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APPLICATION OF EDA WINDOW ANALYSIS FOR CONSTRUCTING ECONOMIC SCALE MODELS OF THE BANANA INDUSTRY

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Abstract

Taiwan is known as the “Banana Kingdom,” and its bananas are an essential economic fruit crop with an excellent flavor and wide appreciation in Japan since the 1960s. Taiwan’s bananas formerly occupied a 90% share of the Japanese market; however, banana yields diminished because of the “Panama disease,” and thus export yields decreased. From 2006 to 2016, Taiwan’s banana market had excess supply as a result of shifting from export to domestic sales, and export yields decreased. Therefore, Taiwan’s banana industry had the wrong operating strategy. This study collected data from the four most prominent banana-producing counties (Taichung, Nantou, Kaohsiung, and Pingtung) and used production efficiency and data envelope analysis to compute banana production efficiency, status of profit and loss, competitive potential, and productivity from the “Agricultural Production Yearbook” from 2010 to 2015. The results revealed that price stability was the most crucial strategy of Taiwan’s banana market. Taichung City had the lowest input cost and best technical efficiency but was inferior to Nantou County regarding scale efficiency. However, Kaohsiung and Pingtung had superior scale efficiency but inferior technical efficiency, input cost, and precautions taken against typhoons. Bananas are an essential economic fruit tree in Taiwan. In the 1960s, Taiwanese bananas became popular in Japan because of their strong aroma and rich taste. In 1967, Taiwanese bananas occupied a market share of 90% of the Japanese market, and Taiwan was known as the "Banana Kingdom." The new banana industry earned a considerable foreign trade surplus for Taiwan. However, as a result of yellow leaf disease, the "Banana Kingdom" has since become history. No research has analyzed the production efficiency of the banana industry in Taiwan. Therefore, this study used data of the annual report on agricultural production and costs of the Agricultural and Food Administration of the Executive Yuan Agricultural Committee. Data envelopment analysis was used to understand the productivity of major producing areas of Taiwan's banana industry. The results indicated that Taichung City and Nantou County had higher pure technical efficiency but lacked scale efficiency. If these areas expanded their production scale, they would have higher productivity. Kaohsiung City and Pingtung County have reached an economic scale; however, they still must strengthen the effective use of input factors.

Key words: EDA Window Analysis, Economic Scale, Data envelope analysis

Introduction

Since banana is the world's most extensive trade and consumption of fresh fruit, the Food and Agriculture Organization of the United Nations (FAO) has ranked banana as the fourth most abundant fruit in the developing countries, after rice, wheat, and corn. According to FAO's statistics (2014), the harvest area of banana in the world was around 5.39 million hectares. The banana's production was about 112 million tons. Furthermore, import and export values accounted for 29.35 billion US dollars, after wheat, soybeans, and corn.

The banana is one of the most important tropical fruits in Taiwan, mainly grown in Pingtung, Kaohsiung, Chiayi, Nantou, and Taichung (Bai et al., 2019). According to a planting period, there are two main seasons; a spring-summer's banana together with an autumn-winter's banana.

Refer to Taiwan's Agricultural Statistics Report in 2015, a cultivation area of banana accounted for 14,605.44 hectares, and a selling price was about NT$27/kg. Besides, the spring- summer's banana and the autumn-winter's banana had annual profits of about NT$ 261,043/ha and NT$ 375,769/ha, respectively (Zhang et al., 2016).

The banana has been considered as a year-round agriculture production in Taiwan. The main production period is generally from February to June because of no torrential typhoons and cold weather. Moreover, there are higher demands from both local and foreign markets. The production outputs for this season accounted for 60-70 percent of all annual outputs, especially the spring-autumn's banana grown in Kaohsiung and Pingtung County (Dai et al., 2019). Nevertheless, the farmlands in Taichung, Chiayi, and Nantou county are mostly hillside, the consequence of no irrigation facilities, and challenging to adjust the production period. Therefore, most of the farmers prefer growing the autumn-winter's banana due to suitable cultivation land and appropriate climate. Most of the production period is from September to December (Ding et al., 2013).

The banana is not only critical economic fruits but also the most significant fresh exporting agricultural products in Taiwan. The banana of Taiwan has increasingly exported to the Japanese market for a hundred years. In 1967, the export was the highest volume, accounting for 51.95 million U.S. dollars (12 kg per hectare). Besides, the harvest areas were more than 50,000 hectares. (Council of Agriculture, Executive Yuan Taiwan R.O.C, 2017)

After 1971, Taiwan's economic structure dramatically changed a lot, a large number of rural labor forces moved far away from their hometown to work in an industrial estate, resulting in a labor shortage in the rural areas and the rising wages (Chaing & Hung, 1991). The banana's production dramatically suffered a lot, facing with Fusarium Wilt, which causes a massive reduction in banana's yields. Moreover, the selling price of a banana in foreign markets like Japan, the Philippine, and South America was lower (Chen et al., 2017). The banana's growers had less profit and gave up quickly towards the banana's industry.

Refer to a literature review, there were many scholars have published more research regarding banana's industry in Taiwan, such as diseases resistant (Chen et al., 2014; Chan et al., 2013; Hwang, 2002), and to establish the production system (Chiang et al., 2012; Lee et al., 2013), and industrial economic (Wang, 2012). There were also many publications in using break-even analysis to study costs and revenues of the banana industry (Chen and Day, 2009; Mahama et al., 2013; Lee et al., 2015; Guo et al., 2011). However, there was no research analyzing the situation of profit and loss and market competition potential of the banana industry in Taiwan.

It is essential to analyze the efficiency of banana's industry in Taiwan and to search for tools to improve the performance of these counties. One of the essential ways of measure performance is the efficiency of banana's industry, and one of the essential approaches to measuring banana's county's efficiency is the method of DEA.

The data set used in this paper was obtained from Taiwan’s Agricultural Statistics Report during 2011~2015. The efficiency of proposed Taiwan's banana industry has been evaluated over time by applying the DEA window analysis.

The objective of the paper is to evaluate the efficiencies of banana counties to identify the sources of inefficiencies and to make proposals for the future planning and improvement of banana's industrial operations.

The results show the variability in the banana's industry efficiency. The window analysis indicates that some counties have inefficiencies during some periods. Therefore, it is necessary to examine the strategic plan for improving banana's industry operations and performance.

Literature Review

Farrell (1957) proposed a new concept for helping firms regarding efficiency measurement. In 1978, Charles, Cooper, and Rhodes developed the concept of Farrell and also applied linear programming to evaluate the frontier of production technology. This idea had been designed to apply linear programming into the production technology frontier region under the condition of constant returns to scale (CRS).

Then, this idea had been named was CCR model. The Model of DEA had been improved and formalized by Banker, Charnes, and Cooper (BCC), (1984), and became BBC model. This model had an element of technical and scale efficiency, which was used in the economist field (Pongpanich and Peng, 2016).

In the year 1985, DEA windows analysis was first introduced for measuring efficiency in cross-sectional. It was used to evaluate efficiency both in the CCR and BCC models by considering the efficiency trends of operation unit under a period. As many previous kinds of the literature of DEA windows analysis have been applied to many fields, which were exhibited as follows; Chung et al. (2008) considered the selection of product family mix within semiconductor fabricator by applying DEA window analysis approach. Hemmasi et al. (2011) applied DEA to evaluate the performance of the Iranian wood panels industry, which is a significant industry for the country.

The authors utilize the results of the DEA window to assess further its stability based on the standard deviation of 10 wood panels firms. Efficiency score showed that all DMUs in the wood panel industry were stable (low standard deviations), but the firm's time trends indicate that almost half of the DMUs were positive. The difference in average efficiency score shows that several DMUs were still inefficient over the period analyzed.

The study of Kuo et al. (2015) conducts an analysis of production efficiency and productivity for Taiwan's 15 counties, which uses Data Envelopment Analysis and Malmquist productivity index.

The results have shown that Chiayi County is the benchmark for other counties in the first crop season; however, there is no one in the second crop season. The findings support the intention behind set-aside policy for the second crop season implanted by agricultural administration to reduce rice production. Finally, progressing productivity pattern has been only observed in Miaoli County and Taichung City in the first crop season, while it has been observed in all counties in the second crop season due to the technical progress. It is worthy of mentioning that the government should pay more attention to the trend of the worsening in productivity for the first season to maintain the overall competitiveness of Taiwan's rice industry.

Due to the impact of globalization and climate change, farmland resource conservation and food security are attracting increasing attention in Taiwan (Chen et al., 2014). To enhance cultivated land utilization and farmers' competitiveness, this paper employed grey relational analysis and data envelopment analysis to examine critical factors affecting the gross income of the rice planting enterprises, which was the primary industry of national farm households and investigated the business efficiency of rice cultivation and key means of improving efficiency. Technical efficiency is an essential factor in promoting the development of modern China's vegetable industry. Based on data envelopment analysis (DEA), it is found in this paper that in 2003 - 2006, the technical efficiency of China's vegetable production is in volatility, but in 2007-2008, it is rising (Xu et al., 2010). The decline of scale efficiency is the main reason for the further loss of technical efficiency. It shows that, in 2008, the technical efficiency of China's vegetable production is at an average level, the production factors input is redundant, and the scale efficiency is low but increasing returns to scale. Hence, to improve the technical efficiency of China's vegetable production, not only the allocate efficiency of resource inputs should be improved, but also the scale of China's vegetable production should be appropriately increased.

HE et al. (2013) using DEA analysis on rice production efficiency in China. The study shows that China's rice production efficiency decreases because of the agricultural production scale, and agricultural technology has not been reasonably used. Therefore, through improving the level of agricultural technology, we can raise the degree of industrialization and the operation scale of agricultural production to increase the production efficiency of rice.

According to the relevant statistical data in the years 1997-2007 in Chongqing Municipality, efficiency of the agricultural economy is calculated from the year 1997 to 2007 by DEA method and the scale efficiency is also analyzed by taking the total output of agriculture, forestry, animal husbandry, and fishery industry as the output index (Chen et al. 2010). The result shows that Chongqing City became a municipality directly under the central government; its agricultural production efficiency is still low. Moreover, the sustainable development capacity of agricultural is weak in Chongqing, and the agricultural resources are not fully used. Based on this , related suggestions are put forward to improve the agricultural production efficiency of Chongqing , such as implementing an appropriate management scale of land , improving the organization degree of peasant households and the rate of industrialization management , enhancing the quality of the rural labor force , strengthening the agricultural science and technology input and extension , perfecting the construction of rural infrastructure , and improving the rate of resource utilization.

Jiang et al. (2015) applies SE – DEA window model to value the input and output efficiency of marine science and technology of 11coastal provinces and cities in China from 2006 to 2012. Then, it applies the Malmquist index analysis and clustering analysis to explore the regional disparity and the reasons of efficiency change. The research finds: at the national level, the overall growth of efficiency is mainly caused by the improvement of management level and scale optimization of marine science and technology activities (Wang et al., 2019). The main factors driving the efficiency of marine science and technology growth vary by region (Tzeng et al., 2019). However, the decrease in efficiency is mainly due to the lack of accumulation and improvement of marine scientific and technological knowledge. In summary, DEA has a wide range of applications. Among them, DEA Window Analysis is developed based on traditional models. It can evaluate the relative efficiency of different decision-making units (DMUs) at the same time, and can also reflect DMU's Trends in window efficiency at different times. Therefore, this study will use DEA's window analysis to explore the production efficiency of Taiwan's banana industry from 2011 to 2015.

Methodology Overview

The study of the efficient frontier began with Farrell (1957), who created a simple measure of a firm's efficiency that can account for multiple inputs. Data envelopment analysis was initially introduced by Charnes et al. (1978) from the research of Farrell (1957). DEA is a nonparametric linear programming approach capable of handling multiple inputs and outputs (Asmild et al., 2004). This methodology allows for handling different types of input and output together. A DEA model can be constructed either to minimize inputs or to maximize outputs. An input orientation objects at reducing the input amounts as much as possible while keeping at least the present output levels, while an output orientation aims at maximizing output levels without increasing the use of inputs. (Cooper et al., 2000).

Data Envelopment Analysis is a mathematical programming technique that measures the efficiency of a decision-making unit (DMU) relative to other similar DMUs with the single restriction that all DMUs lie on or below the efficiency frontier (Seiford and Thrall, 1990).

The causes of inefficiency and how a DMU can improve its performance to become efficient.

Data Envelopment Analysis is performed in only one period, hampering the measurement of efficiency changes when there is more than one period. A DEA model is sometimes applied on a repeated basis, e.g., the so-called window analysis method (Charnes et al., 1995) when a panel data set comprising both time series and cross-section samples are available, but this produces little more than a continuum of static results, when in fact a static perspective may be inappropriate (Sengupta, 1996).

Window analysis is one of the methods used to verify productivity changes over time. Savić et al. (2012) reported that window analysis operates on the basis of the principle of moving averages (Charnes et al., 1995; Yue, 1992; Cooper et al., 2007). DEA window analysis was proposed by Charnes et al. (1985) to measure the efficiency of cross-sectional and time-varying data. Thus, detecting the performance trends of a DMU over time is useful. Each DMU (i.e., bank) is treated as a different bank in different periods, which can increase the number of data points.
DEA window analysis with window widths between one and all periods in the study horizon is a particular type of sequential analysis. Options that were formerly feasible are assumed to remain feasible, and all previous observations are included.

Once the window is defined, the observations within that window are viewed in an intertemporal manner, and the analysis is thus better considered locally intertemporal.

Asmild et al. (2004) reported no technical changes within each window because all DMUs in each window were compared with each other, and a narrow window width was suggested to be used. Charnes et al. (1995) reported that w = 3 or 4 tended to yield the best balance of informativeness and stability of efficiency scores. To ensure the credibility of the results, a narrow window width must be used. Therefore, a 3-year window was selected for this study (w = 3). DEA window analysis generalizes the notion of moving averages to detect efficiency trends of DMUs over time. The rationale is that DMUs in a window are regarded as entirely distinct from one another. Asmild et al. (2004) suggested that the selected window width should be as small as possible to minimize the unfairness comparison over time but still large enough to include a sufficient sample size.

Following Asmild et al. (2004), consider that N DMUs (n = 1, N) of all user inputs produce s outputs and are observed in T (t = 1,……, T) periods. Let DMU_n^t represent observation n in

period t with input vector $X_n^t = \begin{bmatrix} x_n^{1t} \\ \vdots \\ x_n^{rt} \end{bmatrix}$

and output vector $Y_n^t = \begin{bmatrix} y_n^{1t} \\ \vdots \\ y_n^{st} \end{bmatrix}$.

If the window at time k (1 ≦ k ≦ T) has a width w of (1 ≦ w ≦ T – k), then the matrices of inputs and outputs are denoted as follows:

$$X_{kw}\begin{bmatrix} x_1^k & x_2^k & \cdots & x_N^k \\ x_1^{k+1} & x_2^{k+1} & & x_N^{k+1} \\ \vdots & \vdots & \ddots & \vdots \\ x_1^{k+w} & x_2^{k+w} & \cdots & x_N^{k+w} \end{bmatrix},$$

$$Y_{kw}\begin{bmatrix} y_1^k & y_2^k & \cdots & y_N^k \\ y_1^{k+1} & y_2^{k+1} & & y_N^{k+1} \\ \vdots & \vdots & \ddots & \vdots \\ y_1^{k+w} & y_2^{k+w} & \cdots & y_N^{k+w} \end{bmatrix}.$$

Substituting inputs and outputs of DMU_n^t into Models (1) or (2) produces the results of DEA window analysis. This study uses the DEA window analysis method to evaluate the ability of DMUs. The production areas of Pingtung County, Kaohsiung City, Nantou County, and Taichung City in Taiwan's banana industry are regarded as DMU (n=4), with three years (k=3).), each county can be divided into 3 windows (m=3). Using the input-output data (t=5) published by the Agricultural Committee of the Executive Yuan from 2011 to 2015, observe the production cost structure, land rent, family labor (homework), employee labor (including contract labor), and garden fees (Seven items, such as seedling fees, fertilizers, pesticides, equipment and materials (materials), account for 95% of the total production costs). And it refers to Guo Yuhui et al. (2015), Xu Jiapeng et al (2010) for land rent, family labor (home workers), labor costs (including contract labor), garden fees (seedling fees), fertilizer fees, pesticide fees, equipment materials fees (material fees), etc. are defined as input variables, while Banana production is output variables. The efficiency analysis was conducted to evaluate the production efficiency of each banana producing area.

Empirical Analysis

This study used input and output data of the four major producing areas (DMUs) of the Taiwanese banana industry from 2011 to 2015. Relevant research was reviewed, and the seven input items were set as land rent, family labor (homework), labor costs (including contract labor), gardening fees (including for seedlings), fertilizers, pesticides, and equipment and materials (material costs); production was output.

To make up for the shortcomings of the insufficient number of DMUs, this research method uses DEA window analysis to explore the productivity of Taiwan banana industry producing areas (Kaohsiung City, Pingtung County, Taichung City, Nantou County). Use DEA-solver software for analysis, select the input mode of Window mode, and use the formula to calculate 3 windows as a window, and use CCR mode (set to Window-IC) to get the total technical efficiency, and then borrow BCC mode (set to Window-IV) yields pure technical efficiency, and finally divides total technical efficiency by pure technical efficiency to obtain scale efficiency [21]. Sample descriptive statistics are shown in Table 3.

Table 3. Descriptive statistics of input and output of the main producing areas of the Taiwanese banana industry from 2011 to 2015

Variable name	Variable type		2011	2012	2013	2014	2015
Production Quantity and Value Per Ha. (N.T./Ha)	output	Max	424,391	602,558	933,701	1,044,616	634,309
		Min	195,573	251,872	320,291	384,872	366,000
		Average	318,871	420,988	628,032	740,643	537,749
		SD	98,989	154,410	274,174	272,229	107,145
Land Rents (N.T./Ha)	input	Max	30,018	25,432	22,490	24,087	22,894
		Min	1,493	1,756	1,619	1,564	1,576
		Average	14,477	12,669	12,060	12,665	11,901
		SD	12,937	10,921	10,358	11,022	10,242
Family Labor Remuneration (N.T./Ha)	input	Max	169,962	170,450	169,347	149,611	176,125
		Min	94,990	119,352	104,781	93,145	105,645
		Average	132,642	143,433	127,961	123,674	139,706
		SD	32,378	23,123	25,529	24,735	28,393
Man-Labor (N.T./Ha)	input	Max	49,483	42,957	55,796	53,018	27,481
		Min	15,733	4,415	15,000	19,166	0
		Average	34,123	22,603	30,318	32,804	17,031
		SD	13,082	14,249	15,961	12,650	10,465
Established Expenditure	input	Max	24,917	24,468	25,058	24,543	23,936
		Min	11,067	17,005	13,804	13,902	14,000

(N.T./Ha)		Average	18,879	20,850	18,925	18,656	18,859
		SD	5,478	3,204	4,618	4,288	4,238
Fertilizer (N.T./Ha)	input	Max	46,962	48,247	46,256	45,900	46,371
		Min	28,217	32,129	31,791	31,713	31,605
		Average	38,162	39,861	38,830	38,828	39,077
		SD	7,152	6,391	6,437	6,870	6,944
Chemical & Herbicide (N.T./Ha)	input	Max	21,766	22,793	23,623	24,141	25,030
		Min	8,908	9,594	9,269	9,263	9,075
		Average	15,708	16,780	16,695	17,064	17,386
		SD	5,919	6,053	6,185	6,341	6,622
Irrigation Charge (N.T./Ha)	input	Max	60,758	60,250	62,522	63,401	60,830
		Min	32,396	41,378	33,170	26,496	28,144
		Average	49,602	51,358	47,795	44,400	44,247
		SD	11,828	8,298	11,469	13,989	12,557

Source: This study is organized.

As can be seen from Table 3, the average value of input variables such as land rent, family labor, gardening fees, and fertilizer fees in the banana industry in Taiwan remained at a certain level between 2011 and 2015. The average value of the pesticide input exhibited a slight upward trend. Equipment material fees reached their highest point in 2012. The lowest point in the past 5 years was in 2015, at which time the average input per hectare was 7,111 yuan, demonstrating a downward trend. Employment fees exhibited more increases and decreases and were mainly affected by windstorms. In total, 34,123 yuan per hectare was invested. This number decreased to 22,603 yuan per hectare in 2012, rose to 32,804 yuan in 2014, and then dropped to an average of 17,031 yuan per hectare in 2015. The overall trend was downward. Moreover, the output of the output item averaged 318,871 yuan per hectare in 2011 and then increased to 740,643 yuan in 2014 before declining slightly in 2015 and averaging at 537,749 per hectare. From a production perspective, the overall development of Taiwan's banana industry is increasing.

Empirical Results

Pure technical efficiency refers to whether the input projects of each decision-making unit (DMUs) can be effectively used in each year to maximize output or minimize input, and the value indicates the efficiency of input items.

The scale efficiency represents the appropriate ratio of output to input in each decision-making unit (DMUs), that is, whether the maximum productivity is achieved. The higher the value, the more suitable the scale and the higher the productivity. The values of total technical efficiency, pure technical efficiency, and scale efficiency are between 0 and 1, and the larger the value, the higher the efficiency. It can be used to judge whether the source of inefficiency of each production originates from technical inefficiency or scale inefficiency, and the full distance indicates the stability of the performance of the decision-making unit during the evaluation period. The total technical efficiency of the four major producing areas (DMUs) of the Taiwan banana industry is listed in Table 4.

Through window analysis and the input-oriented CCR model, the total technical efficiency of the four major producing areas of the Taiwan banana industry in 2011–2015 was obtained.

The above table indicates that the annual average technical efficiency of Taiwan's banana industry increased from 58.5% in 2011 to 98.22% in 2014 but dropped to 86.31% in 2015. The overall average technical efficiency was 84.47%, indicating that Taiwan's banana industry had absolute technical efficiency. This level of development signified that only 84.47% of the present production factor inputs could be used to achieve the current output, whereas the remaining

Table 4. Total technical efficiency of DMUs according to DEA window analysis (2011–2015)

	2011	2012	2013	2014	2015	Individual mean	Full distance
Kaohsiung City	0.4814	0.6612	1.0000	1.0000	0.8344	0.8487	0.5186
Pingtung County	0.4933	0.6376	0.9681	1.0000	0.6935	0.8185	0.5067
Taichung City	0.6777	1.0000	0.8349	0.9288	1.0000	0.8933	0.3223
Nantou County	0.6874	0.6627	0.8091	1.0000	0.9245	0.8183	0.3373
Annual average	0.5850	0.7404	0.9030	0.9822	0.8631	0.8447	0.3972

Data Source: Organized by this study

All four DMUs had a technical efficiency of 1 across different years, indicating that they were relatively efficient. On average, Taichung City had the highest total technical efficiency, followed by Kaohsiung City, Pingtung County, and Nantou County. The banana industry is vulnerable to major environmental and natural disasters. The technical efficiency of Taiwan's banana industry in 2011–2015 was most stable in Taichung City, followed by Nantou County. The rate of typhoon occurrence in Pingtung County and Kaohsiung City was high, resulting in its full distance being as high as 0.5, indicating relative instability.

The total technical efficiency in Taiwan's banana industry from 2011 to 2015 reached a certain level and demonstrated an upward annual trend. By 2014, the average total technical efficiency was up to 98.22%, indicating that the banana industry in Taiwan was efficient that year. Existing resources were employed to obtain corresponding outputs.

According to the BCC model of window analysis and input-oriented, the pure technical efficiency of the four major producing areas of the Taiwan banana industry in 2011-2015 was obtained, as shown in Table 5. Pure technical efficiency refers to the most effective output from the established input,

Table 5. Pure technical efficiency of DEA window analysis on the origin of each DMU (2011–2015)

	2011	2012	2013	2014	2015	Individual mean	Full distance
Kaohsiung City	0.7725	0.7807	1.0000	1.0000	0.8539	0.9098	0.2275
Pingtung County	0.7061	0.7360	1.0000	1.0000	0.7517	0.8811	0.2939
Taichung City	1.0000	1.0000	1.0000	1.0000	1.0000	0.9999	0.0000
Nantou County	0.9260	0.8871	0.9734	1.0000	0.9817	0.9558	0.1129
Annual average	0.8511	0.8510	0.9933	0.9999	0.8968	0.9367	0.1490

Data Source: Organized by this study

that is, the most effective use of the input factors, under the constant production factors. Taiwan's banana industry has an average annual pure technical efficiency of more than 85%, reaching 99.99% in 2014 and 89.68% in 2015. From various decision-making units, Taichung City has the highest pure technical efficiency, reaching 99.99%, followed by Nantou County, Kaohsiung City, and Pingtung County, meaning that Taichung City is the most efficient in terms of input factors. Maximize output or minimize input. Among them, the pure technical efficiency of Taichung City is quite stable, and it is relatively efficient every year. It is followed by Nantou County, Kaohsiung City, and Pingtung County.

Table 6. Scale efficiency of DEA window analysis on the origin of DMUs (2011–2015)

	2011	2012	2013	2014	2015	Individual mean
Kaohsiung City	0.6231	0.8470	1.0000	1.0000	0.9771	0.8894
Pingtung County	0.6987	0.8662	0.9681	1.0000	0.9225	0.8911
Taichung City	0.6777	1.0000	0.8349	0.9288	1.0000	0.8883
Nantou County	0.7424	0.7470	0.8312	1.0000	0.9417	0.8524
Annual average	0.6855	0.8651	0.9085	0.9822	0.9603	0.8803

Data Source: Organized by this study

Scale efficiency is the value of technical efficiency divided by pure technical efficiency. From the time series, the scale efficiency of the four major producing areas of Taiwan's banana industry, from 68.55% in 2011, maintained an upward trend all the way, reaching a peak in 2014, which was 98.22% but dropped slightly to 96.03% in 2015. Also, from the perspective of various decision-making units, the overall scale efficiency is 88.03%. The decision-making units above this efficiency include Pingtung County, Kaohsiung City, and Taichung City. Among them, Pingtung County has the highest scale efficiency of 89.11%. According to the order of Kaohsiung City, Taichung City, and Nantou County, Pingtung County have the most suitable scale among the four major producing areas, and its productivity is relatively large.

Conclusion

This study used the annual report of agricultural production cost published by the Agricultural and Food Administration of the Executive Yuan Agricultural Committee for data envelopment analysis. From the results of empirical analysis, the conclusions were summarized and the following recommendations were made for future reference. The average total technical efficiency of Taiwan's banana industry is 84.47%, indicating that the technical efficiency of Taiwan's banana industry has a certain level of development. Among them, the total technical efficiency of Taichung City is the highest, followed by Kaohsiung City, Pingtung County, and Nantou County. The average pure technical efficiency is higher than 85% in all counties and cities. The pure technical efficiency of Taichung City and Nantou County is 99.99% and 95.58%, which means that Taichung City and Nantou County have the same production factors. Large output can be obtained from the established investment; since Kaohsiung City and Pingtung County are more susceptible to typhoon attack, the pure technical efficiency during the evaluation period is relatively unstable, making its pure technical efficiency better than that of Taichung City. Nantou County is poor. In terms of scale efficiency, Pingtung County, Kaohsiung City, and Taichung City have a scaling efficiency of over 88%, and Nantou County has a lower scale of 85.24%, indicating that the southern production area is superior to the central production area. Judging from the decision-making units, Kaohsiung City was efficient in 2013 and 2014 and inefficient in other years. In 2011, it was inefficient. In 2012 and 2015, most of the inefficiencies came from pure technical efficiency, indicating that Kaohsiung City The efficiency of the use of input factors still needs to be strengthened. Pingtung County was only efficient in 2014, and the rest of the year was inefficient. The inefficiency in 2011 and 2013 came from scale inefficiency, while the inefficiency in 2012 and 2015 was derived from pure technical efficiency. Taichung City was efficient in 2012 and 2015, and the inefficiency of the rest of the year was due to scale inefficiency. Nantou County is only efficient in 2014, and the inefficiency of the rest of the year comes from scale inefficiency.

In summary, Taiwan's banana industry had a high pure technical efficiency in Taichung City and Nantou County but lacked scale efficiency, which indicated that the two counties would have higher productivity if they expanded their scale. Overall, Kaohsiung City and Pingtung County had an adequate scale but still required improvement regarding the effective use of input factors and the impact of typhoons. Taichung City had high total and pure technical efficiency. Although the inefficiency in 2011, 2013, and 2014 was derived from scale efficiency, Taichung City's average scale efficiency was similar to that of Kaohsiung City, with only a 0.11% difference. Therefore, Taichung City was the most suitable for the production of Taiwanese bananas. In addition, to avoid a sudden increase in banana production, resulting in a price collapse and banana farmers receiving no returns, the government should strengthen control over changes in the total amount of banana production and notify banana farmers at appropriate times to avoid the high price of banana farmers and the market. Estimating market downturns and rushing seed-planting while simultaneously implementing rehabilitation measures after disasters can cause a reduction in the prices of the next batch of bananas.

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