Assessing rice production efficiency of the granary and non-granary areas in Malaysia using data envelopment analysis approach

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Abstract. The performance of rice production efficiency between two homogenous regions (granaries and non-granaries) at the regional level in Malaysia is evaluated by applying the data envelopment analysis (DEA) approach. In general, the granary area receives much attention to achieve sustainable rice development compared to non-granaries. The period observed from 2009 to 2018 related to the comprehensive government transformation in strengthening paddy and rice value-chain after the 2007-2008 international food crisis. Under the new National Agrofood Policy (NAFP) 2011-2020, more agricultural assistance and development expenditure was allotted. The total of eighteen regions was classified into eight granaries and ten regions for non-granaries. The output-input oriented analysis under CRS and VRS specifications were performed. From CRS and VRS technical efficiency scores ratio, the scale efficiencies were calculated. The result shows that eight (44.44%) out of eighteen regions maintain high efficiency with scores greater than 0.9000 for both specifications. Meanwhile, under ‘pure’ technical efficiency (VRS), eleven (61.11%) out of eighteen regions maintain high efficiency with scores greater than 0.9000. For productivity status, twelve (66.67%) out of eighteen areas are optimum and increasing productivity approach and the remaining six (33.33%) are decreasing productivity. This empirical study also demonstrates substantial performance variations between output (rice production) and production factors (land, planting frequency, irrigation areas, total subsidies and incentives received). Overall, the Malaysia paddy and rice industry's efficiency performance can be considered still inefficient but has the potential to maximize the production through rationalizing the inputs used and obtain production efficiency, especially the inefficient regions.

1. Introduction

Rice is a well-known crop and considered one of the major staple food that feeds approximately half of humanity besides other major staple crops such as wheat and maize. Asia region largely depends on rice where more than 90% of rice produced in the world is cultivated and consumed within this continent [1]. Further, this commodity crop is known as daily must carbohydrate sources and receives special treatments in the agricultural policy of many countries.

The empowerment of the rice agenda underwent an enormous transformation since the international food crisis hit globally in 2007-2008 periods. The Self-Sufficient Level (SSL) has risen on the policy agenda of many countries resulting from food price fluctuations [2]. Numerous importing countries have formulated their national agrofood policy generally in twofold, which are to strengthen the rice value-
chain of domestic production and less dependency on importation. More allocations were allotted under the national agrofood program to boost domestic production. The inputs subsidy and output price supports have also become the most common agricultural policy tools for many countries [3].

In the same vein, modernizing the rice sector is done by intensifying rice production systems to maximize the yields of an area. Globally, the International Rice Research Institute (IRRI) suggests that there are four elements in the modern rice intensification process: increasing frequency of crops cultivation, greater use of externals inputs (nutrients, water, energy and pesticides), less diversity of rice varieties with the use of modern varieties and simplification of the cropping systems through rice monocropping [4]. The adoption of rice intensification systems has proven more excellent rice production that would satisfy the agrofood policy of particular nations. Besides, the rice intensification has resulted in the expansions of irrigated areas through developing of modern infrastructures such as dams, canals, reservoirs and conveyance systems. Hence, the rice intensification systems play a crucial role in the modern rice cultivation era to obtain production efficiency.

Though vigorous efforts have been conducted under national food security of many nations to increase production through large investments, the prolonged issues facing by the rice sector of the majority of nations are to reach production efficiency. This issue has been debatable by many parties since it is considered costly policies [5]. The governments of these countries tend to increase their annual expenditure to sustain the rice industry for food security reasons. Besides, most governments believe, relying on the importation policy, in the long run, will affect the food security of a nation. However, there are pros and cons regarding these views, but most importantly, increasing production does not necessarily increase productivity. In addition to economic efficiency context, it could not be achieved by merely allocating a large amount of expenditure in terms of subsidies, investment in modern infrastructures, etc., to increase production level. Conversely, it combines two essential components, which are technical efficiency and allocative efficiency. Technical efficiency measures the aptitude to achieve the maximum output concerning given technology, while allocative efficiency measures the ability to apply the inputs in optimal proportions with respective prices [6][7].

Malaysia had empowered and reviewed its agrofood sector thoroughly as a response to the international food crisis in 2007-2008. The food security agenda has become one of the nation's highest priorities [8]. In the last decade, attempts have been made to increase rice production using SSL as a food security indicator. However, the management of rice production systems in Malaysia for self-sufficiency is considered a complex, dynamic, and multi-faceted system. It involves not only existing technology but also economic, political and social factors [9]. The policy decision to increase production level by introducing more agricultural assistance and expanding irrigated areas has affected rice production. In general, the country manages to increase its rice production through large investments and subsidies, but the SSL remains constant at 70% for the last twenty years [10]. Although the government food policy had maintained its strategies by consistently allocating the annual agricultural budget for the rice development program, the productivity of the rice sector seems to be declining. This approach indicates that there are still weaknesses in managing the resources to obtain production efficiency.

To the best of our knowledge, there is no clear evidence regarding the efficiency and productivity status at the regional level, especially between two homogeneous cultivation areas within the country. This information would help the policymakers and planners to formulate effective strategies to increase production efficiency by maximizing the rice production of these areas.

In this paper, we performed the output-input oriented Data Envelopment Analysis (DEA) between two homogeneous rice main cultivation areas within the country: the granaries and non-granaries. Generally, the granary area receives much attention to achieve the sustainable development of rice compared to non-granaries. There are equipped with modern infrastructures, high cultivation frequency and considered protected under national food policy. Meanwhile, the non-granaries are less-equipped, have a low frequency of cultivation, and non-protected areas could be converted to other crops. Under the current agricultural policy, both areas have the potential to maximize their production whilst increasing their productivity with constant resources. Thus, shifting the strategies by identifying the
potential to maximize the regional production would help the nation achieve production efficiency and sustain productivity in the long run.

2. The data envelopment analysis in agriculture

Data envelopment analysis (DEA) is the non-parametric mathematical programming tool to estimate the efficiency of a Decision Making Unit (DMU) relative to the best practice frontier. It has advantages since it does not require an exact functional form between inputs and outputs [11]. The DEA is also considered a deterministic model that neglects the inherent randomness or so-called stochastic error [12]. In agriculture, the DEA is regarded as an essential mathematical and economical instrument for measuring the DMU’s efficiency and productivity. It has been widely applied since Charnes, Cooper, and Rhodes first demonstrated it in 1978 [13].

The DEA consists of two major orientations, which are input-output and output-input oriented. The input-output oriented is often used in agriculture since most agricultural studies focus on modifying the input usage (fixed output) rather than increasing the output (fixed input) to reach production efficiency. This approach has an advantage in achieving sustainable agricultural development by systematically adjusting the input to reach the optimal level. In other words, we can attain a ‘resource saving approach’ [14]. Nevertheless, the output-input oriented approach could also be favoured if the research aims to maximize the outputs with constant inputs and this approach is called the ‘increasing productivity approach’ [15].

The application of DEA in the agriculture sector is vast, particularly at the farm level. However, the regionals study is still lacking where the insightful information regarding the efficiency and productivity at this level is crucial. Also, this information could help the policymakers and planners emphasize sustainable agricultural policy.

The output-oriented DEA approach is appropriate after considering the Malaysia paddy and rice scenario, which focuses on increasing production. Besides, this study also helps to identify the performance of the region to maximize its production whilst achieving production efficiency.

3. Materials and methods

This section discusses explicitly the output-input-oriented CRS and VRS, which are the main specifications in our DEA methodology to estimate the data points’ technical efficiency scores. The establishment of the DEA as a non-parametric envelopment frontier over the data points could help us identify point locations either on or below the production frontier [16]. This study also adopts the linear programming (LP) methods to construct the non-parametric DEA for efficiency measurement. We performed LP of the DEA constant return to scale (CRS), variable return to scale (VRS) and scale efficiencies (SE) calculation by using R software. Next, we describe the inputs used to perform the DEA for this model.

3.1. Constant return to scale (CRS)

We begin by assuming that suppose we have K inputs and M outputs for each of N firms or DMU’s. For firm i, input and output data are depicted by the column vectors $x_i$ and $y_i$, respectively. The $K \times N$ input matrix and the $M \times N$ output matrix represent the data of all N DMU’s in the sample. The CRS specification to measure the technical efficiency in output-orientated is expressed as follows:

$$\max_{\phi, \lambda} \phi,$$

subject to $-\phi y_i + \lambda y \geq 0,$

$x_i - x \lambda \geq 0,$

$\lambda \geq 0,$

with $1 \leq \phi < \infty$, and $\phi - 1$ is the proportional increase in outputs that could be obtained by $i$-th DMU, with fixed input quantities. The $1/\phi$ value represents the technical efficiency score for the $i$-th DMU.
where the value will satisfy between zero and one. Under CRS specification, we assume that all firms are operating at their optimal scale. Subsequently, equation (1) need to solve N times to obtain technical efficiency for every DMU in the sample.

3.2. *Variable return to scale (VRS)*

Banker, Charnes and Cooper introduced the extension of the CRS model in 1984 to consider the conditions when the DMU is not working at optimal scale [17]. These conditions might be caused by imperfect competition, financial constraints, government regulations, etc. [12]. The model is known as the variable return to scale (VRS) model. The application of CRS when the DMU is not operating at optimal scale resulting scale efficiencies (SE). The VRS specification will allow avoiding these SE effects. The equation of VRS specification can be generated by modifying the CRS linear programming equation (1) through inserting convexity constraint \( N\lambda = 1 \) to produce:

\[
\max_{\phi, \lambda} \phi_i, \lambda \\
\text{subject to } -\phi y_i + Y \lambda \geq 0, \\
x_i - X \lambda \geq 0, \\
N\lambda = 1 \\
\lambda \geq 0
\]

Similar to equation (1), equation (2) need to be solved N times.

3.3. *Scale efficiencies (SE)*

The scale efficiencies (SE) exists upon the same sample when there is a difference in the two technical efficiency scores, one due to technical efficiency (TE) scores of CRS and one due to pure technical efficiency (PTE) scores of VRS for the particular DMU. This difference reflects the maximum potential productivity of that specific DMU can be reached [18]. The SE can be calculated as follows:

\[
SE = \frac{TE}{PTE}
\]

3.4. *Variables definition*

This study adopts the existing quantitative datasets from the Ministry of Agriculture and Food Industries (MAFI) and the Department of Agriculture (DOA), Malaysia. The total of eighteen regions was classified into eight granaries and ten non-granaries. These regions are considered homogeneous in terms of climatic conditions, soil type, irrigation areas, planting frequency and other physical parameters. The period observed (2009 and 2018) is related to the comprehensive government transformation of Malaysia's paddy and rice industry after the intense 2007-2008 international food crisis. More agricultural assistance in the form of subsidies and incentives was introduced and more development expenditure was allotted under the National Agrofood Policy (NAFP) 2011-2020.

The efficiency and productivity depend on the characteristics of the cultivation backgrounds, which involve production factors (inputs) that determine the outputs. In this approach, the output-oriented variables are based on five input variables: land, irrigation area, planting frequency, the total value of federal fertilizer subsidy and the total value of paddy production incentive scheme (a proxy of organic fertilizer, growth enhancer, ploughing and liming) and output variable which refer to the rice production expressed in metric ton.

Specifically, the first input, land, represents the area width of rice cultivation for granaries area and non-granaries area. The granary area receives much attention compared to non-granaries as these areas are equipped with modern infrastructures that support a high frequency of planting. Besides, these territories are gazetted for rice cultivation purposes under the national food security policy. Meanwhile, the non-granaries are less-equipped, have a low frequency of cultivation, and non-protected rice areas.
could be converted to other crops. However, both areas play a significant role in the rice self-sufficiency level of the nation.

The second input, planting frequency, refers to the rice farming seasons in a year. Usually, the granary area is capable of conducting twice cultivation in a year (two seasons) compared to single cultivation (one season) for non-granaries.

The third input, irrigation area variable, represents the watering areas and some are equipped with irrigation systems such as concrete canal, reservoir, dam, barrage, spillage, etc.

The fourth input, the total value in Malaysian Ringgit (MYR) of federal fertilizer subsidy or Skim Baja Padi Kerajaan Persekutuan (SBPKP), refers to the NPK fertilizer that is provided every planting season. This scheme was introduced in 1979 to increase the yield while reducing the cost of the agricultural inputs.

The latter is the total value in MYR of paddy production incentive scheme or Skim Insentif Pengeluaran Padi (SIPP), refers to the agricultural inputs support besides SBPKP. This scheme was introduced in 2009 as a response to the international food crisis in the 2007-2008 period with the aim to produce more yields [19]. Under this scheme, farmers receive additional agricultural supports involving growth enhancers, organic fertilizer, ploughing and liming.

4. Descriptive statistics

The descriptive statistics of the annual mean basis for granaries and non-granaries are shown in table 1. Noteworthy that in the output column, the production level had increased from 227426 MT in 2009 to 241247 MT in 2018. The introduction of the new National Agrofood Policy (NAFP) 2011-2020, which focuses on developing the granaries area, has generally succeeded increase the production level. Conversely, the non-granaries area had shown a decrease in production level from 44375 MT in 2009 to 39521 MT in 2018.

In the inputs column, the average land-based on the annual mean basis was found at 48953 ha for granaries area in 2009. This land had expanded to 50469 ha in 2018. On the other hand, the average land for non-granaries had decreased from 12403 ha in 2009 to 11873 ha in 2018. The area expansion of granaries is considered the center of attraction for national rice development compared to the non-granaries.
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Noteworthy that the mean planting frequency for granaries area was almost stagnant for 2009 and 2018. In 2009, the mean planting frequency was 181 and had slightly increased to 189 in 2018. For non-granaries, the mean planting frequency had increased from 115 in 2009 to 139 in 2018 though the areas had decreased. This indicates that the planting frequency productivity for non-granaries is increasing.

For mean irrigated areas, the granaries ha

Table 1. Descriptive statistics of annual mean basis

|                | Output Production (MT) | Inputs Land (ha) | Plating frequency | Irrigated area (ha) | SBPKP (MYR) | SIPP (MYR) |
|----------------|------------------------|------------------|-------------------|--------------------|--------------|------------|
|                |                        | Granaries        |                   |                    |              |            |
| 2009 Mean      | 227426                 | 48953            | 181               | 25572              | 19777063     | 42995635   |
| Std. Dev.      | 311326                 | 61301            | 29                | 30444              | 24765564     | 51910826   |
| Median         | 147201                 | 28934            | 192               | 14560              | 11689336     | 24810625   |
| Min            | 16853                  | 5952             | 114               | 5156               | 2404608      | 5187789    |
| Max            | 976192                 | 193095           | 200               | 96558              | 78010380     | 164573830  |
| 2018 Mean      | 241247                 | 50469            | 189               | 25726              | 20389527     | 44284046   |
| Std. Dev.      | 26193                  | 62928            | 22                | 31288              | 25422776     | 53226113   |
| Median         | 149713                 | 32302            | 197               | 16599              | 13049806     | 26854157   |
| Min            | 28154                  | 6902             | 136               | 4876               | 2788408      | 5993170    |
| Max            | 1028867                | 201324           | 200               | 108685             | 81334096     | 171567452  |
|                |                        | Non-granaries    |                   |                    |              |            |
| 2009 Mean      | 44375                  | 12403            | 115               | 11635              | 5010893      | 10000387   |
| Std. Dev.      | 55585                  | 16737            | 59                | 12245              | 6761809      | 14224487   |
| Median         | 28193                  | 7142             | 112               | 7195               | 2885166      | 6536599    |
| Min            | 5550                   | 1974             | 38                | 2104               | 797496       | 2144870    |
| Max            | 193976                 | 58152            | 200               | 38689              | 23493408     | 49889148   |
| 2018 Mean      | 39521                  | 11873            | 139               | 7752               | 4796782      | 10557972   |
| Std. Dev.      | 52476                  | 16301            | 41                | 9010               | 6585706      | 13854027   |
| Median         | 23612                  | 7679             | 146               | 5733               | 3102316      | 6993407    |
| Min            | 2142                   | 800              | 90                | 853                | 3323000      | 1147117    |
| Max            | 171715                 | 53414            | 200               | 29328              | 21579256     | 45862440   |

5. Results and discussion

The summarized DMUs scores estimation (technical efficiency, pure technical efficiency and scale efficiency) of CRS and VRS specifications for granaries and non-granaries area are presented in table 2 and table 3, respectively. The output-oriented approach focuses on maximizing the outputs given the constant input(s) [20]. As stated previously, this approach is also called the ‘increasing productivity approach.’ Further, the output-oriented is in accordance with the NAFP aims in the context of maximizing the production of the region while obtaining production efficiency. Indirectly, this approach...
can help the nation increase the level of SSL by identifying the capability of the areas to maximize their level of production. It would also give us the current productivity level after a decade under the new NAFP. Besides, it is momentous to evaluate the variations between production factors and production of each region. This would also confirm in our study that there are significant relationships between these variables.

The results show the varying performance of rice cultivation between study areas. The granaries area in table 2 shows that Muda Agricultural Development Authority (MADA) is the most efficient region in 2009 and 2018, with efficiency scores 1 both under CRS and VRS specifications. This means that, this region is operating at the optimum level. This region is also considered to achieve the maximum efficiency (obtaining production efficiency) using fixed inputs. The Integrated Agricultural Development Area (IADA) Barat Laut Selangor, IADA Ketara and IADA Pulau Pinang are also considered efficient regions since they achieve high technical efficiency with scores greater than 0.9000 for CRS and VRS specifications in 2009 and 2018. These regions nearly to be operating at their optimum level and reach maximum efficiency.

On the other hand, Kemubu Agricultural Development Authority (KADA), IADA Kerian, IADA Kemasin Semerak succeeded in increasing their technical efficiencies in 2009 and 2018 under CRS and VRS specifications. Next, under pure technical efficiency scores (VRS) in 2018, it shows that IADA Ketara, IADA Kemasin Semerak and IADA Pulau Pinang successfully reached production efficiency, in which their technical efficiency scores are 1. Meanwhile, IADA Barat Laut Selangor and IADA Seberang Perak had shown a decrease in technical efficiency scores in 2009 and 2018 under CRS and VRS specifications. Though the decreasing score, IADA Barat Laut Selangor is still considered technically efficient since its score greater than 0.9000.

| Regions           | DMU | Technical efficiency score (CRS) | Pure technical efficiency score (VRS) | Scale efficiency score (SE) | Technical efficiency score (CRS) | Pure technical efficiency score (VRS) | Scale efficiency score (SE) | Scale efficiency ratio (%) |
|-------------------|-----|---------------------------------|--------------------------------------|-----------------------------|---------------------------------|--------------------------------------|-----------------------------|-----------------------------|
| MADA              | 01  | 1.0000                          | 1.0000                               | 1.0000                     | 1.0000                          | 1.0000                               | 1.0000                      | 100.00                      |
| KADA              | 02  | 0.7163                          | 0.7331                               | 0.9771                     | 0.9107                          | 0.9149                               | 0.9954                      | 101.88                      |
| IADA Kerian      | 03  | 0.6592                          | 0.6623                               | 0.9954                     | 0.7645                          | 0.7657                               | 0.9985                      | 100.31                      |
| IADA B. Laut Selangor | 04 | 1.0000                          | 1.0000                               | 1.0000                     | 0.9124                          | 0.9174                               | 0.9945                      | 99.45                       |
| IADA Seberang Perak | 05 | 0.8489                          | 0.9099                               | 0.9329                     | 0.6553                          | 0.6579                               | 0.9961                      | 106.77                      |
| IADA Ketara      | 06  | 0.9166                          | 1.0000                               | 0.9166                     | 1.0000                          | 1.0000                               | 1.0000                      | 109.10                      |
| IADA Kemasin Semerak | 07 | 0.5206                          | 1.0000                               | 0.5206                     | 0.7794                          | 1.0000                               | 0.7794                      | 149.73                      |
| IADA Pulau Pinang | 08  | 0.9662                          | 1.0000                               | 0.9662                     | 1.0000                          | 1.0000                               | 1.0000                      | 103.50                      |

Further analysis under VRS in 2018 shows that KADA and IADA Barat Laut Selangor should be capable of maximizing their level of production by 8.51% and 8.26%, respectively. Meanwhile, it shows that IADA Kerian and IADA Seberang Perak are considered inefficient regions with scores 0.7657 and 0.6579, respectively. To obtain production efficiency with fixed inputs, suppose that these regions should maximize their production level by 23.43% for IADA Kerian and 34.21% for IADA Seberang Perak.

Looking at non-granaries area as shown in table 3, Kedah and Perlis are considered consistent in terms of the most efficient regions in 2009 and 2018 with their efficiency scores 1 for both CRS and VRS specifications. Similar to granaries area, these non-granaries areas are considered operating at their optimum level, whilst obtaining production efficiency using fixed inputs. Meanwhile, Negeri Sembilan is also regarded as an efficient region and its productivity is increasing. The technical efficiency scores
under CRS had increased from 0.7003 in 2009 to 0.9980 in 2018 while under VRS was consistent for both periods with technical efficiency scores 1.

Next, under the VRS specification column, Kelantan and Pahang are considered to reach maximum efficiency in 2018. In 2009, the technical efficiency scores for Kelantan was 0.8123 and 0.9058 for Pahang. Both regions had achieved scores 1 and obtained production efficiency in 2018.

Table 3. Technical, pure technical and scale efficiency of non-granaries area

| Regions       | DMU | Technical efficiency score (CRS) | Pure technical efficiency score (VRS) | Scale efficiency score (SE) | Technical efficiency score (CRS) | Pure technical efficiency score (VRS) | Scale efficiency score (SE) | Scale efficiency ratio (%) |
|---------------|-----|---------------------------------|--------------------------------------|----------------------------|---------------------------------|--------------------------------------|----------------------------|----------------------------|
|               | 2009| 2018                            | 2018/2009                            |                            | 2009                            | 2018                                | 2018/2009                  |                            |
| Johor         | 01  | 0.7153                          | 0.9050                               | 0.7904                     | 0.8292                          | 0.8780                              | 0.9444                    | 119.49                     |
| Kedah         | 02  | 1.0000                          | 1.0000                               | 1.0000                     | 1.0000                          | 1.0000                              | 1.0000                    | 100.00                     |
| Kelantan      | 03  | 0.7491                          | 0.8123                               | 0.9221                     | 0.9285                          | 0.9285                              | 1.0000                    | 100.69                     |
| Melaka        | 04  | 0.5266                          | 1.0000                               | 0.5266                     | 0.7524                          | 0.8598                              | 0.8751                    | 166.18                     |
| Negeri Sembilan | 05 | 0.7003                          | 1.0000                               | 0.7003                     | 0.9980                          | 1.0000                              | 0.9980                    | 142.51                     |
| Pahang        | 06  | 0.8511                          | 0.9058                               | 0.9396                     | 0.6752                          | 1.0000                              | 0.6752                    | 71.86                      |
| Perak         | 07  | 1.0000                          | 1.0000                               | 1.0000                     | 0.9662                          | 0.9940                              | 0.9720                    | 97.20                      |
| Perlis        | 08  | 1.0000                          | 1.0000                               | 1.0000                     | 1.0000                          | 1.0000                              | 1.0000                    | 100.00                     |
| Terengganu    | 09  | 0.9355                          | 1.0000                               | 0.9355                     | 0.8058                          | 0.8780                              | 0.9178                    | 98.11                      |
| Pulau Pinang  | 10  | 1.0000                          | 1.0000                               | 1.0000                     | 1.0000                          | 1.0000                              | 1.0000                    | 100.00                     |

Subsequently, Perak and Terengganu had shown the decreasing scores for both CRS and VRS specifications in 2009 and 2018. However, Perak is still considered efficient in 2018 since its scores are 0.9662 and 0.9940 (greater than 0.9000) for CRS and VRS, respectively. Terengganu is deemed to be inefficient in 2018 since its score under CRS decreased from 0.9355 in 2009 to 0.8058. Similar to VRS, the result for Terengganu shows a decreasing score from 1 in 2009 to 0.8780 in 2018. Both regions are considered facing a decrease in productivity level. Under the VRS specification in 2018, to obtain maximum efficiency, Perak should be capable of increasing the technical efficiency by 0.6% while Terengganu by 12.2% with constant inputs.

Noteworthy also, under the CRS column in 2009 and 2018, Johor and Melaka had shown a decrease in technical efficiency scores. Johor had decreased from 0.9050 to 0.8780 while Melaka had decreased from 1.000 to 0.8598. This means that, the productivity of these regions is decreasing. Besides, these regions are considered efficient if they can maximize their production level by 12.2% and 14.02% in 2018, respectively. Next, the Pulau Pinang region was efficient in 2009 with score 1. However, the remaining areas of this region had been upgraded to granaries area by 2018. Pulau Pinang still maintains its efficiency after converting to granaries status (table 2).

From the overall total of eighteen regions study (table 2 and table 3) under both specifications (CRS and VRS), we found that eight (44.44%) out of eighteen regions are maintaining efficiency with scores greater than 0.9000 in the 2009 and 2018 periods. The latter, considering only ‘pure’ technical efficiency (VRS), the total of eleven (61.11%) out of eighteen regions are maintaining efficiency with scores greater than 0.9000 in the 2009 and 2018 periods.

The productivity status for both granaries and non-granaries area in 2009 and 2018 under VRS are summarized in table 4. In this section, we highlighted the ‘pure’ technical efficiency (VRS) since it takes into consideration the conditions of imperfect competition, the constraint on finance, etc. may produce a DMU to be not working at optimal scale. Further, the use of VRS specification will devoid the scale efficiencies effects [16]. The VRS specification is considered more appropriate rather than CRS in the Malaysian paddy and rice scenario context since the DMUs in our case might not be operating at the ideal state (optimal scale) due to constraints.
We found that for the granary area, the total four (50%) out of eight granary areas are MADA, IADA Ketara, IADA Kemasin Semerak and IADA Pulau Pinang had achieved optimum productivity. Next, the total two (25%) out of eight granaries area KADA and IADA Kerian had achieved increasing productivity approach. Meanwhile, the total two (25%) out of eight granaries which are IADA Barat Laut Selangor and IADA Seberang Perak area had achieved decreasing productivity approach.

| Regions                  | DMU | Pure technical efficiency score (VRS) | Productivity status |
|--------------------------|-----|--------------------------------------|---------------------|
| Granaries                |     |                                      |                     |
| MADA                     | 01  | 1.0000                               | Optimum             |
| KADA                     | 02  | 0.7331                               | Increasing          |
| IADA Kerian              | 03  | 0.6623                               | Increasing          |
| IADA Barat Laut Selangor | 04  | 1.0000                               | Decreasing          |
| IADA Seberang Perak      | 05  | 0.9099                               | Decreasing          |
| IADA Ketara              | 06  | 1.0000                               | Optimum             |
| IADA Kemasin Semerak     | 07  | 1.0000                               | Optimum             |
| IADA Pulau Pinang        | 08  | 1.0000                               | Optimum             |
| Non-granaries            |     |                                      |                     |
| Johor                    | 09  | 0.9050                               | Decreasing          |
| Kedah                    | 10  | 1.0000                               | Optimum             |
| Kelantan                 | 11  | 0.8123                               | Increasing          |
| Melaka                   | 12  | 1.0000                               | Decreasing          |
| Negeri Sembilan          | 13  | 1.0000                               | Optimum             |
| Pahang                   | 14  | 0.9058                               | Increasing          |
| Perak                    | 15  | 1.0000                               | Decreasing          |
| Perlis                   | 16  | 1.0000                               | Optimum             |
| Terengganu               | 17  | 1.0000                               | Decreasing          |
| Pulau Pinang             | 18  | 1.0000                               | -                   |

For non-granary area, we found that the total of three (33.33%) out of nine regions, Kedah, Negeri Sembilan and Perlis, had achieved optimum productivity. Next, a total of two (22.22%) out of nine areas, which are Kelantan and Pahang had reached an increasing productivity approach. However, the decreasing productivity status dominating the non-granary area, four (44.44%) out of nine regions, Johor, Melaka, Perak and Terengganu had decreased productivity approach.

At the regional level, the total eight (44.44%) out of eighteen regions had reached the optimum productivity, the total of four (22.22%) out of eighteen regions had achieved an increasing productivity approach and the remaining regions, six (33.33%) out of eighteen regions had achieved decreasing productivity approach.

Comparatively, the productivity status of the granaries area shows a better performance compared to the non-granary area. A total of six (75.0%) out of eight regions had achieved optimum and increasing productivity approach. Only two (25%) out of eight regions had achieved decreasing productivity approach. Meanwhile, from ten non-granary area, we found a higher percentage of decreasing productivity approach; the total four (40.0%) out of ten regions had decreased. The remaining six (60.0%) out of ten regions had achieved optimum and increasing productivity approach. The result is expected since the concentration of the development of the resources under the NAFP, such as infrastructure development, rice intensifying program, extension program, agricultural aids, etc., has been prioritized to safeguard the granaries area as part of the national food security territory.

Overall, the optimum and increasing productivity dominating the performance of the region compared to decreasing productivity. A total twelve (66.67%) out of eighteen regions are optimum and increasing productivity approach and the remaining areas, the total six (33.33%) out of eighteen regions are decreasing productivity approach.
The latter, the results also demonstrate substantial performance variations between output (rice production) and production factors (land, planting frequency, irrigation areas, total subsidies and incentives received) for both regions.

6. Conclusion
The DEA output-oriented approach gives policymakers and planners valuable information regarding the current status of efficiency and productivity between two homogeneous rice cultivation areas within the country. The period observed in 2009 and 2018 related to the comprehensive government transformation in strengthening paddy and rice value-chain after the intense 2007-2008 international food crisis. Under DEA output-oriented perspectives, the overall performance of the Malaysia main rice cultivation areas at the national level in 2009 and 2018 periods can be considered inefficient and lack competitiveness since the total areas reach the optimum and increasing productivity approach comprises is just around 66.67%. These total areas are relatively far from achieving at least 90% of the total efficient regions. Almost 33.33% of the total areas are inefficient and decreasing productivity approach. These inefficient areas considered significantly affected the national level performance, especially the overall total production and the SSL. Nonetheless, there is still room for improvements, particularly for these inefficient regions to maximize the production through rationalizing the inputs used and obtaining production efficiency [15][20]. Our recommendations regarding this proposal are listed below:

- The inefficient regions could learn or adopt the rice best practices from the nearby efficient regions to increase their efficiency while maximizing their production. Since the areas are considered highly homogeneous, suppose that both inefficient granaries and non-granaries areas can optimize production and obtaining production efficiency. The integrated efforts involve expertise sharing, technology usage, extension programs, etc. could be implemented through collaborating between nearby efficient regions and inefficient regions.

- The evaluation regarding the effectiveness of the government assistance programs should be conducted since the current mechanisms might not be relevant anymore. Generally, the larger the areas and the higher the planting frequency, the greater the amount received. However, this approach might not be compatible with most areas since there is the possibility as it may not be fully utilized or wasted. Our finding suggests that there were large inefficient areas (33%) in 2018, although these areas received the total amount of agricultural aids based on the hectarage covered. Therefore, the readjustment of agricultural aids based on the actual needs of a region, such as ‘soil profiling,’ would raise productivity and increase the efficiency of the regions. A special task force involves ministry, policy agencies and technical bodies could be established to look into this matter.

- Shifting from SSL oriented policy to production efficiency or productivity-oriented. The direction of Malaysia’s rice policy has always considered food security as the highest priority and the SSL indicator has become the benchmark of the food security level. This policy has resulted in continuous support to sustain the SSL of the rice, in which more national budgets are allotted, especially for agricultural assistance. As a result, the Malaysia paddy and rice industry will lack competitiveness and always depend on government support. The country should reconsider switching this approach as the SSL indicator is not the only practical tool to portray food security levels. In the long run, shifting to the production efficiency-oriented will ensure sustaining the paddy and rice industry and food security of the nation.

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