 2018/2019, Thailand was the world's second-largest exporter with about 10.3 million metric tons of rice after India which had the highest export volume of rice worldwide, at 12.5 million metric tons as of 2018/2019 [1].

Thailand has two annual rice-growing periods, the wet-season and the off season (or dry-season). The wet- season rice harvest (May through October) is the larger of two annual crops, normally accounting for roughly 70 percent of total annual production. Wet-season rice is heavily dependent on monsoonal weather systems, with 70 percent of the crop being totally rainfed. The remaining 30 percent lies primarily in the western Chao Phraya river basin and is irrigated from water stored in mountain reservoirs. Off season rice area averages 2.0 million hectares, is approximately 80 percent irrigated, and accounts for roughly 30 percent of total annual rice production. Off season rice (November through May) yield is nearly double the yields of the primarily rainfed wet-season crop. Off season rice cultivation is heavily focused on irrigated farmland in the Lower North and Central Plains regions. With the majority of the irrigation infrastructure and agricultural mechanization, these areas are essentially the nation's rice heartland [6].

Major production comes from the wet season rice crop with the supplement of the off season rice crop. On the othe hand, Water Resources Development Programme: By nature rice is a water-loving plant. Research in Thailand indicated that water consumption for rice production was estimated at about 9,400 m^3/ha in the wet season and 12,500 m^3/ha in the off season, approximately 50 percent higher than for other crops (Tawng-Aram, 1986) [7]. Water resources for rice production in Thailand is limited, especially in off season rice cropping. The central and northern regions are mainly irrigated. More water resources development and irrigation facilities are needed in narrowing rice yield gaps.

Since land and water resources for rice production are limited and the country has to increase its production to meet the increasing demand for domestic consumption and to be more competitive in the world market, the national rice industry needs an effective production system to narrow the yield gaps. Both agricultural technology development and farm infrastructure improvement are [8]. Therefore, the research aimed to study (i) the maximum possible proportional decrease in input usage with a given output levels of off season rice production in the seventeen provinces in the north of Thailand, and (*ii*) trend in off season rice productivity's change over a ten-year period in the crop year 2008/2009 – 2018/2019 by using Malmquist.

METHODS

Data

In this study, to estimate the DEA scores and Malmquist TFP indexes of efficiency, a panel data that has been taken from [9] of off season rice production in the crop year 2008/2009 – 2018/2019 on seventeen provinces where located in the North of Thailand was used. The North region covers the provinces of 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. We used four variables for the DEA. Three inputs (planted area, seed and amount of fertilizer) and one output (off season rice production) are used in the analysis. Then, technical efficiency and total factor productivity growth indices are obtained using the computer program [10] DEAP 2.1.

Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a non-parametric method in operational research and economics, based on the economic notion of Pareto optimality. The method aims to determine the efficiency of a decision making unit (DMU) that has been developed by [11] who first introduced the non-parametric method according to the ideas of [12], calculating relative values about efficiency by means of linear programming under constant returns to scale (CRS). This technique is a useful research method not only to measure the efficiency of DMUs, but also to evaluate their relative values about efficiency by means of linear programming under constant returns to scale (CRS). This method was named as the CCR model. A cross-sectional data, panel data, and time-series data can be evaluated by this method as well. The CCR model has its limitations, and specifically it is unable to judge whether scale inefficiency or technical inefficiency results in final inefficiency. The BCC model presented by [13] and also abbreviated from the authors' names is applicable to technologies of variable returns to scale (VRS). It could further explain the result of efficiency analysis by distinguishing between technical and scale inefficiencies through estimating pure technical efficiency at the given scale of operations.

DEA can be either used in output oriented form or input oriented form depending on the purpose of researcher. In this study, to evaluate the technical efficiency by adopting input-oriented DEA model. The input oriented DEA model can be measured by assuming a constant return to scale in this study mentioned as follows in equation 1 [14];

$$\begin{aligned} &TE = Min_{\theta i,\lambda}\ \theta, \\ &-y + Y\lambda \geq 0 \\ &\text{Subject to} \quad {}_{\theta}x_i - X\lambda \geq 0, \\ &\lambda \geq 0 \end{aligned} \qquad (1)$$

The input oriented DEA model seeks the maximum possible proportional decrease in input usage with a given output levels. Meanwhile, the output oriented DEA model seeks the maximum possible proportional increase in output with a given set of inputs.

The Malmquist index calculated using distance functions is a bilateral index that can be used to compare the production technology of two economies. It is named after a Swedish economist and statistician, Sten Malmquist, who published a quantity index for use in consumption analysis, comparing the distances from two vectors to any indifference curve in the manner of measuring radial scale in 1953. It is also called the Malmquist productivity index [15].

The Malmquist index was firstly introduced in literature of productivity by [16] that based on the distance function, as a quantity index for use in the analysis of consumption of inputs. [17] specified an output-based Malmquist productivity change index as the geometric mean of two indices from period t and period t+1 and also combined ideas on the measurement of efficiency from [12] and the measurement of productivity from [18] to construct a Malmquist productivity index directly from input and output data using DEA.

This DEA based Malmquist TFP index has proven itself to be a good tool for measuring the productivity change of DMUs. The Malmquist productivity change was decomposed into two components measuring technical efficiency change and the other component measuring technological change. The two component indices can effectively identify the causes of the productivity change. The Malmquist index can be written as shown in equation 2 [19]:

$$M(y^{t+1}, x^{t+1}, y^t, x^t) = \left[\left(\frac{D_t^t(x^{t+1}, y^{t+1})}{D_t^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_t^t(x^t, y^t)}{D_t^{t+1}(x^t, y^t)}\right)\right]^{½} \times \frac{D_t^t(x^{t+1}, y^{t+1})}{D_t^t(x^t, y^t)} = TC \times EC \qquad (2)$$

A change value greater than one indicates a positive shift or technical progress, less than one indicate negative shift or technical regress, and equal one indicates no shift in productivity change.

After the calculation,

M can take three different values. $M > 1$ indicates the productivity growth; $M < 1$ indicates productivity declin*e;* M = 1 means no change in productivity from period *t* to *t* + 1. EC > 1 denotes the increase of wet season rice production efficiency from the time period *t* to the time period *t* + 1; EC < 1 denotes the decrease of wet season rice production efficiency; EC = 1 means the wet season rice production efficiency remains stable during the period *t* to the time period *t* + 1. TC > 1 shows there is an advance in technology; TC < 1 shows a deteriorating technology; TC = 1 means that there is unchanged technology.

In addition, technical efficiency change can be further decomposed into pure technical efficiency change and scale efficiency change under VRS. The disadvantage of the Malmquist index is the necessity to calculate distance functions. There are several techniques, like the parametric stochastic frontier analysis and non-parametric DEA, which could be used to measure the distance functions productivity indices. The DEA-like linear programming method is adequate to solve distance functions.

RESULTS

The technical efficiency (TE) is presented in Table 1 of off season rice production in 17 provinces where located in Northern Thailand. The average technical efficiency (TE) score in each year during the period from 2008 to 2019 was 0.908, 0.937, 0.915, 0.923, 0.963, 0.948, 0.930, 0.928, 0.923, 0.955, 0.924, 0.944, and 0.933 respectively. It can be seen that average TE scores are relatively moderate, thus, it is necessary to improve the operational efficiency of off season rice production in Thailand.

The findings from this study showed that the average TE of firm during the period from 2008/2009 to 2018/2019 in Lamphun province was found to be fully efficient with the average TE score of 1.000 followed by 5 provinces where have the high TE score; Chiang Rai, Chiang Mai, Uttaradit, Phichit, and Tak with the average TE score of 0.991, 0.988, 0.983, 0.957, and 0.949, respectively. The lowest TE score was 0.853. Phetchabun province revealed the least efficiency's score.

Besides, the average TE score of wet season rice was 0.933 in the crop year 2008 to 2019 which means that it could be achieved 93.3% by technical efficiency and could be extended the efficient score 6.7% by decreasing of each input. The empirical results suggested that it could be improved the production for increasing the efficiency performance of off season rice production in Northern Thailand.

Table 1: Technical Efficiency Scores of Off Season Rice Production in Northern Thailand from 2008 to 2019

Province	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
Chiang Rai	1.000	1.000	0.985	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.954	0.991
Phayao	0.897	0.858	0.896	0.846	0.967	0.912	0.946	0.937	0.944	0.950	0.843	0.923	0.910
Lampang	0.975	1.000	1.000	1.000	0.922	0.914	0.852	0.830	0.804	0.884	0.815	0.849	0.904
Lamphun	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
Chiang Mai	1.000	0.982	1.000	1.000	0.987	1.000	1.000	1.000	0.946	1.000	0.945	1.000	0.988
Mae Hong Son	0.218	0.822	0.876	0.899	1.000	0.904	1.000	1.000	1.000	1.000	1.000	1.000	0.893
Tak	1.000	1.000	1.000	1.000	1.000	1.000	0.924	0.893	0.780	0.948	0.947	0.899	0.949
KamphaengPet	0.892	0.913	0.801	0.793	0.985	1.000	0.974	0.940	0.955	0.966	0.946	0.972	0.928
Sukhothai	0.933	0.948	0.929	0.971	0.954	0.937	0.899	0.918	0.920	0.963	0.909	0.906	0.932

Phrae	0.952	0.878	0.884	0.885	0.941	0.896	0.810	0.875	0.814	0.855	0.761	0.890	0.870
Nan	1.000	0.976	0.909	0.952	0.874	0.852	0.834	0.812	0.820	0.823	1.000	0.837	0.891
Uttaradit	1.000	0.995	0.974	0.994	0.982	1.000	1.000	1.000	1.000	0.986	0.904	0.966	0.983
Phitsanulok	0.949	0.939	0.866	0.914	0.990	0.984	0.906	0.946	0.897	0.984	0.941	0.960	0.940
Phichit	0.956	0.977	0.941	0.958	1.000	0.950	0.948	0.937	0.978	0.972	0.911	0.961	0.957
Nakhon Sawan	0.974	0.969	0.869	0.889	0.948	0.946	0.965	0.932	0.895	0.940	0.940	1.000	0.939
Uthai Thani	0.914	0.917	0.857	0.880	0.980	0.954	0.918	0.926	0.955	0.965	0.961	0.991	0.935
Phetchabun	0.782	0.754	0.771	0.712	0.847	0.863	0.829	0.830	0.989	1.000	0.931	0.933	0.853
Mean	0.908	0.937	0.915	0.923	0.963	0.948	0.930	0.928	0.923	0.955	0.924	0.944	0.933

Source: Author's calculations

In table 2, it showed the results in the productivity trend of the off season rice production during 2008/2009–2018/2019 by using the Malmquist productivity index (MPI). The average of efficiency change (EC), technological change (TC), and total factor productivity (TFP) change of off season rice producing provinces in Northern Thailand were 1.007, 0.994 and 1.001, respectively.

The findings indicated that, the TFP of off season rice production increased. Besides, for the decomposition effects of the MPI, off season rice production has shown the technical progress and efficiency improvements when the years 2008, 2010-2012, and 2016-2018 are compared, except during of 2009–2010, 2012–2016, and 2018–2019, which have decreased in the production efficiency and technological progress.

Table 2: Malmquist productivity index (MPI) summary of annual means

Year	**Efficiency change**	**Technological change**	**Total factor productivity change**	**Estimates of the productivity trend**
2008 - 2009	1.073	0.982	1.053	increasing
2009 - 2010	0.977	0.946	0.924	decreasing
2010 - 2011	1.008	1.025	1.033	increasing
2011 - 2012	1.047	1.044	1.093	increasing
2012 - 2013	0.984	0.952	0.936	decreasing
2013 - 2014	0.980	0.993	0.973	decreasing
2014 - 2015	0.998	0.998	0.996	decreasing

2015 - 2016	0.994	0.930	0.924	decreasing
2016 - 2017	1.036	1.024	1.061	increasing
2017 - 2018	0.966	1.176	1.137	increasing
2018 - 2019	1.023	0.891	0.911	decreasing
Mean	**1.007**	**0.994**	**1.001**	**increasing**

Source: Author's calculations

An analysis of changing in efficiency showed that in the off season rice productivity increased by firm (province) from 2008 to 2019 in Table 3. Through the MPI decomposing, it is possible to determine the sources of the productivity growth. An upward trend was found for the TFP with greater than 1 (> 1) in Mae Hong Son, Uthai Thani, and Phetchabun provinces, which implied an improvement in the efficiency as well as technology. On the other hand, a downward trend with less than 1 was found in Chiang Rai, Phayao, Lampang, Lamphun, Chiang Mai, Tak, Kamphaeng Phet, Sukhothai, Phrae, Nan, Uttaradit, Phitsanulok, Pichit, and Nakhon Sawan provinces which implied a need to improve performance and technology. In addition, the analysis of the MPI showed the efficiency measurement during over a ten-year period. Therefore, we concluded that the off season rice production in Northern Thailand achieved efficiency, the technical progress and the productivity growth between 2008–2019.

Table 3: Malmquist productivity index (MPI) summary of firm means

Province	**Efficiency change**	**Technological change**	**Total factor productivity change**	**Estimates of the productivity trend**
Chiang Rai	0.996	0.995	0.991	decreasing
Phayao	1.003	0.996	0.998	decreasing
Lampang	0.988	0.992	0.979	decreasing
Lamphun	1.000	0.992	0.992	decreasing
Chiang Mai	1.000	0.995	0.995	decreasing
Mae Hong Son	1.149	1.003	1.152	increasing
Tak	0.990	0.995	0.986	decreasing
Kamphaeng Phet	1.008	0.991	0.999	decreasing
Sukhothai	0.997	0.993	0.990	decreasing
Phrae	0.994	0.997	0.990	decreasing
Nan	0.984	0.996	0.980	decreasing

Uttaradit	0.997	0.992	0.989	decreasing
Phitsanulok	1.001	0.993	0.994	decreasing
Phichit	1.001	0.992	0.992	decreasing
Nakhon Sawan	1.002	0.994	0.996	decreasing
Uthai Thani	1.007	0.994	1.002	increasing
Phetchabun	1.016	0.989	1.005	increasing
Mean	**1.007**	**0.994**	**1.001**	**increasing**

Source: Author's calculations

CONCLUSIONS

The empirical results showed that the technical efficiency of off season rice production in seventeen provinces of Northern Thailand in the crop year 2008/2009 – 2018/2019 by using an application of DEA Malmquist Index. The TE score revealed the production still needs to be improved due to the TE score is not close to 1.000. The empirical revealed that Lamphun province had the most effective from the crop year 2008 to 2019 as compared with other off season rice producing provinces. This suggests that the Lamphun province is the best producing province for off season rice production in Northern Thailand. Meanwhile, Phetchabun province which had the worst efficiency score, revealed the least efficiency's score among all the producing provinces in Northern Thailand. Besides, the average TE score of off season rice production in Northern Thailand was 0.933 in the crop year 2008 to 2019 which means that it could be achieved 93.3% by technical efficiency and could be extended the efficient score 6.7% by decreasing of each input. The empirical results suggested that it could be improved the production for increasing the efficiency performance of off season rice production in Northern Thailand.

In term of the total factor productivity (TFP) change, an average score performed a high efficiency (1.001) during the ten years. The scores with greater than 1.000 in three provinces (Mae Hong Son, Uthai Thani, and Phetchabun) which implied an improvement in the efficiency as well as technology. On the other hand, the scores with less than 1.000 was found in fourteen provinces (Chiang Rai, Phayao, Lampang, Lamphun, Chiang Mai, Tak, Kamphaeng Phet, Sukhothai, Phrae, Nan, Uttaradit, Phitsanulok, Pichit, and Nakhon Sawan) which implied a need to improve performance and technology. Therefore, we concluded that the off season rice production in Northern Thailand achieved the efficiency improvement, the technical progress and the productivity growth between 2008–2019. Moreover, this study can provide important and useful information for farmers, producers, researchers, policy makers, and government agencies to set the plans for using technology to improve efficiency.

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