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Operational Efficiency Measurement of Agricultural Cooperatives: Application of Super-efficiency Data Envelopment Analysis

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Abstract

The purpose of this study is to measure the operational efficiency of agricultural cooperatives applied of Super-efficiency Data Envelopment Analysis (SE-DEA). This study also compares the management efficiency of agricultural cooperatives in Uthai Thani Province categorized between large and very large scale sizes. The data used consisted of secondary data from the performance records of agricultural cooperatives in Uthai Thani Province during the fiscal years 2016 to 2018. A total of 30 cooperatives were categorized into 13 large agricultural cooperatives and 17 very large agricultural cooperatives, which were analyzed using SE-DEA model. The results showed that the average operating efficiency score of large agricultural cooperatives was 1.7979, whereas that of very large cooperatives was 2.0034, indicating that very large cooperatives have higher operating efficiency than large ones. Therefore, agricultural cooperatives in Uthai Thani Province can reduce the use of production factors to increase operational efficiency and promote member participation by incentivizing them to engage in cooperative management, share experiences on cooperative operations, and develop guidelines for cooperative advancement.

Keyword: Agricultural Cooperatives, Operational Efficiency, Uthai Thani Province, Super-efficiency Data Envelopment Analysis, Linear Function

Introduction

Agricultural cooperatives play an important role in Thailand's economy. They are formed by groups of members who work in agriculture, which is the primary occupation of many Thai people. These cooperatives serve as key organizations for the care and promotion of knowledge and modern technology for farmers. By managing agricultural products across upstream, midstream, and downstream processes, they can help solve or alleviate the problems faced by farmers, build livelihoods, and increase income for their members while relying on community support.

In 2017, there were 3,473 agricultural cooperatives in Thailand, accounting for 50.75% of all cooperatives that year. This represented an 11.02% decrease from 2007, when there were 3,903 cooperatives. Additionally, in 2017, there were 6,347,762 members, which accounted for 54.84% of the total cooperative membership that year—an increase of 8.31% from 2007, when there were 5,860,922 members (Department of Cooperative Promotion, 2018). This information reflects the importance of agricultural cooperatives in promoting and addressing issues related to agricultural livelihoods to enhance the well-being of their members (Table 1).

Table 1: Number of Cooperatives and Number of Members in Thailand (2007 and 2017)

Type of Cooperative	2007		2017	
	Number of Cooperatives	Number of Members	Number of Cooperatives	Number of Members
Agricultural Cooperatives	3,903	5,860,922	3,473	6,347,762
Fishery Cooperatives	83	14,254	77	14,932
Land Settlement Cooperatives	91	184,095	89	193,311
Thrift Cooperatives	1,390	2,479,473	1,417	3,107,188
Consumer Cooperatives	230	783,684	140	641,399
Service Cooperatives	790	325,027	1,085	484,943
Credit Union Cooperatives	282	248,689	563	784,736
Total	**6,769**	**9,896,144**	**6,844**	**11,574,271**

Sources: Cooperative Promotion Department, 2018.

Uthai Thani Province has 38 agricultural cooperatives. An overview of the business operations of these cooperatives indicates a tendency for growth. In 2017, the volume of business was 3,342,241,092.87 Baht, representing an increase of 111.29% from 2007 (Table 2). This increase is attributed to the operations of agricultural cooperatives. Although the business volume is rising, measuring business success also requires assessing operational efficiency. This involves examining the scale of production and determining the appropriate operational scale for agricultural cooperatives. Changes in technical efficiency, as well as inputs and outputs, are factors affecting the operating efficiency of agricultural cooperatives in Uthai Thani Province.

Table 2: Number of Agricultural Cooperatives and Volume of Business of Agricultural Cooperatives in Uthai Thani Province (2007 and 2017)

Year	Number of Agricultural Cooperatives	Volume of Business (Baht)
2007	37	1,581,800,291.99
2017	38	3,342,241,092.87

Sources: Uthai Thani Provincial Cooperative Office, 2018.

The study on the management efficiency of agricultural cooperatives in Uthai Thani Province aims to measure the operational efficiency of these cooperatives. This study compares the management efficiency of agricultural cooperatives in Uthai Thani Province during the fiscal years 2559-2561 (2016-2018). The results of this study will contribute to strategic planning and improve the operational efficiency and competitiveness of agricultural cooperatives in Uthai Thani Province.

Theory and Literature Review

The theory of technical efficiency measurement in the super-efficiency model provides performance indicators that range from 0.000 to 1.000. However, the maximum efficiency value can indicate one or more theories called "super efficiency," which is rare according to Anderson and Petersen (1993). This method is a nonparametric estimation technique, which is the most popular internationally. This popularity arises because

traditional measurements of technical efficiency can be inaccurate due to control issues in the production process, whether from the manufacturer or external errors that cannot be controlled by the producer. The impact on all production lines is influenced by Stochastic Frontier Analysis (SFA) indicators and efficiency (Inefficiency Efficiency Model; IEM). Simultaneously, this model is referred to as the "one-step stochastic frontier production model," which typically involves two production functions: the Cobb-Douglas production function and the logarithmic transformation of the production function (Piyawit, 2016).

The SE-DEA model is based on linear programming.

Minimize $$E_S = \sum_{i=1}^{m} v_{iu} X_{iu} \quad (1)$$

Subject to $$\sum_{j=1}^{n} w_{ju} Y_{ju} = 1 \quad (2)$$

$$\sum_{j=1}^{n} w_{ju} Y_{ju} \leq \sum_{i=1}^{m} v_{iu} X_{iu} \quad (3)$$

Where $$r \neq u$$

$$v_{ir} w_{jr} \geq 0 \ \ For\ i, j, r\ \ all \quad (4)$$

Definitions: X_{iu} : Input
Y_{ju} : Output
v_{iu} : Form of maximum efficiency
w_{ju} : Gravity Factor of output

In this study, the ultra-high efficiency DEA measurement method was examined, as discussed by Liu et al. (2012). The efficiency of university teachers in Thailand is analyzed using SE-DEA and the Toby model. The purpose of this study is to evaluate 40 normal universities in Bangkok, the surrounding areas, and across the country. Universities in seven countries received scores higher than one, while those with scores lower than one indicated inefficiency; a score of 0.33 denotes inefficiency. The most efficient university is Kalasin Rajabhat University, with an efficiency score of 2.6934, while the teacher college with the lowest performance score is Phranakhon Rajabhat University, which had a score of 0.1922.

In the same year, Wongchai et al. (2012) conducted a study on the use of advanced efficiency (super-efficiency) as an alternative method for assessing the performance of information and communication technology companies in Thailand. They employed the SE-DEA method to study a total of 28 large conglomerates in the information and communication technology sector that have considerable operational experience and are well-known. The analysis revealed that only five companies achieved the highest absolute efficiency score of 1, while the other 23 companies scored less than 1, indicating technical inefficiencies according to the DEA method. The SE-DEA method was further applied to analyze these five companies with the highest efficiency scores, revealing additional information not obtainable from standard DEA analysis.

Additionally, Wongchai et al. conducted a financial performance analysis of food industry companies in Taiwan using super-efficiency and Tobit methods. The sample included 22 food industry companies in Taiwan. The results showed that Tian-Ren Company had the highest score, while Nan-Qiao Company had the lowest efficiency score. Furthermore, performance scores and rankings can assist inefficient companies in

improving their financial performance with the aim of becoming leading food companies in the Taiwan market.

Ma and Zheng (2011) investigated the application of SE-DEA to assess the harmony between water resources and economic development using the SE-DEA analysis method, which proved to be superior to the simple DEA analysis method (Normal Efficiency Data Envelopment Analysis: NE-DEA). Their study focused on water resources and economic development in water conservation areas within 16 cities involved in China's South-to-North Water Diversion Project (SNWDP). They found that NE-DEA indicated that 8 out of 16 cities had a harmonious relationship between water resources and economic development (efficiency score of 1), while the SE-DEA model was able to rank each city's degree of harmony from low to high (efficiency score greater than 1), which NE-DEA could not analyze.

The simulation results demonstrate that the SE-DEA model provides accurate analyses, as shown by Lin and Li (2020) in their management studies on holmium and super-efficiency in the American capital market. They found that super-efficient methods could also be used to determine investment portfolios.

This paper studies the efficiency of China's green economic performance using the SE-DEA model. The results indicate significant regional differences in green economic efficiency improvement between eastern and western China. Moreover, environmental regulations impact green economy efficiency; thus the model is employed for performance analysis due to its accuracy. The findings suggest that the DEA model is more effective than traditional DEA models.

In the research on efficiency measurement, many researchers have conducted studies, including Prasopchai and Suda (2022), who evaluated agricultural cooperation efficiency in Phetchaburi Province (2018). Additionally, research on factors influencing the operating efficiency of credit cooperatives in Maha Sarakham Province was conducted. Later, Phupetchara and Twain (2018) researched the operating efficiency of government savings cooperatives in Thailand. The research by Wang et al. (2012) evaluated the efficiency of agricultural cooperatives in Langao City, northern China. This study adopts DEA efficiency analysis, and the analytical components include large, medium, and small cooperatives. However, while efficiency analysis using DEA can assess overall efficiency, it does not clearly reflect differences in performance. Therefore, this study adopts the SE-DEA model for analysis. The results show that the DEA model is more accurate than traditional DEA models.

Methodology

This study utilized secondary data collected from the performance records of 30 agricultural cooperatives in Uthai Thani Province, obtained from the Uthai Thani Cooperative Auditing Office, the Cooperative Auditing Department, and the Cooperative Promotion Department's database, as well as the Uthai Thani Provincial Cooperative Office. The data covers three fiscal years from 2016 to 2018 and is divided into two parts for analysis:

1) The SE-DEA method is employed to analyze the operational efficiency of agricultural cooperatives in Uthai Thani Province. The purpose of this analysis is to assess the operating efficiency of these cooperatives from 2016 to 2018. The key analysis focuses

on output efficiency under the assumption of output orientation and variable returns to scale (VRS).

In terms of output and input factors used in this study:

Output Factor: *Y* is total income (Baht/year).

Input Factors:

X_1: Cost of loan business (Baht/year).
X_2: Cost for procurement business (Baht/year).
X_3: Operating cost (Baht/year).

2) A comparison of the operational efficiency of agricultural cooperatives in Uthai Thani Province is conducted by dividing them into two groups: large and very large cooperatives. This involves comparing and ranking these two groups.

Empirical Results

1. Operating Efficiency of Agricultural Cooperatives in Uthai Thani Province

The analysis of data on the operations of agricultural cooperatives in Uthai Thani Province was conducted using the SE-DEA method to analyze operational efficiency. The results of the analysis are presented in the form of efficiency scores, divided into two groups as follows:

1.1 Large Agricultural Cooperatives

The results revealed that in 2016, 11 agricultural cooperatives achieved an efficiency score (Score ≥ 1) and were ranked accordingly among 13 large agricultural cooperatives in Uthai Thani Province. The top three cooperatives were:

- Thung Wali Agricultural Cooperative Limited
- Ban Phum Tham Electric Water Pumping Station Cooperative Limited
- Ban Tha Sung Tai Electric Water Pumping Station Cooperative Limited

These were ranked first, second, and third respectively. The last cooperative in this ranking was Pakklai Agricultural Cooperatives Co., Ltd., which had an average operational efficiency score of 1.4920 in 2016.

Among effective agricultural cooperatives (Score ≥ 1), there were seven in operation that year. The ranking for these effective partners included:

- Cooperative Fund
- Chuandengxi
- Pakklai Agricultural Cooperation Co., Ltd.
- Ban Tha Sung Tai Electric Water Pumping Station Cooperative Limited

These were ranked first, second, and third respectively.

In 2017, the last-ranked cooperative had an average operating efficiency score of 1.8754.

In 2018, there were seven effective agricultural cooperatives (Score ≥ 1) again in operation. The top three score cooperatives were:

- Ban Saphan Hin Electric Water Pumping Station Cooperative Limited
- Ban Tha Klai Agricultural Cooperative Limited
- Ban Tha Sung Tai Electric Water Pumping Station Cooperative Limited

These were ranked first, second, and third respectively. The Ban Bang Kung Electric Pumping Station Water User Cooperative Limited was ranked last in 2018 with an average operating efficiency score of 2.0263.

When observing the average operating efficiency over three years, it can be seen that Ban Saphan Hin Electric Pumping Station Water User Cooperative Limited had the highest operational efficiency score at 3.7025 while Ban Bang Kung Electric Water Pumping Station Water User Cooperative Limited had the lowest at 0.4278 (Table 3).

From 2016 to 2018, the average operating efficiency of agricultural cooperatives increased year by year. The results indicate that these cooperatives are effectively managed due to strong operations and cooperation among partners with minimal risk of defects.

Overall, most agricultural cooperatives are successful.

Table 3: Operating Efficiency of Large Agricultural Cooperatives in Uthai Thani (2016-2018)

Order	DMU/Years	2016		2017		2018		Average (3 years)
		Rank	Score	Rank	Score	Rank	Score	
1	Ban Phumtham Station User Cooperative Co., Ltd.	2	2.5977	9	0.9495	8	0.9817	1.5096
2	Ban Bang Kung Station User Cooperative Co., Ltd.	12	0.5257	13	0.2179	13	0.5398	0.4278
3	Ban Saphan Hin Station User Cooperative Co., Ltd.	7	1.3253	5	1.6441	1	8.1380	3.7025
4	Ban Thasungtai Station User Cooperative Co., Ltd.	3	1.8691	3	3.2634	3	2.4360	2.5228
5	Satreenongkhayang Agricultural Cooperative Co., Ltd.	4	1.6716	7	1.2243	6	1.1395	1.3451
6	Ban Khao Kong Chai Hydropower Station User Cooperative Co., Ltd.	11	1.0251	8	0.9902	9	0.8266	0.9473
7	Ra Bam Cooperative Co., Ltd.	8	1.3183	11	0.9093	11	0.8120	1.0132

8	Ban Thap Klai Agricultural Cooperative Co., Ltd.	13	0.4214	2	4.4915	2	6.1188	3.6772
9	Thung Salee Agricultural Co., Ltd.	1	3.4549	4	1.6952	7	1.0713	2.0738
10	Uthai Thani Agricultural Cooperation Development Co., Ltd.	6	1.3316	10	0.9344	10	0.8200	1.0287
11	Sunyang Huayuth Cooperative Fund Co., Ltd.	10	1.0500	1	5.9737	5	1.3610	2.7949
12	Uthai Thani Farmers Cooperation Co., Ltd.	9	1.1698	12	0.7847	12	0.6093	0.8546
13	Pineapple Growers Agricultural Cooperative in Uthai Thani Land Reform Co., Ltd.	5	1.6358	6	1.3026	4	1.4882	1.4755
Average/Years			1.4920		1.8754		2.0263	-
Max			3.4549		5.9737		8.1380	3.7025
Min			0.4214		0.2179		0.5398	0.4278
Standard Deviation (S.D.)			0.8140		1.6783		2.3519	1.6148

Sources: Calculated from the Uthai Thani Provincial Cooperative Office data (2016-2018).

1.2 Large Agricultural Cooperatives

The analysis of the operating efficiency of large-scale agricultural cooperatives in Uthai Thani Province found that there were 17 cooperatives. In 2016, seven agricultural cooperatives achieved efficiency (Score ≥ 1) in their operations. When ranking effective cooperatives, it can be seen that the top three are: Agricultural Cooperatives for Customer Marketing BAAC Uthai Thani Co., Ltd., Tluk Du Agricultural Cooperative Limited, and Khao Din Nuea Land Reform Cooperative Limited, which were ranked first, second, and third respectively. The last large agricultural cooperative was Nong Khayang Agricultural Cooperative Limited, which had an average score of 1.8592 in 2017. In that year, six agricultural cooperatives were effective (Score ≥ 1). The top three with scores were: Agricultural Cooperatives for Customer Marketing BAAC Uthai Thani Co., Ltd., Tluk Du Agricultural Cooperative Limited, and the Rubber Replanting Land Reform Fund Cooperative Limited, which were ranked first, second, and third respectively. Nong Chang Agricultural Cooperative Limited was ranked last in 2017 with an average operating efficiency score of 1.8151.

In 2018, there were nine efficient agricultural cooperatives (Score ≥ 1) in operation. When ranking effective cooperatives again, the top three scores were achieved by: Agricultural Cooperatives for Customer Marketing BAAC Uthai Thani Co., Ltd., Sawang Arom Agricultural Cooperative Limited, and the Rubber Land Reform Fund Cooperative Limited—ranked first, second, and third respectively—while Nong Chang Agricultural Cooperative Limited was again ranked last with an average operating efficiency score of 2.3359.

When examining the average operational efficiency over a three-year period, it can be seen that Agricultural Cooperatives for Customer Marketing BAAC Uthai Thani Co., Ltd. had the highest operational efficiency score at 10.3233 while Nong Khayang Agricultural Cooperative Limited had the lowest at 0.3290 (Table 4). However, in 2017, the average operating efficiency of agricultural cooperatives decreased significantly from 2016 but increased again in 2018. Therefore, the efficiency of large-scale agricultural cooperatives in Uthai Thani Province is effective due to strong operations and management cooperation among partners with minimal risk of defects. Overall, most agricultural cooperatives are successful.

Table 4: Operational Efficiency of Very Large Agricultural Cooperatives in Uthai Thani (2016-2018)

No.	DMU/Years	2016		2017		2018		Average (3 years)
		Rank	Score	Rank	Score	Rank	Score	
1	Uthai Thani Agricultural Cooperative Limited	7	1.0611	7	0.9320	16	0.3658	0.7863
2	Agricultural Cooperatives for Customer Marketing BAAC Uthai Thani Co., Ltd.	1	8.7565	1	10.8340	1	11.3794	10.3233
3	Nong Kha Yang Agricultural Cooperative Limited	17	0.1880	16	0.3905	15	0.4085	0.3290
4	Ban Lumkhao Agricultural Cooperative Limited	11	0.4634	15	0.4843	11	0.8399	0.5959
5	Nongchang Agricultural Cooperative Limited	8	0.8081	17	0.1538	17	0.3450	0.4356
6	Thap Than Agricultural Cooperative Limited	16	0.2738	13	0.6075	10	0.9957	0.6257
7	Tluk Du Agricultural Cooperative Limited	2	6.1316	2	7.5863	8	1.1906	4.9695
8	Nong Chik Yao Livestock Cooperative Limited	14	0.2999	8	0.9309	7	1.4517	0.8942
9	Supanimit Nong Yai Da Agricultural Cooperative Limited	5	2.2892	9	0.7561	4	2.9564	2.0006
10	Sawang Arom Agricultural Cooperative Limited	9	0.5065	4	1.4820	2	7.9682	3.3189
11	Lan Sak Agricultural Cooperative Limited	12	0.3481	14	0.5722	13	0.5369	0.4857

12	Lan Sak Land Reform Cooperative Limited	10	0.4886	11	0.6329	6	1.5173	0.8796
13	Khao Din Nuea Land Reform Cooperative Limited	3	5.0637	6	1.0000	5	1.9707	2.6781
14	Ban Rai Agricultural Cooperative Limited	6	1.1107	5	1.1760	9	1.1201	1.1356
15	Good Land Reform Rubber Plantation Fund Cooperative Limited	4	3.2197	3	2.0028	3	5.4869	3.5698
16	Huai Khot Agricultural Cooperative Limited	15	0.2900	12	0.6257	12	0.7254	0.5470
17	Supanimitphumen Agricultural Cooperative	13	0.3068	10	0.6896	14	0.4510	0.4825
Average/Years		1.8592		1.8151		2.3359		-
Max		8.7565		10.8340		11.3794		10.3233
Min		0.1880		0.1538		0.3450		0.3290
Standard Deviation (S.D.)		2.5123		2.8744		3.0941		2.8269

Sources: Calculated from the Uthai Thani Provincial Cooperative Office data (2016-2018).

From the comparison of the operating efficiency of large and very large agricultural cooperatives over a three-year period, it can be concluded that during this time, very large agricultural cooperatives demonstrated higher operating efficiency than large agricultural cooperatives. The average efficiency of large agricultural cooperatives was 1.7979. This difference is attributed to capital constraints faced by large cooperatives, while very large agricultural cooperatives are able to secure more operating capital, which contributes to their effective operations.

Table: Operating Efficiency of Large and Very Large Agricultural Cooperatives in Uthai Thani Province

Type of Cooperative	**Technical Efficiency Score**	
	Large Agricultural Cooperative	**Very Large Agricultural Cooperative**
Mean	1.7979	2.0034
Median	1.4755	0.8796
S.D.	1.0741	2.5405
Max	3.7025	10.3233
Min	0.4278	0.3290

Source: Calculated from data
Note: The calculation is based on the average over three years.

Conclusions and Recommendations

The operating efficiency of large and very large agricultural cooperatives in Uthai Thani Province for the years 2016, 2017, and 2018 is summarized as follows: the efficiency of large agricultural cooperatives was 1.4920, 1.8754, and 2.0263, respectively. The average operating performance of the large segment was 1.8592, 2.851, and 2.3359, respectively. Overall, the average operating efficiency in both categories has shown an increasing trend.

From the comparison of the operating efficiency of the two types of agricultural cooperatives, it can be concluded that the operating efficiency of large-scale agricultural cooperatives is higher than that of smaller agricultural cooperatives.

Conclusions drawn from this study suggest that improvements in the operating efficiency levels of agricultural cooperatives in Uthai Thani Province can be achieved by optimizing production costs, including loan business costs, procurement costs, sales expenses, and operational costs. Additionally, technology should be integrated into existing agricultural cooperatives to enhance their potential and maximize member participation. It is important to encourage members to engage in cooperative management and share their experiences while providing guidance on cooperative operations and development.

For future research, it is recommended to study cost efficiency or profit efficiency in greater detail. More time should be allocated to improve data analysis efficiency. Furthermore, members of agricultural cooperatives should be encouraged to explore the quality of life within their communities. This study also suggests establishing indicators to measure the quality of life for cooperative members, reflecting the challenges faced in agriculture and within agricultural cooperatives.

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