OPERATIONAL EFFICIENCY OF RUBBER FARMERS' COOPERATIVES IN THE SPECIAL ECONOMIC ZONES (SEZs) OF THAILAND: A TWO-STAGE DATA ENVELOPMENT ANALYSIS (DEA) APPROACH

Winyoo Kromkratoke, King Mongkut's Institute of Technology Ladkrabang
Panya Mankeb, King Mongkut's Institute of Technology Ladkrabang
Suneeporn Suwanmaneepong, King Mongkut's Institute of Technology Ladkrabang

ABSTRACT

As rubber farmers' cooperatives expand their operation and market through the special economic zones (SEZs) of Thailand, the question arises whether these cooperatives are operationally efficient or not since they have to compete with neighbouring countries. This study investigated the operational efficiency of rubber farmers' cooperatives in Thailand and explores the factors affecting their operational performance using a two-stage data envelopment analysis approach. Three-year comparative data (2016-2018) were collected from six major rubber-producing provinces in the SEZs of Thailand, and categorized into three business phases, the beginning, progressive, and developed phases. The results showed that the efficiency level among cooperatives in the three phases ranges from 24% to 65%. Cooperatives operating under the beginning phase showed less stability in their mean efficiency score, while cooperatives in the developed phase showed more stability in their yearly mean efficiency scores. Moreover, most factors affecting cooperatives' efficiency relate to managerial and entrepreneurial aspects. This finding implied that while farmers specialize in the technical skills of rubber farming, most of them still lack the managerial and entrepreneurial skills to operate. This study suggested stronger policy support for strengthening farmers' managerial and entrepreneurial skills to achieve long-term improvement in the operational efficiency of rubber farmers' cooperatives.

Keywords: Rubber farmers' cooperatives; Special economic zones; Technical efficiency; Data envelopment analysis; Tobit model.

INTRODUCTION

Thailand is the world's number one producer and exporter of natural rubber. In 2020, the country produced and exported approximately 4.908 million tons 3.978 million tons of rubber, respectively (Negash et al., 2021). This volume accounts for approximately 36% of global natural rubber production (Promme et al., 2017). Since 1991, Thailand has remained an attractive destination for investment in the rubber industry due to its strategic location at the centre of Southeast Asia and its abundance of natural rubber (Angthong & Fujita, 2019; Nobnorb & Fongsuwan, 2015). Driving this achievement are the strong government support, policies, and dedication to research and development that have helped the country consistently improve its

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natural rubber output (Parichatnon et al., 2018). The government's most recent programs and policies are set in its 20-year rubber development strategy (2017-2036), aiming to strengthen and increase the potential of farmers and farmer organizations. As the lead implementing agency, the Ministry of Agriculture and Cooperatives seeks to achieve these goals through collaboration with other government agencies, private sector actors, and farmer organizations.

Rubber farmers' cooperatives are among these important organizations, ranked as the second most abundant type of agricultural cooperative in Thailand. Data from the Dejchanchaiwong et al. (2019) reported a total of 535 farmers' cooperatives in this sector, which comprise a total of 112,556 members. These cooperatives help promote and develop the rubber industry and encourage its members to earn more income (Angthong & Fujita, 2019). In addition, agricultural cooperatives enhance the access of members to modern production inputs and markets for their products, thereby reducing rural poverty (Parichatnon et al., 2018). In addition to these efforts, the Royal Thai Government promoted special economic zones (SEZs) in 2015 to improve trade with border countries – Myanmar and Cambodia – and other Southeast Asian countries (Promme et al., 2017). SEZs support rubber farmers' cooperatives as leaders in the agriculture and agro-processing industries. Since these cooperatives have expanded their operation and market through these efforts, the question arises whether these cooperatives are operationally efficient because they have to compete with neighbouring countries. Accordingly, to help these cooperatives further define their business strategies and cope with competition, operational efficiency and factors that affect their performance should be investigated (Alberca & Parte, 2018).

Efficiency analysis is of vital interest in the plant production sector. In a competitive environment, it is important to use inputs efficiently to remain in the market and produce the highest output with the fewest inputs (Dalei & Joshi, 2020). Data envelopment analysis (DEA) models are commonly adopted to evaluate production units' operational efficiencies, as they can accommodate multiple inputs and outputs. The original DEA was proposed by Charnes et al. (1978) and has been extensively applied to evaluate operational production efficiency. The DEA method can assess many organizations' performance in a nonparametric way since it does not assume a functional form among multiple production factors (Anouze Abdel Latef & Bou-Hamad, 2019). Through this analysis, resource efficiency can be compared by assessing the farms' conditions with respect to their production frontier. Ultimately, farms' revenues can be developed by addressing the reasons for the farms' inefficiency (Tumer et al., 2020). In addition, a two-stage approach has been widely used in recent studies employing Tobit regression analysis to test for the statistical significance of the effect of organizational factors on technical efficiency (Despotis & Koronakos, 2014). A better knowledge of the variables impacting cooperatives' efficiency can provide cooperative managers with insights on enhancing efficiency by benchmarking (Ghondaghsaz et al., 2018; Habib & Shahwan, 2020).

This study aims to contribute to the literature on operational efficiency in a farmers' cooperative context in three ways. First, using a two-stage data envelopment analysis (DEA) approach, this study investigates the operational efficiency of rubber farmers. Many published studies on efficiency in the context of plant production sector have focused on agronomic crops, such as rice (Boubacar et al., 2016; Panpluem et al., 2019), maize (Abdulai et al., 2018; Ali et al., 2019) and wheat (Sherzod et al., 2018; Wang et al., 2018), and horticultural crops, such as vegetables in general (Sanusi et al., 2017; Wahid et al., 2017; Xu et al., 2018). However, there are a limited number of studies about industrial crops, such as rubber.

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Second, this study intends to be the first to analyze the operational efficiency of rubber using a sample of farmers' cooperative in the SEZs of Thailand, which contributes to the literature uniquely. Rubber farmers' cooperative are regarded as leaders in rubber production and export in Thailand (Angthong & Fujita, 2019). This is an important contribution since Thailand's rubber industry must explore new ideas to maintain profitability and competitiveness within its expanding market reach (Majumder & Rahman, 2020; Salamzadeh, 2020). The findings will help improve the operational performance of rubber farmers in the study areas and define better business strategies to cope with competition (Doshmanli et al., 2018; Singh, 2020). The study will also provide insights to policymakers and managers about setting resource allocation priorities.

Finally, this study intends to contribute to the literature on operational efficiency of rubber farms and explores the factors affecting their operational performance. This study will be a source of useful information for future empirical studies aiming to improve the production and efficiency of rubber farms (Salamzadeh, 2020). Furthermore, there is insufficient literature on the operational efficiency of rubber farmers' cooperatives in Thailand despite their significant contribution to the agricultural sector in terms of total production output and export volumes. Rubber cooperatives play important roles in this aspect, which the government has been continuously supported through dissemination of relevant rubber production technologies (Angthong & Fujita, 2019).

The rest of the paper is organized as follows: first, the research methodology employed has been introduced with emphasis on the data envelopment and Tobit regression analysis. Second, the results of the analysis are presented. Finally, the key findings are discussed, and the theoretical and practical implications, and conclusion are given.

RESEARCH METHODOLOGY

Study Area and Data Source

Six major rubber-producing provinces located in the SEZs of Thailand were selected for this study: Nong Khai, Songkhla, Kanchanaburi, Trat, Chiang Rai, and Tak. These provinces are active and innovative players in rubber production and marketing. This study utilized three-year comparative data (2016-2018) obtained from the annual report of the Cooperative Promotion Department of Thailand, an agency under the Ministry of Agriculture and Cooperatives. A total of 37 rubber farmers' cooperatives with complete data according to the specified variables were purposively considered for the analysis. These cooperatives were categorized into three phases - beginning (S), progressive (P), and developed (D) - as described in Table 1.

TABLE 1
NUMBER OF RUBBER FARMERS' COOPERATIVES, CATEGORIZED ACCORDING TO PHASES OF DEVELOPMENT (2016-2018)

Phases of development	Code	Description	Number of cooperatives
Beginning phase	(B)	Rubber farmers' cooperatives with activities mainly involved in the production, collection, and marketing of rubber in limited areas, with basic knowledge on budgeting and financial planning.	3 (B_1, …, B_3)

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Progressive phase	(P)	Rubber farmers' cooperatives with primary and secondary rubber processing facilities.	15 (P_1, …, P_{15})
Developed phase	(D)	Rubber farmers' cooperatives with improved business operations, established networks and planned expansion to support core products. There is also quality control in the aspects of production and marketing.	19 (D_1, …, D_{19})

Data Analysis

This study utilized a two-stage DEA approach. This approach has been widely used in efficiency studies (Tung, 2013; Despotis & Koronakos, 2014; Zhao, 2017). In the first stage, conventional DEA was employed to evaluate the operational efficiency of rubber farmers' cooperatives as measured by the level of technical efficiency (TE). Then, Tobit regression analysis was applied to explain the variations in efficiency levels using the specified explanatory variables. These two stages were described in the following sections.

Data envelopment analysis

DEA is a nonparametric approach that calculates the relative performance of decision-making units (DMUs) as the ratio of the weighted sum of outputs to the weighted sum of inputs (Anouze Abdel Latef & Bou-Hamad, 2019; Long & Cuong, 2020). DEA is based on the production frontier concept, which has been widely used to compare efficient and inefficient DMUs (Asawaruangpipop & Suwunnamek, 2014; Kumar et al., 2019). This study utilized the input-oriented DEA model (constant returns to scale or CRS) instead of the output-oriented model (variable returns to scale or VRS) since rubber farmers in the study area have more control over the inputs than the outputs. The DMUs, in this case, are represented by the rubber farmers' cooperatives. The input factors in the DEA model were adopted from the studies of Alberca & Parte (2018), Horvat et al. (2020), and Moreno-Moreno et al. (2018), and considered after a discussion with representative cooperative managers. These include the (1) number of members (head), (2) total assets (Thai Baht: THB), (3) capital (THB) operating expenses (THB). The rubber farmers' cooperatives' net profit margin served as the output factor - the variable in the model. The DEA framework was show in Figure 1.

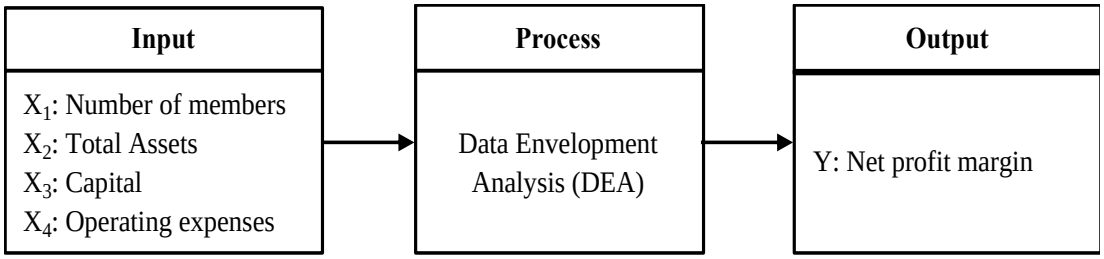

FIGURE 1

CONCEPTUAL FRAMEWORK OF INPUT-ORIENTED DATA ENVELOPMENT ANALYSIS

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The input-oriented model CRS model was represented by Equation 1. The model assumes that farmers' cooperative units (i) produce outputs (M) using different inputs (K). In the formula, the vector of M is represented by $y_{i,}$ while the vector of K is represented by x_i. The output matrix MxN is given as Y, the input matrix KxN is represented by X, and the value of λ is given as the vector of constants Nx1.

$$\begin{gathered} \text{Min}_{\theta,\,\lambda}\theta \\ \theta \text{ subject to - } yi + Y\lambda > 0 \\ \theta xi - X\lambda > 0 \\ X\lambda > 0 \end{gathered} \qquad (1)$$

Technical efficiency measurements, or the θ, range from 0 to 1 and represent the degree of efficiency by the farmers' cooperatives. An extreme score of 1 indicated that the farmers' cooperatives are efficient; otherwise, they are considered inefficient (Charnes et al., 1978).

Tobit regression analysis

The Tobit regression model is a nonlinear statistical tool proposed by Tobin (1958) to describe the relationship between a nonnegative independent variable Y_i and an independent variable X_i. This model is appropriate because it makes up for the design flaws of ordinary least squares (OLS) regression (Dalei & Joshi, 2020). The Tobit regression model has been widely used in previous studies combined with conventional DEA, as it accurately measures the degree and direction of the influence of independent variables on the dependent variables (Linn & Maenhout, 2019; Okello et al., 2019; Shetty & Kumar, 2017). For the current study, the parameters used to analyse the factors affecting rubber farmers' cooperatives' efficiency consisted of the (1) development period, (2) establishment period, (3) shareholder size, (4) debt, and (5) income of rubber farmers' cooperatives. The Tobit model can be written mathematically in Eq. 2 as:

$$yi = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon I \qquad (2)$$

Where:
y_i is the efficiency score according to the DEA model
β_0 is the constant of the Tobit regression model
β_i represents the Tobit regression coefficients of the explanatory variables
X_1 *to* X_5 refer to the following explanatory variables:
X_1 = development period (year)
X_2 = establishment period (year)
X_3 = shareholder size (%)
X_4 = debt (THB)
X_5 = income (THB)

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RESULTS

Input and Output of the Rubber Farmer Cooperatives' Operations

The summary statistics of the input and output variables used in DEA was shown in Table 2. The study used the net margin as the output variable, while inputs considered in estimating operational efficiency are member size, total assets, operating expenses, and capital the cooperative holds. The study result showed wide variations in the cost related to the cooperative's operation, shown by its high standard deviations. It reflects the differences in the attributes of the cooperatives included in the study. Moreover, the cooperative under study were grouped into three stages, operation under the start phase, progressive phase, and developed phase, to address the observed variations to some extent.

TABLE 2
SUMMARY STATISTICS OF THE INPUT AND OUTPUT VARIABLES USED IN DEA, 2016-2018

Variables	2016		2017		2018	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Net margin (Y)	919.85	1,684.84	1,521.91	2,478.68	841.28	1,427.89
No. of members (X_1)	378.1	740.65	378.1	740.65	378.1	740.65
Total asset (X_2)	27,633.94	94,924.85	29,039.03	99,185.24	31,042.35	11,1071
Capital (X_3)	10,327.25	2,7505.9	11,649.82	30,288.43	11,681.42	31,719.03
Operating expenses (X_4)	34,245.24	59,197.69	37,365.32	71,781.75	32,347.65	53,566.78

Operational Efficiency of Rubber Farmers' Cooperatives

A graphical summary and descriptive statistics of the computed efficiency scores at each business phase for the years 2016 to 2018 was shown in Figure 2 and Table 3. Meanwhile, the detailed computed efficiency scores of each cooperative across the special economic zones of Thailand is provided in Appendix A. The yearly mean efficiency scores across three phases vary and are mostly below 50%.

TABLE 3
EFFICIENCY SCORES OF THE RUBBER FARMERS' COOPERATIVES (n = 37)

TE scores	2016			2017			2018		
	B	P	D	B	P	D	B	P	D
0.00 - 0.20	-	2	6	2	2	6	-	1	6
0.21 - 0.40	2	8	6	1	2	3	2	4	1
0.41 - 0.60	-	3	1	-	1	7	-	8	3
0.61 - 0.80	-	2	1	-	5	-	1	1	3
0.80 - 1.00	1	-	5	-	5	3	-	1	6
Mean	0.49	0.37	0.45	0.24	0.65	0.44	0.48	0.47	0.56
Max	1.00	0.72	1.00	0.40	1.00	1.00	0.67	1.00	1.00
Min	0.23	0.18	0.05	0.12	0.02	0.02	0.38	0.14	0.11
Std. Dev.	0.25	0.05	0.08	0.08	0.07	0.07	0.10	0.05	0.08
Note: B = Beginning phase; P = Progressive phase; D = Developed phase									

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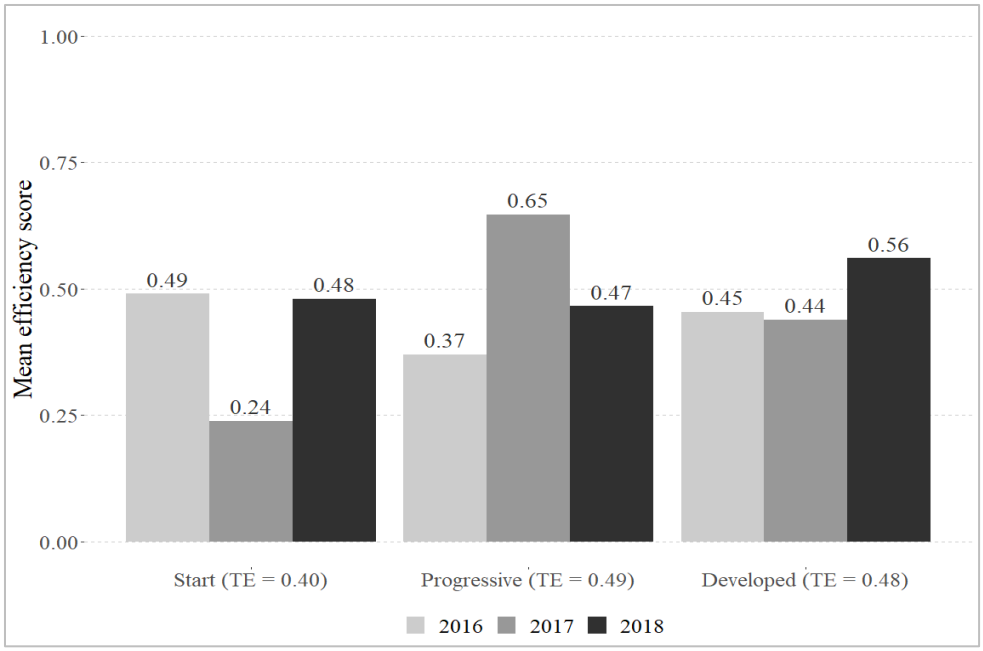

FIGURE 2

MEAN EFFICIENCY SCORES BY BUSINESS PHASE (2016-2018)

Factors Affecting the Operational Efficiency of Rubber Farmers' Cooperatives

The study examined the effect of the selected explanatory factors summarized in Table 4 on rubber cooperatives' efficiency. The development period refers to the years it takes for a cooperative to make its product ready for marketing. The establishment period refers to the years it takes for farmers to achieve an established network and market. On average, these two periods last for approximately 2 and 21 years, respectively.

The shareholder size (X_3) reflects the degree of the concentration of equity in the hands of shareholders. The study used X_3 as an indicator of cooperatives' governance and a potential factor affecting their efficiency level. In addition, the amount of debt and income for each cooperative were included as factors affecting operational efficiency.

TABLE 4
DESCRIPTIVE STATISTICS OF THE EXPLANATORY VARIABLES USED IN TOBIT REGRESSION ANALYSIS

Factors	Unit	Mean	Min	Max	Std. Dev.
Development period (X_1)	Year	2.43	1.00	3.00	0.64
Establishment period (X_2)	Year	21.54	5.00	53.00	13.47
Shareholder size (X_3)	Percentage	93.78	70.00	100.00	9.81
Debt (X_4)	Thousand THB	19,356.80	0.00	468,940.08	79,847.25
Income (X_5)	Thousand THB	33,188.93	69.65	300,267.93	54,381.22
Note: 1 USD = 30 THB; based on 2014-2019 yearly mean exchange rate					

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The effect of the selected factors on the efficiency of rubber cooperatives using Tobit regression was shown in Table 5. The results show the establishment period and the amount of debt to be statistically significant factor. A longer establishment period is associated with lower operational efficiency, whereas development period, shareholder and income were found to be statistically not significant among sampled rubber farmer cooperatives in Thailand.

TABLE 5
RESULTS OF THE TOBIT REGRESSION ANALYSIS

Factors	Coef.	Std. Error	t-stat	p-value
Development period (X_1)	-0.006	0.116	-0.050	0.958
Establishment period (X_2)	-0.010**	0.004	-2.340	0.026
Shareholder (X_3)	0.061	0.123	0.490	0.625
Debt (X_4)	2.35E-06**	1.13E-06	2.070	0.046
Income (X_5)	-0.046	0.076	-0.600	0.550
Constant	0.918	0.374	2.450	0.020
Note:$* p < 0.10;\ ** p < 0.05;\ *** p < 0.01$				

DISCUSSION

Key Findings

Rubber farmers' cooperatives play an important role in economic development. They have been regarded as leaders in rubber production and export. However, there is insufficient literature on the operational efficiency of rubber farmers' cooperatives in Thailand despite their significant contribution to the agricultural sector in terms of total production output and export volumes. Thus, this research has explored this gap and further offers comprehensive findings, which could provide insights to policymakers and cooperative managers about setting resource allocation priorities. This study found four key findings for rubber farmers' cooperatives in Thailand that are further discussed in the following section.

First, this study's main original results showed that operational efficiency of the rubber cooperative differs across their operational stage in the start phase, progressive phase, and developed phase. Rubber cooperatives operating under the start phase show less stability in their mean efficiency score than cooperatives in the progressive and developed phases. This finding adds evidence to the recent study of Fonte & Cucco (2017) which supports the assumption that a cooperative operates differently from a business oriented entity. Moreover, it was also observed in the study area that operations management tends to lack stability for rubber cooperatives under the start phase. In contrast to this study's results, cooperatives in the developed phase showed more stability in their yearly mean efficiency score from 2016 to 2018 than those operating in earlier phases. This indicated the cooperatives' maturity which resulted in a more systematic operation (Linn & Maenhout, 2019) compared to cooperatives operating in the beginning and progressive phases.

Second, the results of Tobit regression found that the establishment period and the amount of debt are statistically significant factors for the variations in the operational efficiency of rubber farmer cooperatives. More specifically, the amount of debt is positively associated with the cooperative's efficiency level. The observed association seems plausible, as the pooling of

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members' resources is the primary means of financing a cooperative's operation, acquiring enough equity is vital for continued operation (Gong et al., 2019). If borrowing is done to achieve the needed capital equity, a positive association of debt with the cooperatives' efficiency score will likely occur. The same results were also observed in the study of Ezeh & Abubakar (2019).

Third, results showed that a long establishment period is associated with lower efficiency performance. A similar but nonsignificant association is observed for the development period. This finding can be explained by the fact that the establishment period is often characterized by the inefficient use of inputs and sensitivity to changing economic conditions (Yu & Huang, 2020). Additionally, it is a period in which cooperatives are developing managerial and overall business strategies. Hence, a longer establishment period has an adverse effect on the operational efficiency of rubber cooperatives. Similar results were also found by Garrido & Zambrano (2019) that various stages of development and establishment have impacts on a cooperative's performance.

Finally, compared with other related research, the study result shows similarity with the computed mean efficiency scores ranging from approximately 46%-75% in China (Huang et al., 2013; Yu & Huang, 2020), 25%-55% in El Salvador (Ahn et al., 2012), and 62% to 67% in Ethiopia (Abate et al., 2014). While in terms of factors affecting efficiency, Ma et al. (2018) found that financing capability affects farmers' technical efficiency. In addition, Hailu et al. (2007) emphasize that using borrowed money to increase a cooperative's assets could provide financial leverage, resulting in improved efficiency. The findings indicated the importance of developing farmers' financial literacy and embedding skills in their everyday operations (Raza, 2019).

Theoretical Implication

Many prior studies on efficiency in the plant production sector have focused on crops other than rubber. Furthermore, there is insufficient literature on the operational efficiency of rubber farmers' cooperatives in Thailand despite their significant contribution to the agricultural sector in terms of total production output and export volumes. Thus, this study contributes to the literature on operational efficiency of rubber farms by providing a more comprehensive analysis of this area of research.

First, this study is the first attempt to investigate the operational efficiency of rubber farmers using a two-stage DEA approach. Parichatnon et al. (2018) measured the efficiency of Thai rubber production and found that Thai rubber production has shown a good performance and an upward productivity trend. Moreover, Angthong & Fujita (2019) assessed the impact of processing and marketing activities among Thailand's rubber cooperatives in Chumphon province and found that cooperative membership ensured a higher profit per rai and member households earned 50% higher income than non-members. However, these studies have not employed the two-stage DEA approach in the rubber industry context. Thus, this study examined the operational efficiency of rubber farmers using the two stage DEA approach. This study extends the previous findings related to operational efficiency (Dalei & Joshi, 2020; Habib & Shahwan, 2020), thereby contributing to research possibilities that will assist in further developing the increasing market reach of rubber farmers in Thailand.

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The second main implication of this study is that it extends the concept of operational efficiency to rubber farmers in the SEZs of Thailand. While operational efficiency in the plant production sector have been studied in agronomic crops, such as rice (Boubacar et al., 2016; Panpluem et al., 2019), maize (Abdulai et al., 2018; Ali et al., 2019) and wheat (Sherzod et al., 2018; Wang et al., 2018), and horticultural crops, such as vegetables in general (Sanusi et al., 2017; Wahid et al., 2017; Xu et al., 2018), there have been limited studies about industrial crops such as rubber. Therefore, this study provides a research finding that contributes to the literature in the plant production sector on the area of operational efficiency.

Finally, this study is the first study to investigate the operational efficiency of rubber farmers and at the same time explores the factors affecting their operational performance. Investigating these two aspects is crucial as it provides useful information for future empirical studies aiming to improve the production and efficiency of rubber farms. It should be noted that there is insufficient literature on the operational efficiency of rubber farms in Thailand, and this contribution to literature will be a useful input for future similar studies.

Practical Implication

This study provides three main practical implications for the rubber farmers' cooperatives and policymakers based on the identified factors affecting operational efficiency. First, the factors considered in the study relate mainly to the managerial and entrepreneurial aspects of farmers. The study emphasizes that cooperative members and owners mainly specialize in farming through their field experience. Generally, farmers lack managerial and entrepreneurial skills. Therefore, the pooling of members' resources as the primary source of equity is likely to limit a cooperative's mobility. Mobility refers to farmers' capacity to spread the investment risk by diversifying their investment to different activities (Jumpah et al., 2018). For example, since a cooperative's cost management directly affects its members' net income, members become more sensitive to these issues. As a result, decision-making may become difficult and negatively affect the cooperatives' overall efficiency.

Second, developing entrepreneurial and managerial skills to improve farmers' efficiency should be among the priorities of Thailand's policy to improve farmers' human capital. The real challenge now would be how to embed the acquired skills in cooperatives' daily operation to achieve a long-term effect in developing their operational efficiency. This aspect should be addressed.

Third and final practical implication is that, although this study did not sufficiently prove the significance of shareholders' percentage and income variable to the cooperative's efficiency, the identified association still provides an important implication. For a cooperative, performance is operationalized in conjunction with its identity as an association that pools people's resources with a common interest to collectively promote or uphold their interest (Ezeh & Abubakar, 2019). Thus, a cooperative's efficiency could be positively associated with the percentage of shareholders, all else held constant. It is also essential to recognize that a cooperative's decision-making includes factors not limited to the cooperative level. It is also important to recognize that the members' interests are not always perfectly homogenous (Tadesse et al., 2019). Members' behaviours may reflect their relative bargaining power in the cooperative and promote their own interests rather than the cooperative's defined objective.

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CONCLUSION

This study concludes that the level of efficiency among rubber cooperatives under the three business phases ranged from 24% to 65%. Factors affecting rubber farmer cooperatives' efficiency reveals a more extended development and establishment period associated with a lower efficiency score. Although Thailand's development program includes investment in improving farmers' human capital, the more challenging aspect considered by the study is embedding the provided training in farming operations to achieve a long-term effect on developing farmers' efficiency.

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