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Supply chain resilience after the Covid-19 pandemic in Thai industry

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A B S T R A C T

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The epidemic of the COVID-19 has spread rapidly worldwide. This phenomenon has changed people's lifestyles as well as business activities. Many businesses are unable to operate normally, which is caused /or affected by supply chain disruption. Therefore, supply chain resilience after the COVID-19 pandemic is essential to maintaining the liquidity of businesses and increasing supply chain efficiency. This research aimed to examine factors influencing supply chain resilience and construct a structural equation model for supply chain resilience after the COVID-19 pandemic in Thailand's industries. A research framework was developed according to previous literature in the context of supply chain resilience. Five constructs, namely Technology, Flexibility, Collaboration, Agility, and Supply chain resilience, with seven hypotheses were established. A questionnaire survey was developed from the research framework and previous literature. Then, the validity and reliability test of the questionnaire were performed with the Index of Item Objective Congruence (IOC) technique and Cronbach's alpha, respectively. The data was obtained from 426 business organizations in both the industrial and service industry in Thailand. The structural equation model (SEM) technique was conducted to examine the relationship between constructs. The results revealed that agility was only a factor that directly influenced supply chain resilience, while technology had an indirect effect on it via agility. However, technology has had direct effects on flexibility, agility, and collaboration.

1. Introduction

Since the discovery of the initial outbreak of coronavirus disease (COVID-19) in Wuhan, China, the virus has rapidly spread to numerous countries. The World Health Organization (WHO) declared COVID-19 a pandemic on March 11, 2020 (Belhadi et al., 2021). The pandemic caused by COVID-19 has not only had an effect on public health but has also had a significant influence on economies all across the world. According to the World Bank (2021), the level of global GDP in 2021 was 3.2% lower than what had been projected before the pandemic, and the level of the Asian economy fell by 2.1–5.45 percentage points below the normal situation. In particular, Thailand was the most affected among ASEAN countries because the number of tourists dropped by 60% in 2019, as well as because of the disruption of supply chains in the production sector (Krungsri Bank, 2020).

Thailand's government issued several measures to control the epidemic. As a result, businesses, both production and service sectors, suffered greatly. Raw material exports and imports were forced to halt until the epidemic situation stabilized. Some businesses have to be temporarily closed, and somes cannot operate normally. A number of businesses decided to close. According to the Department of Business Development (2022), the number of shut down businesses was 19,326 and dissolved registered capital accounts for 384,376.83 million Baht in 2022. The COVID-19 pandemic caused disruption of the supply chain for both manufacturing and service industries in Thailand. Supply chain resilience is crucial for businesses to recover from negative effects or disruptions. This study aimed to explore factors influencing supply chain resilience and develop a

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model for supply chain resilience after the COVID-19 pandemic in Thailand. The contributions of this research were to understand the ways in which the supply chain is recovering in the Thai industry and to increase the ability of the business to cope with the crisis, which in turn strengthens international trade.

2. Literature Review and Hypothesis Development

2.1 Concept of Supply chain resilience

During the COVID-19 pandemic, the disruption of a supply chain affected businesses and the economy, as mentioned above. As a result, practitioners and policymakers have placed a greater emphasis on risk and vulnerability management in supply chains. Golan et al. (2020) defined supply chain resilience as the ability of a supply chain to recover from the negative effects of an unanticipated disruption and adapt to uncertain future events. Additionally, Rice and Caniato (2003) and Pettit et al. (2013) described supply chain resilience as the ability to anticipate and recover from interruptions in the supply chain. According to Blos et al. (2012), the term "supply chain resilience" refers to the speed with which supply chains can recover to normal operation after supply chain disruption.

2.2 Technology

Businesses should reduce or enhance their reliance on existing resources in order to adapt to a changing environment (Ambulkar et al., 2015). Technology enables organizations to create new innovations or modify existing ones (Marsh and Stock, 2006). According to the findings of a study conducted by Kwak et al. (2018), innovation plays a significant part in both the enhancement of an organization's supply chain capabilities and the management of risks in an organization. Belhadi et al. (2021) found that the application of technology 4.0 in the operations and collaboration of the manufacturing sector was the best risk mitigation strategy for the COVID-19 pandemic in the manufacturing industry. Sabahi and Parast (2020) conducted research to determine how firm innovation impacted the supply chain resilience. They came to the conclusion that businesses with organizations with an innovative environment had a beneficial impact on the supply chain resilience. That is because innovation enables effective collaborative knowledge building, agility, and flexibility that have direct effects on the efficiency of supply chain resilience. According to the findings of Cardoso and Ramos (2016), innovation enables supply chain resilience in two ways: first, it lowers the risk of disruptions occurring, and second, it raises the amount of collaboration among supply chain participants. Dosh (2009) also found that innovation had a positive effect on supply chain resilience. Thus, the first to fourth hypotheses can be formulated as follows:

H_1: *Technology positively influences supply chain resilience.*
H_2: *Technology positively influences flexibility.*
H_3: *Technology positively influences collaboration.*
H_4: *Technology positively influences agility.*

2.3 Flexibility

According to Sanchez and Pérez (2005) and Upton (1994), flexibility is defined as the ability to adapt certain characteristics to changes in the environment with little reaction in time, effort, cost, or performance. Additionally, Jüttner and Maklan (2011) defined flexibility as the ease with which a supply chain can be quantified (for example, the number of feasible alternatives) and ranged differently (for example, the degree of distinction between alternatives) in order to accommodate changes in the market or the environment while still being able to function as usual. Stevenson and Spring (2007) stated that a supply chain should be flexible and able to be adjusted in the least amount of time possible. The studies of Chowdhury and Quaddus (2017), Rajesh (2020), Sabahi and Parast (2020), and Dubey et al. (2021) found that flexibility increased business recovery, supply chain resilience, and the competitive advantage of the organization. Pettit et al. (2010) categorized various types of flexibility, such as flexibility in transport, flexibility of an action plan, flexibility of time, flexibility of purchasing, or flexibility of ordering. Meanwhile, Rajesh (2020) stated that flexibility included sourcing strategies, product operation, and price. During the COVID-19 pandemic, businesses were struggling to control risks in their supply chains due to a lack of short-term planning and supply chain flexibility. Therefore, Remko (2020) suggested that organizations should reduce potential risks by preparing a short-term plan and balancing global, nearshore, and local sourcing. Therefore, the fifth hypothesis can be formulated as:

H_5: *Flexibility positively influences supply chain resilience.*

2.4 Collaboration

Collaboration in a supply chain simply refers to supply chain operations in which two or more organizations operate together for mutual benefit (Simatupang and Sridharan, 2008). Collaboration in the supply chain can be done in several ways, such as by sharing information, sharing resources, cooperating in communication, and building new knowledge together (Cao et al., 2010).

Belhadi et al. (2021) revealed that collaboration significantly impacts supply chain resilience. Scholten and Schilder (2015) investigated the impact that collaboration plays in the resilience of supply chains. They discovered that activities that involve collaboration lead to efficient supply chain resilience due to the fact that collaboration promotes clarity, speed, and flexibility in supply chains. Collaboration in a supply chain allows for better prediction and risk management (Sinha et al., 2004). Collaboration in times of crisis enables companies along the supply chain to work together, which could mitigate potential risks (Richey and Autry, 2009; Hsieh, 2019). According to supply chain collaboration conceptions and previous research, the sixth hypothesis can be formulated as follows:

H_6: *Collaboration positively influences supply chain resilience.*

2.5 Agility

Agility refers to the ability of a supply chain to adapt in a timely manner to unanticipated changes in the market and to manage those changes into a business opportunity (Jain et al., 2008). According to Dubey et al. (2018), agility was defined as the ability of a supply chain to change or respond rapidly based on demand fluctuations. Agility is a significant factor for supply chain resilience as it facilitates a quick response (Christopher and Lee, 2004; Chowdhury and Quaddus, 2017). In the context of the COVID-19 pandemic, Ivanov (2020) proposed the concept of a viable supply chain, which included an agility angle. The findings indicated that a viable supply chain can help organizations survive during the disruption. Wieland and Wallenburg (2013) argued that supply chain resilience depends on two factors: agility, which enables proactive recovery strategies; and strength in the supply chain, which is a passive revival. Moreover, agility not only drives supply chain resilience, but it also adds value to the supply chain. Therefore, the seventh hypothesis can be formulated as:

H_7: *Agility positively influences supply chain resilience.*

According to hypothesis development, the research conceptual model of the relationship between latent variables and supply chain resilience is shown in Fig. 1.

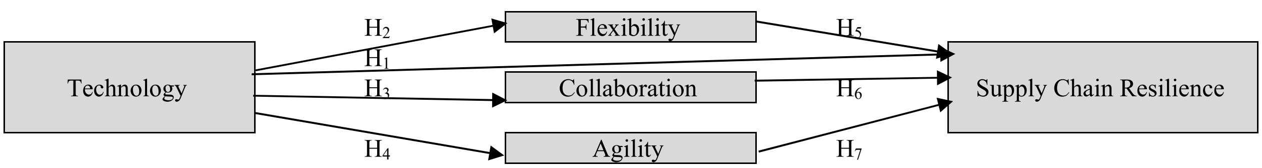


Fig. 1. Conceptual model of supply chain resilience

3. Methodology

3.1 Population and sample

The population for this study consisted of 138,807 companies in the Thai manufacturing industry (Department of Industrial Works, 2020) and 423,009 companies in the Thai service industry (Department of Business Development, 2022). Therefore, the total population was 561,816 establishments. The appropriate size of the sample was determined by employing Yamane's formula (Yamane, 1967);

$$n = \frac{N}{1 + Ne^2}$$

where N = Population size, n = Sample size and e = Level of precision. Thus, for this research with N = 561,816 at 95% confidence level we have n ≈ 400. The sample size for the structural equation model analysis was also assessed by Comrey and Lee (2013) as follows: 50 is considered to be very poor, 100 is considered to be poor, 200 is considered to be fair, 300 is considered to be good, 500 is considered to be very good, and 1000 is considered to be excellent. According to the calculation from Yamane's formula and the range of a good sample size stated by Comrey and Lee (2013), at least 400 cases were collected for this study.

3.2 Questionnaire design

The questionnaire was developed from a research conceptual framework and literature review. There were two parts of the questionnaire. The first section was related to business characters, including type, size, age, and model of a business. The second part was on factors influencing supply chain resilience, namely, flexibility, collaboration, agility, technology, and supply chain resilience. The respondent's opinion was evaluated using a Likert scale of five points, where 1 indicated that the respondent strongly disagreed and 5 indicated that the respondent strongly agreed. Then, the Index of Item Objective Congruence (IOC) method was conducted to analyze the content's validity. Two academic experts and one professional expert were asked to measure the questionnaire whether all items were clear and consistent with research objectives (Bell et al., 2018). The IOC values of the questionnaire were between 0.67 – 1.00, which exceeded the criteria of 0.50 (Rovinelli, 1976). Meanwhile, the reliability of the questionnaire was evaluated using Cronbach's alpha. According to Sarjono and Julianita (2011), the value had to be higher than 0.600 for the questionnaire to be regarded as reliable. The Cronbach's alpha of this questionnaire was 0.928, which was higher than the criteria. Thus, it can imply that the questionnaire is valid and reliable.

3.3 Data collection

A questionnaire survey based on a convenience sampling technique was conducted from February to November 2022. However, the spread of the COVID-19 virus required strict measures in every establishment to prevent contact with outsiders. Therefore, the researcher prepared an online questionnaire via Google Form, then contacted each company by phone and sent the questionnaire link via email. In total, 426 companies completed the survey. The number of cases exceeded the sample calculation and was rated as a good sample size level for SEM (Yamane, 1967; Comrey & Lee, 2013).

3.4 Data analysis

In this study, a structural equation model (SEM) was employed to investigate the relationship between supply chain resilience variables. According to Hair et al. (2006), SEM is a multivariate method that simultaneously estimates a number of interdependent dependence relationships and combines aspects of multiple regression and factor analysis. The evaluation criteria of the data-model fit are shown in Table 1.

Table 1
The criteria for evaluating the data-model fit

Indicator	Criteria	Source
CMIN/df	<3	Hair et al. (2006)
GFI	>0.9	Hooper (2010)
CFI	>0.9	Hair et al. (2006)
NFI	≥ 0.95 good and 0.90-0.95 acceptable	Bentler (1990)
TLI	≥ 0.9	Marsh et al. (2004)
RMSEA	0.03-0.08	Hair et al. (2006)

4. Results

4.1 Business characteristics

According to the findings presented in Table 2, 53.1% of the respondents were in the service industry, while 46.9% were in the manufacturing industry. The largest group of the sample was small businesses, accounting for 53.8%, followed by large businesses (28.2%), and medium businesses (18.1%). Most of the respondents' businesses were operated over a period of 15 years (34.5%). The majority of the businesses (43.2%) were sole proprietorships or family businesses.

Table 2
Business characteristics

Business characteristics		Frequency	Percentage
Type of business operation	Manufacturer	200	46.9
	Service	226	53.1
Size of business	Small (Less than 50 staff)	229	53.8
	Medium (50-200 staff)	77	18.1
	Large (More than 200 staff)	120	28.2
Period of operation	0-5 years	132	31.0
	6-10 years	94	22.1
	11-15 years	53	12.4
	More than 15 years	147	34.5
Type of business	Sole Proprietorship / Family Business	184	43.2
	Partnership	33	7.7
	Limited company	141	33.1
	Public limited company	68	16.0

4.2 Measurement model assessment

In order to achieve statistical reliability and measurement validity, factor loadings should be higher than 0.4 (Stevens, 2009) and Cronbach's alpha should be above 0.60 (Hair et al., 2017). The results of the model fit analysis performed on the first structural model revealed that the fit indices did not reach an acceptable level. Thus, the model was modified by removing two observed variables (T1 and T2) according to the modification indices and tested again. The findings of the final model revealed that all of the factor loadings and Cronbach's alpha values were higher than the recommended levels of 0.4 and 0.7, respectively. The list of constructs and items used in this study is illustrated in Table 4.

Table 3
Psychometric analysis of constructs

Construct	Item	Factor loadings	Cronbach's Alpha
Technology	T3	0.538	0.829
	T4	0.511	
Flexibility	F1	0.661	0.831
	F2	0.697	
	F3	0.724	
	F4	0.674	
	F5	0.668	
Collaboration	C1	0.776	0.880
	C2	0.835	
	C3	0.783	
	C4	0.826	
Agility	A1	0.675	0.853
	A2	0.762	
	A3	0.829	
	A4	0.675	
	A5	0.675	
Resilience	R1	0.756	0.878
	R2	0.829	
	R3	0.773	
	R4	0.724	
	R5	0.720	

Table 4
Constructs and items un this study

Construct	Items	Indicator
Technology	T3	The company has online systems for employees to work online
	T4	The company uses modern technology in the operation process.
Flexibility	F1	The company has flexible operations in both acquiring raw materials and operating schedules.
	F2	The company provides various types of products or services to meet customer demand.
	F3	Business contracts are flexible in terms of order flexibility, payment flexibility, and delivery flexibility.
	F4	The company employs workers with diverse skill sets who can conduct a variety of tasks.
	F5	Employees are trained to deal with possible problems.
Collaboration	C1	Information sharing
	C2	Trust
	C3	Communication cooperation
	C4	Collaborative knowledge building
Agility	A1	The company can recognize changes and risks in the supply chain from the pandemic quickly.
	A2	The company can make decisions to deal with changes quickly.
	A3	The company can manage its operations in the supply chain to comply with its decision-making.
	A4	The company can increase or decrease its operating capacity as needed.
	A5	The company can modify customers' orders upon request.
Supply chain resilience	R1	Executives support the adoption of new concepts or innovations for use in operations.
	R2	The company can easily restore the flow of materials and services.
	R3	The company takes a short period of time to effectively return to normal operations.
	R4	The supply chain can recover quickly.
	R5	Businesses can deal with disruptions quickly.

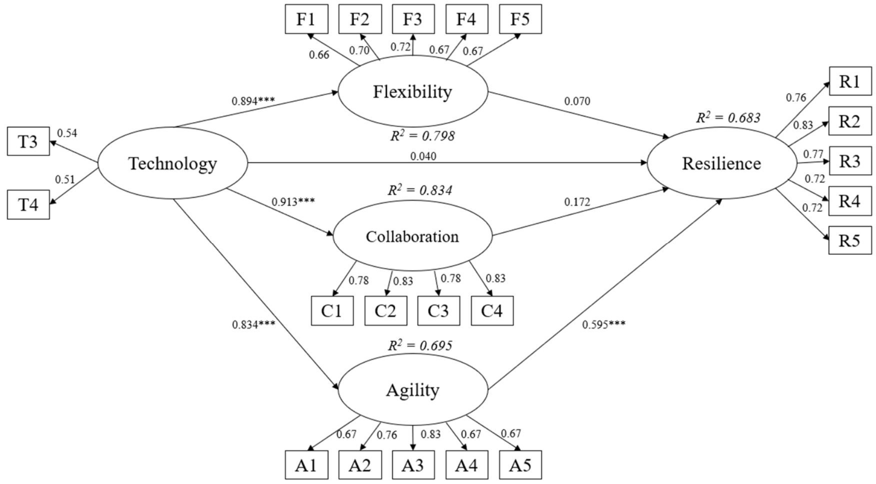
4.3 Hypothesis testing

The results of model and hypothesis testing are shown in Fig. 2 and Table 5. The results of SEM analysis showed that the structural equation model was consistent with empirical data with values of CMIN/df = 2.267, GFI = 0.918, CFI = 0.957, NFI = 0.925, TLI = 0.948, and RMSEA = 0.055, which is higher than the criteria (as stated in Table 1). Four relationships were statistically supported, while three relationships were rejected. There were significant positive direct relationships between technology and flexibility, collaboration, and agility. Thus, H_2, H_3, and H_4 were supported. Additionally, agility had a positive direct effect on supply chain resilience. So, H_7 was supported. On the other hand, technology, flexibility, and collaboration did not have a significant direct effect on supply chain resilience. Therefore, H_1, H_5, and H_6 were rejected.

Table 5
Summary of hypothesis test

Hypothesis	Standardized path coefficients	Support
H_1: Technology → Resilience	0.040	No
H_2: Technology → Flexibility	0.894***	Yes
H_3: Technology → Collaboration	0.913***	Yes
H_4: Technology → Agility	0.834***	Yes
H_5: Flexibility → Resilience	0.070	No
H_6: Collaboration → Resilience	0.172	No
H_7: Agility → Resilience	0.595***	Yes

***p<.01



Chi-square = 398.918, CMIN/df = 2.267
GFI = 0.918, CFI = 0.957, NFI = 0.925, TLI = 0.948, RMSEA = 0.055

Fig. 2. Structural equation model of factors influencing supply chain resilience after the COVID-19 pandemic in Thailand's industry

Table 6
Squared multiple correlations (SMC)

	R^2
Flexibility	0.798
Collaboration	0.834
Agility	0.695
Resilience	0.683

The assessment of model fit provides details about how well the model fits the empirical data but squared multiple correlations (SMC) determine the strength of the model's structural paths. According to Arbuckle (2005), the standard model correlation (SMC) measures the amount of a variable's variance that can be attributed to a given set of predictors. The results of squared multiple correlations in Table 6 revealed that the structural model explained 68.3% of the variance in supply chain resilience (R^2 = 0.683), which was driven by agility but not technology, flexibility, or collaboration. Impressively, technology significantly explained flexibility at 79.8% (R^2 = 0.798), collaboration at 83.4% (R^2 = 0.834), and agility at 69.5% (R^2 = 0.695). When analyzing a separate group of sample (manufacturing and service organizations) using multi-sample analysis, the fit indices of the model were above the recommended values (as stated in Table 1), with Chi-square = 511.666, CMIN/df = 1.570, GFI = 0.900, CFI = 0.965, NFI = 0.910, TLI = 0.955, and RMSEA = 0.037. The results found that the model of manufacturer and service group were similar (Table 7). Technology positively influenced flexibility, collaboration, and agility. Thus, H_2, H_3, and H_4 were supported in both groups. Conversely, no significant effect of technology, flexibility, collaboration, or agility was found on supply chain resilience. Therefore, H_1, H_5, H_6, and H_7 were rejected. The results of the squared multiple correlations of manufacturer and service group are shown in Table 8. In the manufacturing industry, 87.4% (R^2 = 0.874) of the variance in flexibility in the model was significantly explained by technology. Nearly the same value as the manufacturing industry, 84.1% (R^2 = 0.841) of the variance in flexibility in the model was significantly explained by technology in the service industry. The model of the manufacturing industry showed that 67.7% (R^2 = 0.677) of the variance in collaboration was determined by technology, while there was 92.3% (R^2 = 0.923) in the service industry. Technology was responsible for 93.0% (R^2 = 0.930) of the variance in agility in the manufacturing industry and 60.4% (R^2 = 0.604) in the service industry.

Table 7
Summary of hypothesis test in separate group

	Manufacturer		Service	
Hypothesis	Standardized path coefficients	Support	Standardized path coefficients	Support
H_1: Technology → Resilience	0.841	No	0.500	No
H_2: Technology → Flexibility	0.935***	Yes	0.917***	Yes
H_3: Technology → Collaboration	0.823***	Yes	0.961***	Yes
H_4: Technology → Agility	0.964***	Yes	0.777***	Yes
H_5: Flexibility → Resilience	-0.387	No	0.039	No
H_6: Collaboration → Resilience	0.091	No	-0.308	No
H_7: Agility → Resilience	0.328	No	0.611	No

***p<.01

Table 8
Squared multiple correlations (SMC) between manufacturing and service sector

	R^2 (Manufacturer)	R^2 (Service)
Flexibility	0.874	0.841
Collaboration	0.677	0.923
Agility	0.930	0.604
Supply chain resilience	0.785	0.667

5. Conclusion and Discussion

The epidemic caused by COVID-19 has had a huge influence on economies all around the world, particularly the sector in Thailand. The development of a strategy for supply chain resilience is certainly necessary for business organizations in order to recover from the detrimental effects and disruptions that were brought on by the epidemic. This research aimed to explore factors influencing supply chain resilience and develop a structural equation model for supply chain resilience after the COVID-19 pandemic for both the manufacturing and service industries in Thailand. The findings of the study provide important new perspectives on the factors that have an impact on the supply chain resilience in the Thai sector. The results indicated that agility directly affects supply chain resilience, and technology drives supply chain resilience via business agility as well as promoting business flexibility and collaboration.

According to the findings, agility is a key factor influencing supply chain resilience. This is consistent with the study of Christopher and Lee (2004) who found that agility is the most crucial factor for supply chain resilience because it facilitates rapid response. Additionally, Wieland and Wallenburg (2013) discovered that agility not only contributes to supply chain resilience but also adds value to the supply chain. Agility enables organizations to respond quickly to unexpected market changes and turn them into business opportunities. Organizations with agile supply chains can proactively implement recovery strategies and quickly adapt to changes, thereby enhancing their overall resilience.

The findings highlight technology has a significant positive influence on supply chain resilience, flexibility, collaboration, and agility. The results are consistent with studies by Dosh (2009), Cardoso and Ramos (2016), and Sabahi and Parast (2020) that found innovation and technology have had a positive impact on supply chain resilience. Technology enables organizations to create new innovations or modify existing ones, reducing reliance on existing resources and enhancing supply chain capabilities (Marsh & Stock, 2006; Kwak et al., 2018). Organizations that utilize technology in their supply chain operations are more resilient in recovering from disruptions. Additionally, technology increases sustainability because it allows the consideration of selected factors, while synchronizing all logistics activities (Tinkov et al., 2023). By adopting technology-driven solutions, such as automation, data analytics, and digital platforms, businesses can enhance their ability to predict and overcome disruptions, increase flexibility, support collaboration, and respond quickly to market changes.

Technology enables flexibility in the supply chain by adapting operation processes to be more flexible, such as employing automatic operation technologies like robots to replace workers in the manufacturing processes due to social distancing measures or employee strikes due to COVID-19 infection. In addition, technologies lead to new forms of products, services, or sales channels, such as online marketplaces, online services, and automated systems to serve customers. Moreover, technology certainly creates agility because the use of technology allows for quick business operations and responsiveness to both business partners and customers. Furthermore, technology enhances communication and cooperation among supply chain partners. During the COVID-19 lockdowns, it was difficult for businesses to interact with their customers, partners, or staff; thus, digital technologies or communication platforms, such as online marketplaces or online meeting platforms, were inevitable to streamline all stakeholders. Besides, technology allows transparent information sharing among supply chain partners. Information is crucial to every organization because it enables them to make the best decisions. According to Nguyen et al. (2023), information sharing among a supply chain network could improve work performance in terms of speed and accuracy, thereby enhancing the efficiency of global supply chains. Several studies (Gölgeci and Kuivalainen, 2020; Belhadi et al., 2021; and Dubey et al., 2021) found that real-time information, data analysis, and the use of information also influence supply chain resilience.

6. Research Implications

The findings of this study have important implications for businesses and policymakers in Thailand. Businesses should prioritize the adoption of technology and invest in innovation to enhance their supply chain resilience. This includes leveraging technology 4.0 solutions, improving flexibility, fostering collaboration, and embracing agility. By doing so, businesses can not only recover from disruptions but also strengthen their competitive capabilities. On the other hand, policymakers should support and incentivize the adoption of technology in the industry, promote collaboration platforms, and provide guidance on enhancing flexibility and agility in supply chain operations. Additionally, policymakers can play a role in facilitating knowledge sharing and creating a supportive ecosystem for innovation and resilience in the industry.

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