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The Measurement of Managerial Efficiency Changes of Dairy Cooperatives in Saraburi Province, Thailand based on The Malmquist Data Envelopment Analysis Approach

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Abstract The research objectives were to measure: 1) the technical efficiency change (TEC) relative to Constant Return to Scale (CRS) technology of the dairy cooperative in Saraburi province, 2) the technological change (TC), 3) pure technical efficiency (PTE) change relative to a Vary Return to Scale (VRS) and 4) the scale efficiency (SE) change of cooperative. The research was a quantitative research. The secondary data were collected from the Cooperatives Auditing Department from 2013 to 2022. The data were collected from the entire population using electronic spreadsheets. The findings were: 1) the TEC relative to the CRS had an average score of 1.000, expressing the cooperatives had no TEC; 2) the average score of TC was equal to 0.995, expressing their decreasing of TC; 3) the average score of pure efficiency change of cooperative was equal to 1.000 expressing the increased managerial technique of operational performances, and 4) the average score of the total factor of productivity change was equal to 0.996 expressed the decreased total factor of productivity change. It was concluded that dairy cooperatives had no TEC change. The pure efficiency change of dairy cooperatives expressed the increased managerial technique of their operational performances. In contrast, their score for the total factor of productivity change expressed the decreased total factor of productivity change of dairy cooperatives. The findings suggested that the modern dairy farming and dairy cooperatives are constantly searching for innovations to increase milk yields, enhance milk quality, and reduce costs.

Keywords Managerial efficiency; Cooperatives; Data envelopment analysis

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Introduction

Most raw milk is produced in Thailand's central, northeastern, and Northern provinces. The dairy industry in Thailand, like every sector, encounters some challenges. However, it is a significant contributor to the country's economy, and great strides are being made to develop the sector through cooperation (Dairy Global, 2023). In 2023, Thailand had 811,756 head of dairy cattle and 24,229 dairy producers running dairy farms. The three regions with the most significant concentrations of dairy farms are Nakhon Ratchasima, Saraburi, Lopburi, Chiang Mai, Ratchaburi, and Prachuap Khiri Khan, all of which are found in the north and center of the country (Dairy Global, 2023). The nation produced 1.29 million tons of raw milk in 2023. The output volume of milk and milk products was anticipated to reach 1.42 million tons of milk (Dairy Global, 2023). The domestic raw milk supply in Thailand isn't enough to meet demand, according to the United States Department of Agriculture (2023), because practically all of it is used to make liquid milk for ready-to-drink milk and school milk. A school milk program was started in 1992 to enhance the health and nutrition of students (United State Department of Agriculture, 2023). Pasteurized and ultra-high-temperature (UHT) milk, condensed milk, evaporated milk, ice cream, drinkable yogurt, yogurt, and butter are Thailand's main dairy exports. Since most of Thailand's dairy exports are made from imported dairy goods, such as concentrated milk and cream (skimmed and whole milk powder), imports of dairy products are crucial for the nation. These are crucial basic materials for producing dairy foods in Thailand. The ASEAN nations, which include Myanmar, Laos, Cambodia, Malaysia, Singapore, and the Philippines, are the main destinations for the nation's exports. According to a 2021 USDA study, Thailand exported dairy products worth US$389 million in 2019, an 8.7% rise from the previous year (United State Department of Agriculture, 2023).

For the last 10 years, Thai dairy producers have faced the high cost of raw milk production for Thai dairy farmers due to inadequate supplies of roughage and concentrate feeding formula and inadequate quality (Nationthailand, 2023). Thai dairy farmers transport milk at a considerable expense, and the transportation also affects the quality of the milk (Nationthailand, 2023). Dairy product consumption was impacted by the Covid-19 pandemic's economic downturn (Nationthailand, 2023). Thailand needs to advance in building milk production systems and motivating dairy farmers to plant feed crops that are appropriate for domestic dairy cows (Nationthailand, 2023).

One of Thailand's central provinces is Saraburi. The neighboring provinces are Lopburi, Nakhon Ratchasima, Nakhon Nayok, Pathum Thani, and Ayutthaya. It is thought to have been built as a center for recruiting soldiers in 1548, during the reign of King Maha Chakkraphat of Ayutthaya. Saraburi is on the east side of the valley of the Chao Phraya River. While the province's western portion is primarily low, flat plains, the province's eastern portion comprises high plains and plateaus. 848 km^2 (327 sq mi), or 24.2 percent of Saraburi province, is covered with forest. The town is 108 kilometers from Bangkok and serves as a gateway to the northeastern region. It covers 3,577 square kilometers of space (Wikipedia, 2023).

Saraburi province was selected as the site for this prototype research project because it was the birthplace of dairy cow husbandry and the top milk producer in the nation, in addition to being home to Chula's learning and research center. Twenty percent of Thailand's cow milk can currently be produced by more than 3,000 dairy cow farmers, or one-fourth of the nation's total (Nationthailand, 2023).

According to the Cooperative Auditing Department, 2023, the Saraburi provincial area has nine active business dairy cow operations and 3,043 dairy farmers. Most of them operate their farms as business owners.

In this research, the researcher emphasized 8 out of 9 dairy cooperatives except Central Dairy Cooperative Federation Ltd. because of some information that needed to be included.

Over 50 years of dairy farming and dairy cooperatives were founded in Saraburi province, and a small number of dairy farming and dairy cooperatives' operational performance focuses on technical efficiency. Even Saraburi of dairy farming province is the first place Dairy was founded in Thailand. With the research interest in mind, the researcher researched measuring the managerial efficiency change of dairy cooperatives in Saraburi Province, Thailand. As a pilot research project, the research results would be beneficial for dairy cooperatives and farmers who are cooperative members. In addition, the application of research results would be spread to other scholars.

Based on the information and research reviewed, the researcher found that consolidating dairy cooperative members in Saraburi Province is importance. Clear principles and guidelines to enhance the value of the cooperative are significant for its members. Economic participation and control over the cooperative's capital are key factors affecting the efficiency of dairy cooperative operations. These studies are crucial for improving and developing dairy cooperatives in Saraburi Province, leading to the utilization of research results to enhance the efficiency of cooperative operations, aligning with the researchers' objectives.

Therefore, the primary research aimed to measure the technical efficiency change relative to the Constant Return to Scale (CRS) technology.

Table 1 The number of dairy cooperatives members in Saraburi Province, Thailand

Cooperative name	Numbers of dairy cooperative members (People)
Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd.	511
Thai-Danish Dairy Cooperative (Mitraphap) Ltd.	253
Thai-Denmark Dairy Cooperative (Sapkradan) Ltd.	179
Muak Lek Dairy Cooperative Ltd	552
Wihan Daeng Dairy-Livestock Cooperative Ltd.	193
Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd.	102
Thai Milk Dairy Cooperative Ltd.	1,050
Dairy Cooperative in the Subsanun Land Reform Ltd.	188
Central Dairy Cooperative Federation Ltd.	15
Total	3,043

Source: Cooperative auditing department (2023)

Research objectives

The research objectives were:

1 To measure the technical efficiency change relative to Constant Return to Scale (CRS) technology of Dairy cooperative in Saraburi province,

2 To measure the technological change of Dairy cooperatives in Saraburi province,

3 To measure pure technical efficiency change relative to a Vary Return to Scale (VRS) technology Dairy cooperative in Saraburi province, and

4 To measure scale efficiency change Dairy cooperative in Saraburi province

Research hypothesis

1 there was an increase in the technical efficiency change relative to the Constant Return to Scale (CRS) technology of Dairy cooperatives in Saraburi province

2 there was an increase in the technological change of Dairy cooperatives in Saraburi province,

3 there was an increase in pure technical efficiency change relative to a varied return to scale technology Dairy cooperative in Saraburi province, and

4 there was an increase in scale efficiency change Dairy cooperative in Saraburi province

Literature review

1 Dairy farming in Thailand

Dairy Farming in Thailand began in 1960; His Majesty King Bhumibol Adulyadej and Her Majesty Queen Sirikit visited Denmark and were very interested in their dairy farming. Then, the Danish government and the Danish Dairy Farming Association offered a promotion project on raising dairy cows (Dairy Farming Promotion Organization of Thailand, 2023). They coordinated with the Thai government to establish the Thai-Danish Dairy Farm (TDDF) and a training center in Muak Lek District, Saraburi Province. King Bhumibol and King Frederik IX of Denmark together inaugurated the farm on 16 January 1962. All business was later transferred to the Royal Thai Government and became the Dairy Farming Promotion Organization of Thailand (DFPO), to promote the occupation of dairy farms (Dairy Farming Promotion Organization of Thailand, 2023).

2 Dairy production

The overall number of dairy cows in Thailand has dramatically expanded, with 24,251 households producing milk, according to the Department of Livestock Development of Thailand (2023). This showed that Thailand's dairy business has grown significantly in recent years. The founding of dairy cooperatives in Thailand in the 1970s marked the beginning of systematized dairy cultivation and production (Sarttra et al., 2023). The main benefits of cooperatives are that they can incorporate goals for long-term sustainability, fair pricing, and mutual benefits overseen by cooperative boards rather than just emphasizing maximum profit-making. In cooperatives, the owners and those who vote for the board of directors during a particular term can play a crucial role (Dairy Farming Promotion Organization of Thailand, 2023).

Due to the efforts of the Thai government, domestic dairy consumption has been steadily rising over the past few decades. Numerous dairy farms are located in Thailand's rural areas. As part of a government program, practically all raw milk in Thailand is pasteurized domestically for ready-to-drink and school milk (Sarttra et al., 2023).

3 Dairy cooperatives

To guarantee members a market for their milk, farmer-owned dairy cooperatives in Thailand participate in several activities. They can bargain prices and promote milk and dairy goods to wholesalers, retailers, or stores. They can also assemble, haul, produce, and process these items (Wittayakorn-Puripunpinyoo, 2020). Dairy cooperatives come in a wide range of sizes and perform various tasks; some only organize the sale of milk produced by their members and offer a limited number of services, while others produce a wide range of goods and may sell their branded goods straight to consumers. Many organizations also provide their members with supportive services, including fieldwork, testing and confirming milk weights, selling supplies and equipment for milk production, and offering health insurance (United States Department of Agriculture, 2023), (Wittayakorn-Puripunpinyoo, 2020).

The dairy farmers who use the services provided by a dairy cooperative enterprise own, run, and manage it. According to the amount of milk they sell through the cooperative, members contribute to the cooperative's funding and receive some earnings (United States Department of Agriculture, 2023) (Wittayakorn-Puripunpinyoo, 2020). For smallholder farmers to produce raw milk, dairy cooperatives are crucial. The cooperatives can provide their farmer members with expertise, negotiating power, a fair product price, technical assistance with agricultural equipment, animal

healthcare, artificial insemination, and a low-interest loan. The main benefits of cooperatives are that they can incorporate goals for long-term sustainability, fair pricing, and mutual benefits that are overseen by cooperative boards rather than just emphasizing maximum profit-making. In cooperatives, the owners and those who vote for the board of directors during a particular term can play a crucial role (United States Department of Agriculture, 2023) (Wittayakorn-Puripunpinyoo, 2020).

The cooperative currently offers dairy farmers in the provinces of Nakhon Pathom, Ratchaburi, and Kanchanaburi milk collection centers, a medium-sized pasteurization processing plant, points of sale for consumer goods, auxiliary farming equipment in a dairy farm, a cattle feed factory, and financial support. The preliminary study indicates that the cooperative has experienced both an excess and a shortage of raw milk supplies in response to shifting demand, the number of cows and the composition of the herd directly affect the amount of raw milk produced by cooperative members. Farmers, a cooperative production facility, and consumer demand currently do not have any transparent value chains connecting them (Wittayakorn-Puripunpinyoo, 2020; Sarttra et al., 2023).

4 Technical efficiency

Technical efficiency is the effectiveness with which a given set of inputs is used to produce an output. A firm is technically efficient if it produces the maximum output from the minimum quantity of inputs, such as labor, capital, and technology (Economicshelp, 2023). Technical efficiency refers to how productive a business can be given the fewest inputs or resources, necessary to do the job. An input is any quantifiable resource necessary to create an output or a product. Labor is a form of input, as are materials and equipment.

In addition, a technically efficient company aims to be productive while using the minimum quantity of inputs. In other words, the company wants to be as efficient as possible with as few inputs as possible-while still hitting its production goal. Those efficiency aspects are concerned with obtaining the most significant possible output level for a given quantity of inputs or using the smallest possible quantity to obtain a given output. This is production efficiency. It is distinguished from efficiency in exchange, which is concerned with the distribution of outputs between different users, and the efficient choice of the set of outputs to produce. Technical efficiency is a necessary condition for the overall efficiency of the economy. However, it is insufficient since an economy could be better off producing the right mix of goods by technically inefficient methods than producing an unsuitable set of goods with complete technical efficiency (Oxfordreference, 2023). From the literature review, the researcher can create the following conceptual framework:

From figure1. The conceptual framework was demonstrated with the 1st step of inputs which composed of total expenses, total assets, total debt, total cooperatives funds, and shared capital, the 2nd step of the process which expressed the technical efficiency calculation applied Malquist data envelopment analysis, the 3rd step of outcome which gave the total income, and the 4th step of the calculation results from Malquist data analysis expressed the measurement outcomes of technical efficiency which comprised of: 1) the technical efficiency change relative to constant return to scale (CRS); 2) the technical change relative to constant return to scale (CRS); 3) pure efficiency change relative to variable return to scale (VRS), and 4) scale efficiency change. These 4 measurement outcomes were the key research results presented in Table 2.

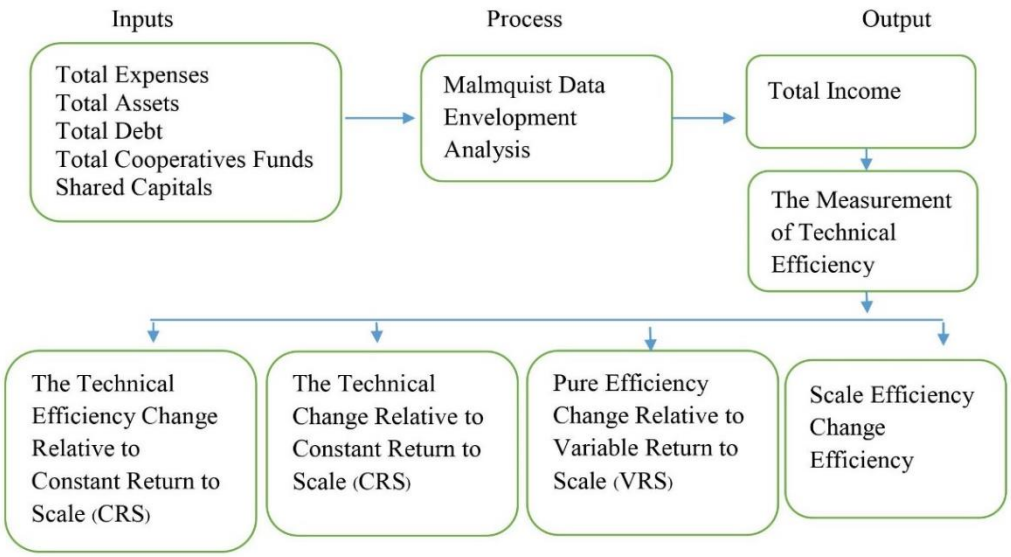

Figure 1 The conceptual framework

2 Data analysis

As a quantitative research, the secondary data were rigorously analyzed using the Data Envelopment Analysis Model (DEA Model) with the Malmquist Data Envelopment Analysis Approach. This approach allowed us to evaluate the efficiency and productivity changes of the dairy cooperatives over the years.

Research results

Table 2 The technical efficiency, technological change, pure efficiency change, and scale efficiency of Dairy Cooperative Ltd. in Saraburi Province, Thailand, from 2013 to 2022

No.	Coop Code	Cooperative Name	Effch[1]	Techch[2]	Pech[3]	Sech[4]
1	5388	Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd.	1.000	1.005	1.000	1.000
2	5570	Thai-Danish Dairy Cooperative (Mitraphap) Ltd.	1.002	0.989	1.002	1.000
3	5812	Thai-Denmark Dairy Cooperative (Sapkradan) Ltd.	1.000	0.944	1.000	1.000
4	8015	Muak Lek Dairy Cooperative Ltd.	1.002	1.014	1.000	1.002
5	8275	Wihan Daeng Dairy-Livestock Cooperative Ltd.	1.003	0.999	1.000	1.003
6	8276	Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd.	1.000	0.976	1.000	1.000
7	8652	Thai Milk Dairy Cooperative Ltd.	0.998	1.010	1.000	0.998
8	15174	Dairy Cooperative in the Subsanun Land Reform Ltd.	1.000	1.027	1.000	1.000
		Average	**1.000**	**0.995**	**1.000**	**1.000**

Source: Calculation

[1] The Technical Efficiency Change Relative to Constant Return to Scale (CRS)

[2] The Technical Change Relative to Constant Return to Scale (CRS)

[3] Pure Efficiency Change Relative to Variable Return to Scale (VRS)

[4] Scale Efficiency Change

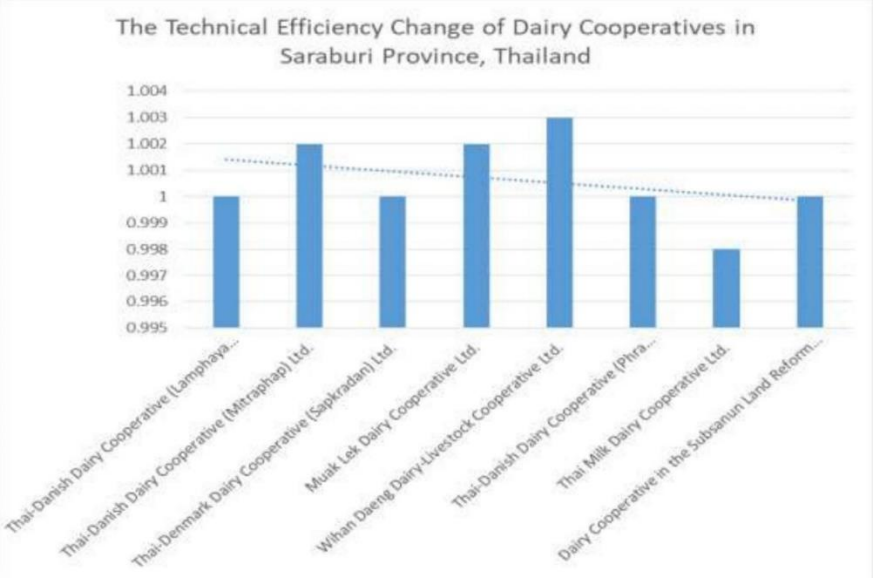

Figure 2 The technical efficiency change of dairy cooperatives in Saraburi Province, Thailand
Source: Calculation

Part 1. Following the 1st Research Objective, The Technical Efficiency Change Relative to Constant Return to Scale (CRS) could be expressed as:

According to Table 2 and Figure 2, from 2013 to 2022, the research results showed that there were 3 Dairy cooperatives in Saraburi province, namely: 1) Thai-Danish Dairy Cooperative (Mitraphap) Ltd., 2) Muak Lek Dairy Cooperative Ltd., and 3) Wihan Daeng Dairy-Livestock Cooperative Ltd. had their increased technical efficiency expressing by the technical efficiency change score of 1.002, 1.002, and 1.003 respectively. Other 4 out of 8 Dairy cooperatives namely 1) Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd., 2) Thai-Denmark Dairy Cooperative (Sapkradan) Ltd., and 3) Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd., and 4) Dairy Cooperative in the Subsanun Land Reform Ltd. which had no the technological efficiency change expressing its score of 1.00 expressing the constant technological change. On the other hand, Thai Milk Dairy Cooperative Ltd. had only the average score of technological efficiency change of 0.998, expressing a decrease in technological efficiency change. The average technological efficiency change score was 1.000, revealed the overall Dairy Cooperative in Saraburi province had no technological efficiency change.

Part 2. Following the 2nd Research Objective, The Measurement of Technological Change of Dairy Cooperatives in Saraburi province could be expressed as:

According to Table 2 and Figure 3, when considering technological changes, it was found that there were 4 out of 8 dairy cooperatives, namely 1) Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd., 2) Muak Lek Dairy Cooperative Ltd., 3) Thai Milk Dairy Cooperative Ltd., and 4) Dairy Cooperative in the Subsanun Land Reform Ltd. had the score of technological change of 1.005, 1.014, 1.010, and 1.027 respectively. It was expressed that all 4 Dairy cooperatives had upward technological change in their operational management, which can be seen from its scores. Every technological change score had a value greater than 1.00. The other 4 out of 8 namely 1) Thai-Danish Dairy Cooperative (Mitraphap) Ltd., 2) Thai-Denmark Dairy Cooperative (Sapkradan) Ltd., 3) Wihan Daeng Dairy-Livestock Cooperative Ltd., and 4) Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd. had the score of technological change of 0.989, 0.944, 0.999, and 0.976 respectively which expressed their decreased technological change. Overall, the average technological change score was equal to 0.995,

which expressed the decrease in technological change for the dairy cooperative in Saraburi province, Thailand.

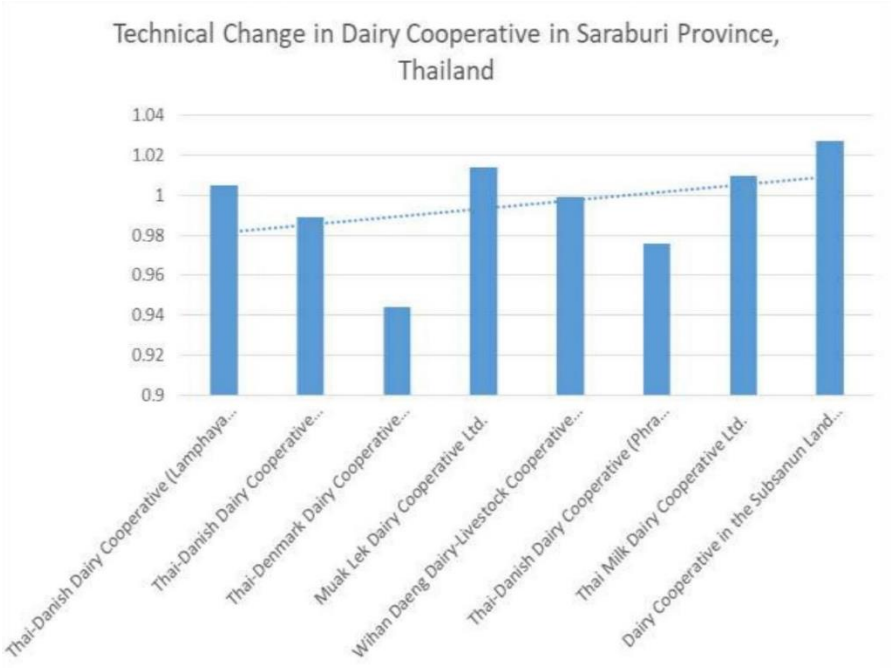

Figure 3 Technical change in dairy cooperatives in Saraburi Province, Thailand
Source: Calculation

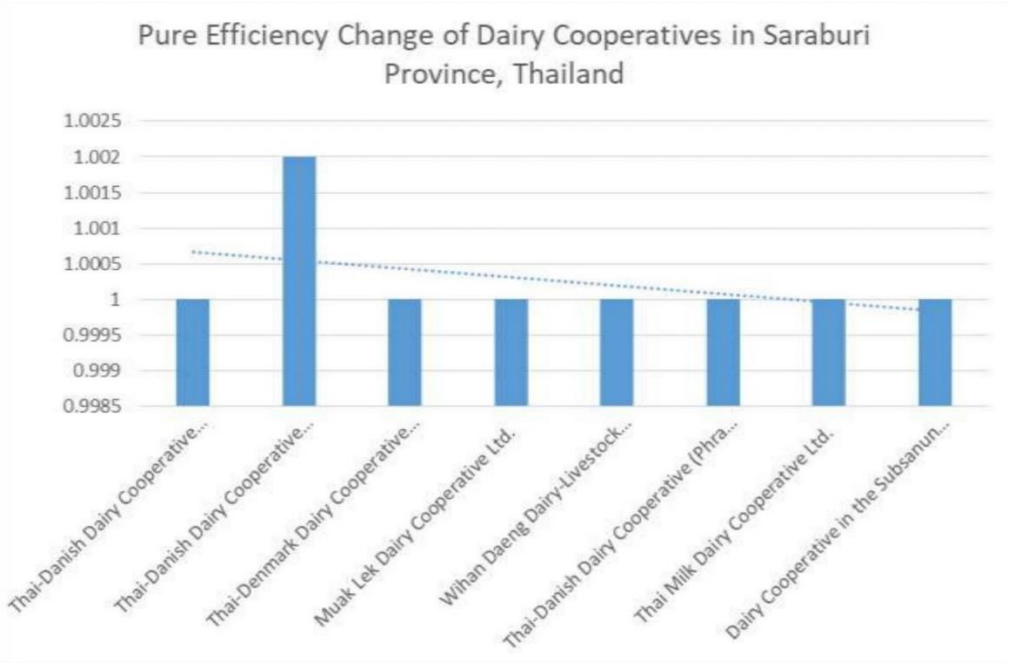

Figure 4 Pure efficiency change in dairy cooperatives in Saraburi Province, Thailand
Source: Calculation

Part 3. Following the 3rd Research Objective, Pure Efficiency Change Relative to Variable Return to Scale (VRS) could be expressed as:

According to Table 2 and Figure 4, considering the pure efficiency change, from 2013 to 2022, Thai-Danish Dairy Cooperative (Mitraphap) Ltd. was the only Dairy cooperative that had a pure efficiency change showed a score of 1.002 which was more significant than 1.000. According to the research results, there were 7 out of 8 cooperatives had scores of managerial technique and operational performances of 1.000 expressed the constant managerial technique of operational performances which were: 1) Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd., 2) Thai-Denmark Dairy Cooperative (Sapkradan) Ltd., 3) Muak Lek Dairy Cooperative Ltd., 4) Wihan Daeng Dairy-Livestock Cooperative Ltd., 5) Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd., 6) Thai Milk Dairy Cooperative Ltd., and 7) Dairy Cooperative in the Subsanun Land Reform Ltd. The average score of the pure efficiency change of the dairy cooperative was equal to 1.000, which indicates increase in the managerial technique of operational performance.

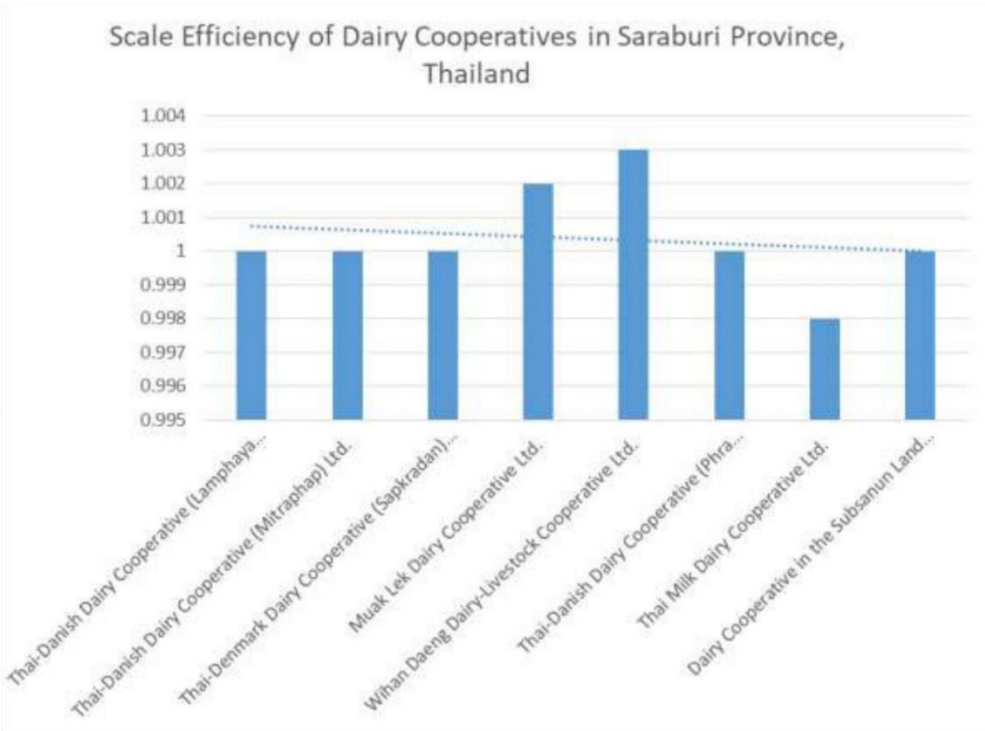

Figure 5 Scale efficiency of dairy cooperatives in Saraburi Province, Thailand
Source: Calculation

Part 4. Following the 4th Research Objective, The Measurement of scale efficiency change of dairy cooperatives in Saraburi province could be expressed as:

According to Table 2 and Figure 5, in terms of scale efficiency change from 2013 to 2022, there were 2 out of 8 Dairy cooperatives Ltd., namely 1) Muak Lek Dairy Cooperative Ltd. and Wihan Daeng Dairy-Livestock Cooperative Ltd. had their score of scale efficiency change of 1.002, and 1.003 respectively expressing their score of increased scale efficiency change. There were 5 Dairy cooperatives had their score of scale efficiency change of 1.000 namely 1) Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd., 2) Thai-Danish Dairy Cooperative (Mitraphap) Ltd., 3) Thai-Denmark Dairy Cooperative (Sapkradan) Ltd., 4) Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd., and 5) Dairy Cooperative in the Subsanun Land Reform Ltd. which showed the constant scale

efficiency change. Thai Milk Dairy Cooperative Ltd. was the only dairy cooperative whose scale efficiency change score of 0.998 expressed a decreased scale efficiency change. In sum, the average score of scale efficiency change was equal to 1.000. This meant the scale efficiency change of Dairy cooperatives in Saraburi province was likely constant.

For the ten years measuring from 2013 to 2022, the total factor of productivity change of Dairy cooperative in Saraburi province expressed two features, which were 1) the increased total factor of productivity change of Dairy cooperative of Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd., Muak Lek Dairy Cooperative Ltd., Wihan Daeng Dairy-Livestock Cooperative Ltd., Thai Milk Dairy Cooperative Ltd., and Dairy Cooperative in the Subsanun Land Reform Ltd. with the total factor of productivity change scores of 1.005, 1.016, 1.002, 1.008, and 1.027 respectively, and 2) the decreased total factor of productivity change of Dairy cooperative of Thai-Danish Dairy Cooperative (Mitraphap) Ltd., Thai-Denmark Dairy Cooperative (Sapkradan) Ltd. Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd. Overall, the average score of total factor of productivity change was equal to 0.996125 expressed the decreased total factor of productivity change of Dairy cooperative in Saraburi province.

Discussion

The average technological efficiency change score was 1.000, revealed the overall Dairy Cooperative in Saraburi province had no technological efficiency change. Theoretically, the technological efficiency change score was more significant than 1.000, meaning that the Dairy cooperative in Saraburi province still performed their business in good shape. When we had to focus on the individual dairy cooperatives in Saraburi province, the results found that only one dairy cooperative, Thai Milk Dairy Cooperative Ltd., scored 0.998. This meant that from 2013 to 2022 Thai Milk Dairy Cooperative Ltd. performed its business at a lower than standard score. On the other hand, there were four dairy cooperatives in Saraburi province, namely Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd., Thai-Denmark Dairy Cooperative (Sapkradan) Ltd., Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd., and Dairy Cooperative in the Subsanun Land Reform Ltd. These obtained the technical efficiency change score of 1.000. This meant that all four dairy cooperative should improve their operational performance. According to the previous study, this research finding was consistent with Aydemir et al. (2020) research work. Who conducted their research on cost analysis and technical efficiency of dairy cattle farms: a case study of Artvin, Turkey, applying the Data Envelopment Analysis Model (DEA Model) found that inefficiency scores increased with increasing herd sizes. Similarly, it was consistent with Yilmaz et al. (2020), whose works analyzed technical efficiency in milk production: a cross-sectional study on Turkish dairy farming.

From 2013 to 2022, the average score of technological change was equal to 0.9955 which was less than 1.000, which expressed the decreased score of technological change. Theoretically, the overall technological change has yet to progress. There were 4 out of 8 dairy cooperatives had a technological change score greater than 1.00, expressing the increased technological change. On the other hand, these four dairy cooperatives had directly applied technology for their production and management. These four dairy cooperatives were the Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd., Muak Lek Dairy Cooperative Ltd., Thai Milk Dairy Cooperative Ltd., and Dairy Cooperative in the Subsanun Land Reform Ltd.

The other four dairy cooperatives had a technological score smaller than 1.000, which were Thai-Danish Dairy Cooperative (Mitraphap) Ltd., Thai-Denmark Dairy Cooperative (Sapkradan) Ltd., Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd., and Thai Milk Dairy Cooperative Ltd. This exhibited the decreased technological utilization in dairy farming and management. All of these four dairy cooperatives should improve their technological application. Compared to the previous study, these research findings complied with Naglova and Rudinskaya's (2021) work. Who studied factors influencing technical efficiency in the EU dairy farms. Who founded that technological application in

Dairy farm management played a crucial role in technical efficiency in Dairy cooperatives. Dairy farming has significantly evolved over the last decade and continues to change incredibly fast. From robotic milking to fit bits for bovines, modern dairy farming is constantly searching for innovations to increase milk yields, enhance milk quality, and reduce costs.

In addition, focusing on dairy farming technologies, there are nowadays the top three technology trends in the dairy farming industry today. Robotic or automatic milking systems (AMS) were developed in the late 20th century. Since their release, these systems have soared in popularity. Robotic milking is when a mechanical system – or a robot – automatically milks a dairy cow without having human labor involved. The system is set up to guide the herd into the milking shed, identify each cow individually by scanning an identification tag, milk the cows, check the milk, and record any data. Introducing the cow collar, a fit bit for cows. With cow collars, farmers can gather data on their herd's health, habits, and happiness. This includes the number of steps per day as well as rumination. The automatic feed pusher was another top technological trend, taking the dairy industry by storm. This machine pushes feed toward the feed fence during times and routes you set.

The average score of the pure efficiency change of the dairy cooperative was equal to 1.000, which is the increased pure efficiency change. All eight dairy cooperatives exhibited almost the same score of pure efficiency change. From 2013 to 2022, the pure efficiency. These findings were compatible with the research work of Katarzyna et al. (2022) who studied the technical efficiency of cooperative and non-cooperative dairies in Poland toward the first link of the supply chain.

For the scale efficiency of Dairy cooperative in Saraburi province, Thailand, there were five dairy cooperatives namely Thai-Danish Dairy Cooperative (Lamphaya Klang) Ltd., Thai-Danish Dairy Cooperative (Mitraphap) Ltd., Thai-Denmark Dairy Cooperative (Sapkradan) Ltd., Thai-Danish Dairy Cooperative (Phra Phutthabat) Ltd., and Dairy Cooperative in the Subsanun Land Reform Ltd. had scale efficiency score of 1.00 expressed that all of these five dairy cooperatives did not have the advancement in scale efficiency. Thai Milk Dairy Cooperative Ltd. Thai Milk Dairy Cooperative Ltd. had a scale efficiency of 0.998, expressing its inefficiency in dairy cooperative performance. According to the research findings, two dairy cooperatives with a scale efficiency change score greater than 1.000 were Muak Lek Dairy Cooperative Ltd. and Wihan Daeng Dairy-Livestock Cooperative Ltd. The score of scale efficiency change reflected significantly the operational efficiency. According to the previous study, this research findings were compatible with the research works of Wittayakorn-Puripunpinyoo (2020) who studied the analysis of operational performance and efficiency of dairy cooperatives Ltd. in Nakhon Ratchasima Province, Thailand. Also, the research results were consistent with the work of Priyanka et al. (2020) who studied the determinants of technical efficiency of dairy farmers in Sirsa cooperative milkshed in India. In addition, the research results were consistent with the study of Beber et al. (2021), who conducted their research on the organizational forms and technical efficiency of the dairy processing industry in Southern Brazil. Compared to other studies, the results corresponded to those of Wanglin et al. (2018). Who studied feed use intensification and technical efficiency of dairy farms in New Zealand.

Conclusions

In this research work, the measurement of the managerial efficiency change of Dairy Cooperatives in Saraburi Province, Thailand, the researcher focused on the Technical Efficiency (TE) related to Constant Return to Scale (CRS), Technical Change related to Constant Return to Scale (CRS), Pure Efficiency (PE) change related to Variable Constant Return to Scale (VRS), and Scale Efficiency (SE) change. The overall operational efficiency expressed the whole picture of the business operation of dairy cooperatives in Saraburi province, Thailand, which had been slowly applied in technological applications in dairy farming and dairy cooperative business operations. The Thai government should consider and encourage them to use technology since technology is still and has

been one of the key factors for the success of business operations. This conclusion could be synthesized as the diagram below:

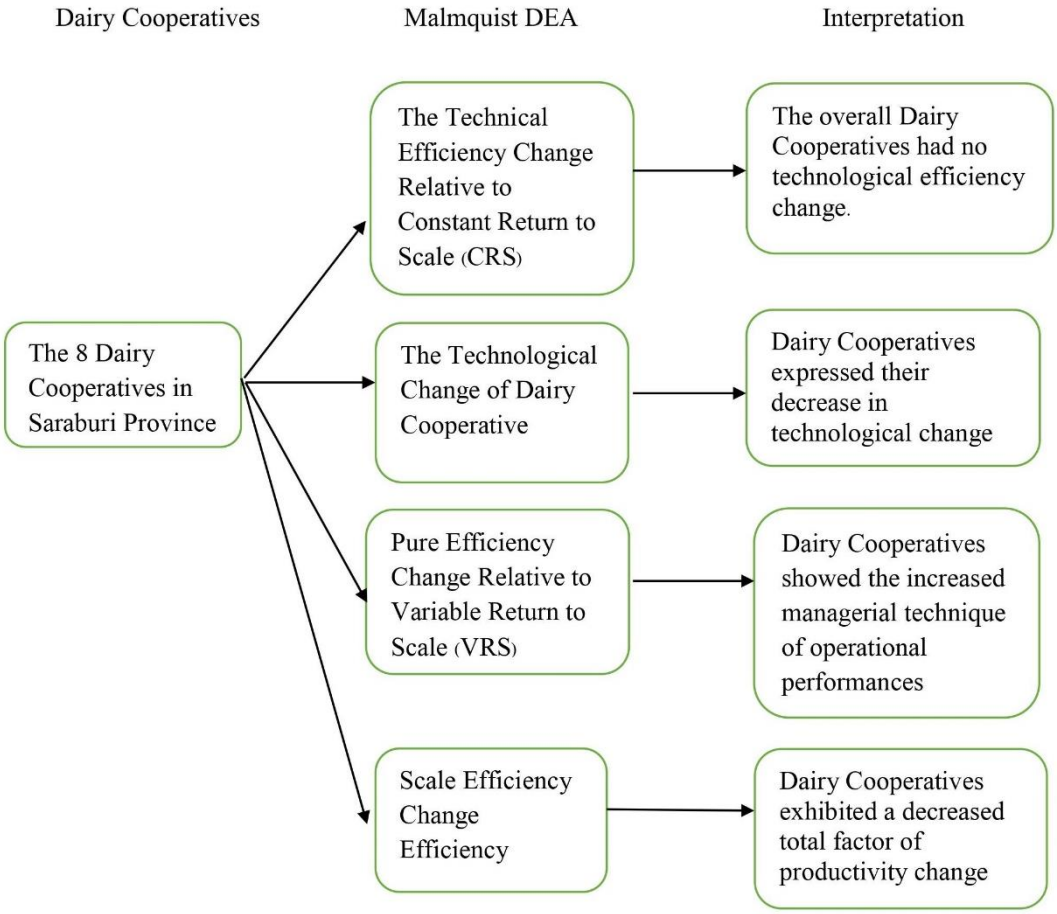

Figure 6 The synthesized diagram of research findings

According to Figure 6, the synthesized diagram of research findings explained that the eight dairy cooperatives in Saraburi province exhibited their outcome characteristics in 4 manners, which were: 1) the overall dairy cooperatives had no technical efficiency change; 2) dairy cooperatives expressed their decrease in technological change; 3) dairy cooperatives showed the increased managerial technique of operational performances; and 4) dairy cooperatives exhibited a decreased total factor of productivity change. All of these 4 manners led to the following recommendations:

Recommendation

According to the research results, the researcher would like to address the recommendations for improving operational performance in Saraburi province, Thailand, dairy cooperatives. It could be achieved through various strategies. Here are some key approaches:

1. **Efficient Resource Management**: Ensure effective utilization of resources, including land, labor, capital, and technology. This involves optimizing milk production, processing, packaging, and distribution processes.

2. **Technology Adoption**: Implement modern technologies for dairy farming, milk processing, and distribution. This may include automated milking systems, monitoring equipment for animal health and productivity, and advanced processing and packaging machinery.
3. **Quality Control**: Maintain high milk quality and safety standards throughout the production and processing chain. Implement quality control measures at every stage to ensure compliance with regulations and customer expectations.
4. **Supply Chain Optimization**: Streamline the supply chain from farm to consumer to reduce inefficiencies and minimize wastage. This includes improving transportation logistics, inventory management, and distribution channels.
5. **Training and Capacity Building**: Invest in training programs to enhance cooperative members' and employees' skills and knowledge. This can include training in dairy farming practices, milk processing techniques, quality control procedures, and business management.
6. **Market Development**: Identify and develop new markets for dairy products to increase sales and revenue. This may involve diversifying product offerings, exploring export opportunities, and implementing marketing strategies to promote dairy products to consumers.
7. **Cooperative Governance and Management**: Strengthen the cooperative' s governance structures and management systems to ensure effective decision-making, accountability, and transparency. This may involve implementing best practices in cooperative governance, conducting regular audits, and fostering collaboration and trust among members.
8. **Financial Management**: Improve financial management practices to ensure the cooperative's financial sustainability. This includes budgeting, financial planning, cost control, and investment in income-generating activities.
9. **Research and Innovation**: Invest in research and development to identify new technologies, practices, and products to enhance operational performance and competitiveness in the dairy industry.
10. **Partnerships and Collaboration**: Collaborate with other stakeholders, including government agencies, research institutions, and private sector organizations, to leverage resources, expertise, and networks for mutual benefit.

By implementing these strategies, dairy cooperatives can enhance their operational performance, increase productivity and efficiency, and ultimately contribute to the sustainable development of the dairy cooperatives.

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