Digitalization of Cold Chain Logistics: Examining Information Technology, Cultural Capabilities, and Performance Outcomes

Zhou Yunan, Prof. Madya Dr. Zulkifli Mohamed Udin, Dr. Kafi Md Abdul

[1]Senior Lecturer, COLLEGE OF BUSINESS ,Universiti Utara Malaysia, Kedah , Malaysia.

[2]Lecturer, COLLEGE OF BUSINESS ,Universiti Utara Malaysia, Kedah , Malaysia, zulkifli@uum.edu.my

[3]Senior Lecturer， COLLEGE OF BUSINESS ,Universiti Utara Malaysia, Kedah , Malaysia, md.abdul.kafi@uum.edu.my

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ABSTRACT:

This study investigates the effects of information technology capabilities (ITC), cultural capabilities (CC), supply chain management practices (information sharing), and supply chain technology adoption (SCTA) on supply chain operational performance (SCOP) in the Chinese cold storage industry. It also examines the mediating role of technology adoption in strengthening the relationship between organizational capabilities and operational performance. A quantitative research design was used, and data were collected from employees of cold storage firms in China through a structured questionnaire. The collected data were analyzed using SPSS and SmartPLS, applying Structural Equation Modelling (SEM) to test the proposed hypotheses. The results reveal that IT capabilities, cultural capabilities, and information sharing all have significant positive effects on supply chain operational performance. Similarly, supply chain technology adoption shows a strong positive impact on operational performance, highlighting its importance in improving efficiency, coordination, and responsiveness in cold storage operations. Furthermore, IT capabilities, cultural capabilities, and information sharing are found to significantly influence the adoption of supply chain technologies. The findings also confirm that supply chain technology adoption plays a key mediating role between organizational capabilities and operational performance. This suggests that the positive effects of IT and cultural strengths on performance are largely achieved through effective adoption and use of supply chain technologies. The study concludes that enhancing supply chain performance requires both strong organizational capabilities and effective technology adoption. Managers should invest in modern IT infrastructure, promote a collaborative organizational culture, and encourage digital transformation. The study provides practical insights for improving operational efficiency and competitiveness in the Chinese cold storage sector.

 Key words: Supply Chain management, Informational Technology, Culture, Technology Adoption, Operational Performance.

BACKGROUND

The cold storage industry in China is growing quickly, but it still faces many challenges. These include high costs, poor infrastructure in some regions, and a lack of skilled workers (Zhang, & Ho, 2021). In addition, companies often face problems like overstocking or product loss, which increases costs. As demand for fresh and temperature-sensitive goods increases, efficient cold storage systems are becoming very important. Technology adoption is now necessary to improve speed, flexibility, and cost efficiency (Scott Robinson, 2020; Niu et al., 2024a). In today's competitive business environment, companies must improve quality, respond quickly to customers, and remain flexible. Advanced technologies such as RFID and automation are helping firms improve efficiency and reduce costs (Daifuku, 2023). Government regulations in China have also encouraged the use of these technologies, making supply chains more reliable (Niu et al., 2024).

Globally, supply chain management faces similar challenges, especially in developing regions where technology adoption is still low. However, studies show that using supply chain technology can improve firm performance (Shahzad et al. 2018a) and reduce costs (Chen et al., 2024). Although the industry has improved, small and medium enterprises (SMEs) still face difficulties due to limited resources (Sun, & Karia, 2024). There is also limited research on how technology adoption affects the cold storage sector specifically (Zhang et al., 2023). Issues like lack of data sharing and weak infrastructure remain major challenges (Mohammad et al., 2022). This study focuses on Beijing and uses theories like RBV, TOE, and DOI to understand technology adoption. It aims to help firms, especially SMEs, improve supply chain performance and become more efficient and competitive.

INTRODUCTION

Previous studies show that there is still limited theoretical understanding of supply chain management (SCM) and its real-world application (Halldorsson et al., 2007). Although supply chain management practices (SCMP) and technology adoption can improve performance (Shahzad et al. 2020), research in the service sector, especially cold storage, is still developing (Qian et al., 2022). This creates a clear need for further investigation. In China, the cold storage industry faces strong competition and changing customer behavior. Consumers are more careful in spending, while firms must handle increasing demand and operational challenges. This makes it necessary for companies to improve their supply chain capabilities and adopt advanced technologies. However, current research shows that these areas are still not fully developed in the cold storage sector.

The Supply Chain Operations Reference (SCOR) model has been widely used to measure supply chain performance, focusing on reliability, responsiveness, flexibility, cost, and efficiency (Supply Chain Council, 2010; Gao et al., 2021). However, most studies focus on manufacturing, and there is limited research in service industries like cold storage (Fynes et al., 2015). This study focuses on supply chain operational performance (SCOP), which is more relevant for understanding real operational improvements. The literature also shows that supply chain competencies and technology capabilities play an important role in improving performance (Shahzad & Bhatti 2008), but their effects are not consistent across industries (Afreen & Bajwa, 2021). In addition, the role of information technology in improving supply chain performance is still not fully understood, especially in developing countries (Gao et al., 2021; Niu et al., 2024a).

Another important gap is the limited understanding of how technology adoption acts as a mediator between supply chain practices and performance (Shahzad et al. 2018b; Ahmadi et al., 2025). Many firms, especially SMEs, struggle with integrating information sharing, IT capabilities, and organizational culture. Therefore, this study aims to examine how these factors influence supply chain operational performance and how technology adoption helps improve efficiency in the cold storage sector.

This research focuses on supply chain management (SCM) within the cold storage industry in China. It includes both small and large firms and studies the full supply chain network, such as suppliers, manufacturers, distributors, service providers, and customers. The research mainly collects data from firms located in Beijing, where cold storage businesses operate in a highly competitive environment. The respondents include professionals like purchasing managers, supply chain managers, and related staff who are directly involved in managing supply chain activities such as procurement, inventory, and customer coordination. This helps the study capture real and practical insights from industry experts. The significance of this study lies in both theoretical and practical contributions. From a theoretical perspective, the study fills an important research gap by examining the relationship between supply chain competencies, technology adoption, and operational performance in the cold storage sector, which has received limited attention in previous studies. It also integrates three important theories; Resource Based View (RBV) model, Technology Organization Environment (TOE), and Diffusion of Innovation (DOI), to provide a better understanding of how firms improve supply chain performance. This combined approach helps explain how internal resources, organizational factors, and technology adoption work together.

LITERATURE

Information sharing and Supply Chain Operation Performance (SCOP): Many researchers agree that firms adopt SCMP mainly when they expect clear benefits, especially in terms of efficiency, competitiveness, and overall performance. SCMP has been shown to improve different aspects of organizational performance, including economic, environmental, and operational outcomes. Recent studies highlight mixed results. For example, Cheng et al. (2024) found that SCMP improves economic and competitive performance, but its impact on environmental performance is not always significant. Similarly, Shaharudin and Fernando (2024) emphasized that quality management and proper implementation of SCMP can improve performance in manufacturing industries. Earlier researchers also confirmed a strong link between supply chain practices, competitiveness, and economic performance.

However, some studies show that improvements in operational practices do not always lead to higher profits. For instance, Li et al. (2024) found that reducing energy use lowers environmental impact but does not necessarily increase sales or profit margins. This shows that the impact of SCMP can vary depending on context and industry. Research also highlights the importance of evaluating performance correctly. Soto-Silva et al. (2024) identified cost efficiency, especially material purchasing cost, as a key factor in supply chain performance. Other studies stress the importance of innovation, supplier relationships, and collaboration in improving competitiveness (Wang et al., 2024).

From a theoretical perspective, the Resource-Based View (RBV) suggests that firms gain competitive advantage through unique resources and capabilities (Leng et al., 2024). These include relationship capabilities, organizational culture, and IT capabilities. Information sharing is also critical, as it improves coordination, reduces delays, and helps firms respond to market demand (Liao et al., 2023). Overall, the literature shows that SCMP, supported by strong capabilities and effective information sharing, plays a key role in improving supply chain performance, although results may differ across industries.

Information Technological Capabilities and Supply Chain Operation Performance (SCOP): In developed countries, companies usually have strong IT infrastructure, but this is not always the case in developing economies (Gu et al., 2023; Zhang et al., 2023). Many firms face shortages of computer systems, software, and technical resources, which makes information sharing difficult. In addition, companies need to invest in employee training to use these technologies effectively. Without proper IT systems, firms may rely on manual processes or a mix of manual and digital systems, which reduces efficiency (Ning, Li, Xu, & Yang, 2023). Another major challenge is the lack of compatibility between technologies used by different companies. Even if firms adopt advanced systems, they may not work well with their supply chain partners' systems (Xia, Li, & He, 2023). This creates "isolated systems" that limit communication and reduce the benefits of information sharing. In contrast, strong IT capabilities allow firms to better coordinate activities such as production, purchasing, and logistics, which helps reduce costs and improve performance.

Many studies confirm that IT capability is a key factor in supply chain success. It improves operational flexibility, reduces costs, and enhances transparency (Wang et al., 2023; Zhou et al., 2024). IT systems also help reduce corruption and improve trust within supply chains. Human resources also play an important role. Skilled IT staff help organizations solve technical problems and use technology effectively (Gong et al., 2024). Similarly, IT knowledge among employees is essential for fully utilizing technology. IT capability supports flexibility, agility, and better performance in supply chains. However, some studies suggest that IT may improve performance indirectly through other factors such as supply chain agility.

Cultural Capabilities and Supply Chain Operation Performance (SCOP): The performance of the supply chain and business processes may suffer from variations in the norms, values, cultures, and business practices of its partners. Goal and objective alignment among supply chain partners promotes information exchange on sales, demand, and strategy, which boosts cooperation and facilitates forecasting and planning across the chain. Consequently, when supply chain partners' business practices, aims, objectives, strategies, and cultures align, information sharing is more likely to happen.

"Organizational culture has proven to be a critical factor in organizational performance for many years". Generally, "culture has a direct effect on the success or failure of the organization. Several researchers demonstrated that organizational culture must be aligned with organizational objectives". This is because "organizational culture has a significant and positive effect on supply chain performance", "specifically greater flexibility" and greater supply chain responsiveness. The study found that "organizational culture had a significant effect on the supply chain performance of SMEs" Braunscheidel et al. (2009) revealed a direct beneficial association between supply chain performance and organizational culture. The survey included 218 replies from supply chain professionals registered at the Institute of Supply Management (ISM) in New York.

Firms in the twenty-first century need to be adept at providing goods at competitive costs and quick to adjust to a market that is changing swiftly (Cooper, 2010). Additionally, the company needs to be able to rapidly and reliably provide creative, high-quality items for the market (Cooper, 2010). Innovations in technology and administration fall under the category of supply chain operations management. "Several studies found that supply chain innovation brings benefits to supply chain performance" (Camisón & Villar-López, 2014), such as "greater flexibility" (Omar et al., 2006), "labor cost savings, manufacturing costs, inventory" (Collins et al., 2010). Furthermore, "employee participation in related job functions significantly affected supply chain performance" Studies revealed that "organizational participation was important in improving supply chain responsiveness as it can identify gaps in organizational capabilities." Therefore, "it is difficult for organizations to achieve desired performance without the full participation of employees" (Katila & Ahuja, 2002).

Technological Adoption and Supply Chain Operation Performance (SCOP):

Scientific and technological capability is a key factor in improving supply chain management (SCM) performance. Studies show that IT capability has a direct positive impact on supply chain performance (Zhang & Wang, 2011). Strong IT infrastructure helps firms reduce costs (Hassan Hussein & Rahman, 2013) and improve operational flexibility (Lu & Ramamurthy, 2011). It also increases transparency and reduces corruption (Qiu, 2013). IT staff play an important role in organizations by solving technical problems and improving processes (Li & Liu, 2023). Their flexibility allows them to suggest effective solutions, which enhances overall performance (Samad et al., 2023). However, some studies suggest that IT capability may not always directly improve performance but may work through other factors such as supply chain agility (Yadegari et al., 2024). In developing countries, many firms face challenges such as lack of IT infrastructure, limited software, and low employee skills (Greengard, 2010). These issues make information sharing difficult. Without proper systems, companies may rely on manual processes or limited digital tools (Ning et al., 2023). Another challenge is the lack of compatibility between systems used by supply chain partners, which reduces efficiency.

Advanced technologies such as extranets, intranets, and electronic data interchange (EDI) improve communication and coordination in supply chains (Fu et al., 2023). These technologies help firms reduce costs, improve accuracy, and increase flexibility (Wang et al., 2023). Research also shows a strong link between IT systems and tools like ERP and SCM systems (Zhou et al., 2024). Supply chain technology adoption (SCTA) plays a mediating role between supply chain capabilities and performance. This means that capabilities such as IT, culture, and relationships improve performance mainly through technology adoption. Studies confirm this mediating effect (Lin, 2008), and also highlight that efficient supply chains depend heavily on technology (Gunasekaran et al., 2008).

Technological capability strongly influences technology adoption. Firms need proper infrastructure, skilled employees, and financial resources to adopt new systems (Nguyen et al., 2015). Lack of knowledge or training can slow this process. Organizational culture is also very important. A supportive culture improves communication, trust, and collaboration. It also helps in adopting technologies such as ERP systems (Hwang & Min, 2015). Employee involvement and top management support are critical for success (Lee et al., 2007), while resistance to change can cause failure (Song et al., 2024). Overall, IT capability, organizational culture, and technology adoption are essential for improving supply chain performance and gaining competitive advantage. Based on the above discussion following research framework (figure 1) and research hypotheses are postulated.

Hypothesis one (H1): Information Technological Capabilities (ITC) has significant positive impact on Supply Chain Operational Performance (SCOP) in Chinese cold storage industry. Hypothesis two (H2): Cultural Capabilities (CC) has significant positive impact on Supply Chain Operational Performance (SCOP) in Chinese cold storage industry. Hypothesis three (H3): Information Technological Capabilities (ITC) has significant positive impact on Supply Chain Technology Adoption (SCTA) in Chinese cold storage industry. Hypothesis four (H4): Cultural Capabilities (CC) has significant positive impact on Supply Chain Technology Adoption (SCTA) in Chinese cold storage industry. Hypothesis five (H5): Supply Chain Technology Adoption (SCTA) has significant positive impact on Supply Chain Operational Performance (SCOP) in Chinese cold storage industry. Hypothesis six (H6): Supply Chain Technology Adoption (SCTA) mediates the relationship between Information Technological Capabilities (ITC) and Supply Chain Operational Performance (SCOP) in Chinese cold storage industry. Hypothesis seven (H7): Supply Chain

Technology Adoption (SCTA) mediates the relationship between Cultural Capabilities (CC) and Supply Chain Operational Performance (SCOP) in Chinese cold storage industry.

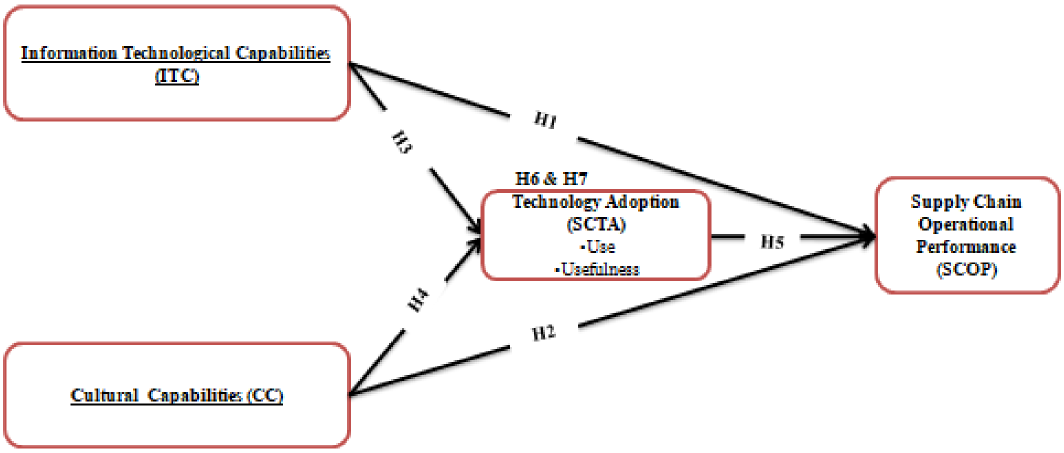

Figure 1: Research Framework

METHOD

This study adopts a quantitative research approach based on the positivist paradigm, which focuses on testing theories through measurable data. In this study, a deductive approach is used, where hypotheses are developed from existing theories and tested using collected data. This helps in making generalizable conclusions (Creswell, 2011). The research design follows a sequential explanatory approach, where survey data plays a central role in answering research questions (Creswell, 2013). The study develops measurement items through multiple stages, ensuring validity and reliability. Key constructs include IT capabilities (staff and infrastructure), cultural capabilities, technology adoption, and SCOP. Population consists of Chinese cold storage firms, particularly in Beijing, where around 200–300 facilities operate. The industry is growing rapidly, expected to reach USD 138 billion by 2029. A sample of 169 supply chain managers was selected using convenience sampling (Krejcie & Morgan, 1970) and the unit of analysis is supply chain managers, as they are directly involved in operations and can provide reliable insights into supply chain performance.

This study uses a survey questionnaire as the main research instrument to collect data. The questionnaire includes closed-ended questions, which are easy to answer and help in collecting consistent data. For measuring Information Technological Capabilities (ITC), six items are used, adapted from Wu et al. (2006). These items assess factors such as the use of modern IT systems, skilled IT staff, experience in IT applications, system compatibility with partners, and electronic coordination. Similarly, Cultural Capabilities (CC) is measured using five items taken from Sambasivan and Nget Yuen (2010). These items evaluate cultural alignment, shared values, compatible management styles, and similar business practices between firms and their supply chain partners. The mediating variable, Supply Chain Technology Adoption (SCTA), is measured using six items adapted from Kurnia et al. (2015) and Slone (2006). These include the adoption of systems like CRM, ERP, SRM, internet use, and mobile technologies, as well as the ability to respond quickly to changes. The dependent variable, Supply Chain Operational Performance (SCOP), is measured using different approaches from past studies (Niu et al., 2024; Gunasekaran et al., 2008). The study emphasizes a balanced approach, combining financial and non-financial measures across strategic, tactical, and operational levels (Bhagwat and Sharma, 2007). Modern performance measurement focuses on long-term, customer-oriented, and value-based outcomes rather than only cost efficiency (Mkumbo, 2008). The final questionnaire consists of 36 items divided into five sections: demographic information, ITC, CC, SCTA, and SCOP. The questionnaire was carefully designed for clarity and ease of use to encourage participation. Overall, the instrument ensures valid and reliable measurement of all key variables in the study.

First, the instrument (questionnaire) was carefully structured using clear and simple questions. The questions followed good survey rules such as avoiding confusion, asking one idea per question, and ensuring respondents had enough knowledge to answer. A five-point Likert scale was used to measure responses. It ranged from "1 = Strongly Disagree" to "5 = Strongly Agree," allowing participants to show their level of agreement easily. Only respondents who agreed to take part were included. Online survey link was shared through emails, phone, and social media where follow-ups were done to improve response rates (Grant et al., 2005). The data collection process took about two months, and the questionnaire was also translated into Chinese and checked by experts. Ethical rules were followed to protect respondents' privacy and ensure voluntary participation. Data analysis was done using SPSS 23 and SmartPLS 3.0. A pilot study with 32 respondents tested reliability, showing good Cronbach's alpha values above 0.70 (Hair et al., 2011), confirming the questionnaire was reliable and valid for the main study.

RESULTS

First, in total, 212 responses were received, and 196 were valid, giving an 82% valid response rate. This rate is considered good for research. Next, data screening was done to clean the dataset before analysis. Only 169 usable responses were finally used in SPSS. Screening included checking missing data, errors, outliers, and statistical assumptions (Hair et al., 2007; Preacher & Kelley, 2011). Sixteen questionnaires were removed due to problems such as incomplete or incorrect answers. Data entry accuracy was checked and no errors were found, since all answers were within the correct 1–5 Likert scale range. Missing data were also checked because unanswered questions can affect results (Hair et al., 2014). Cases with too many missing values were removed or adjusted using standard methods. Outlier analysis was also conducted to identify extreme values that could distort results. Methods such as standardized scores, box plots, and Mahalanobis distance (D^2) were used (Hair et al., 2010). Results showed no serious outliers, so all remaining data were suitable for analysis. Normality tests were then performed to check whether the data followed a normal distribution where most values were within acceptable ranges, meaning the data was approximately normal. Finally, linearity and multicollinearity checks were conducted. Results confirmed normal relationships between variables and no serious multicollinearity problems. Overall, the dataset was clean, reliable, and suitable for advanced statistical analysis using structural equation modeling.

First, the common method variance (CMV) test was used to ensure that the results were not biased by the survey method itself (Podsakoff et al., 2003). Harman's single-factor test was applied, including all variables in SPSS. The results showed 22 factors, and the first factor explained only 28.43% of the total variance. Since this is below the 50% threshold, it confirms that CMV is not a serious problem in this study (Podsakoff et al., 2003). Second, nonresponse bias was tested to ensure that people who did not respond would not change the study results. Early and late respondents were compared using t-tests (Armstrong & Overton, 1977). The results showed no significant differences between the two groups, meaning nonresponse bias is not a concern. Researchers also used strategies like reminders and follow-ups to improve response rates (figure 2-5).

Descriptive statistics were also analyzed. Most variables had mean values between 3.29 and 3.80, showing generally positive responses from participants. Standard deviations were low, meaning responses were consistent. Finally, demographic results (table1) showed 169 valid respondents. About 61% were male and 39% female. Most respondents were aged 26–35 years. In terms of education, the majority held a bachelor's degree (42%), followed by certificates (25%), master's degrees (22%), and others (11%). Overall, the sample represents a balanced group of managers from China's cold storage companies.

Table 1: Demographical results of the study

Variables	Description	Number	Percentage (%)
Gender	Male	102	60.36
	Female	67	39.64
TOTAL		**169**	**100**
Marital Status	Single	78	46.15
	Married	91	53.85
TOTAL		**169**	**100**
Age	below 25	19	11.24
	26 to 35	81	47.93
	36 to 45	34	20.12
	46 to 55	27	15.98
	56 and above	8	4.73
TOTAL		**169**	**100**
Education	Certificate	43	25.44
	Bachelors	71	42.01
	Masters	37	21.89
	PhD	0	0.00
	Others	18	10.65
TOTAL		**169**	**100**
Experience with current firm	less than 3	52	30.77
	4 to 5	91	53.85
	6 to 7	15	8.88
	8 to 9	4	2.37
	10 and above	7	4.14
TOTAL		**169**	**100**
Experience (total)	less than 10	55	32.54
	11 to 15	61	36.09
	16 to 20	36	21.30
	21 to 25	8	4.73

	above 26	9	5.33
TOTAL		**169**	**100**

Respondents' work experience. Most participants (54%) had 4–5 years of experience in their current jobs, while 33% had less than 3 years. Only a small number had more than 6 years of current experience. For total experience, the largest group (36%) had 11–15 years, followed by 33% with less than 10 years. Fewer respondents had over 16 years of experience. Overall, the sample includes different experience levels, making it more balanced. According to Hair et al. (2010), this helps ensure the sample properly represents China's cold storage employees and supports reliable research results.

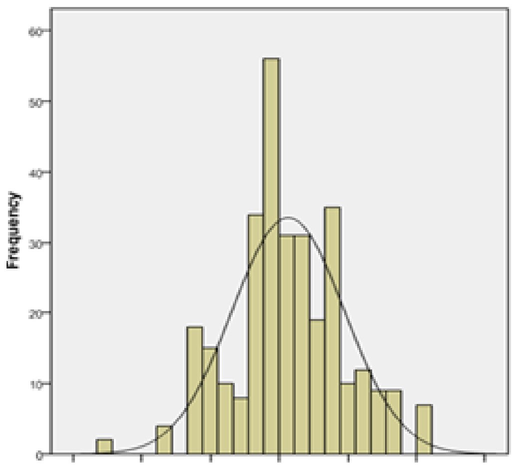

Figure 2: Histogram of information technology capabilities

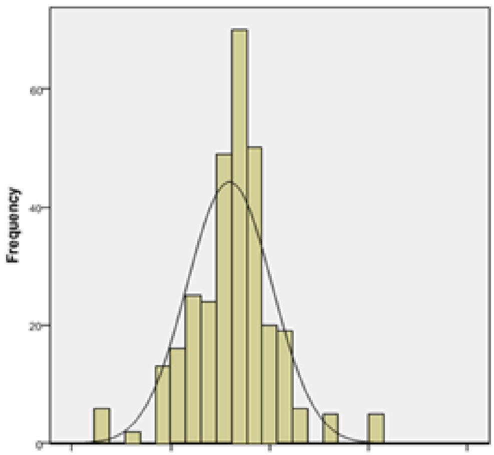

Figure 3: Histogram of cultural capabilities

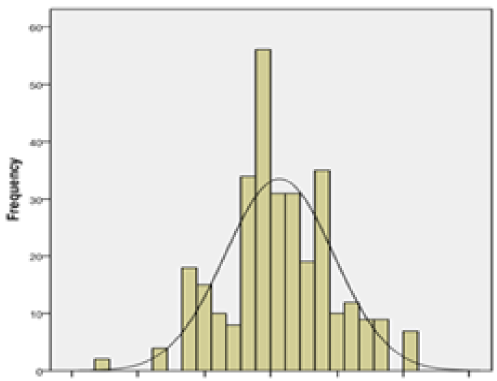

Figure 4: Histogram of technology adoption

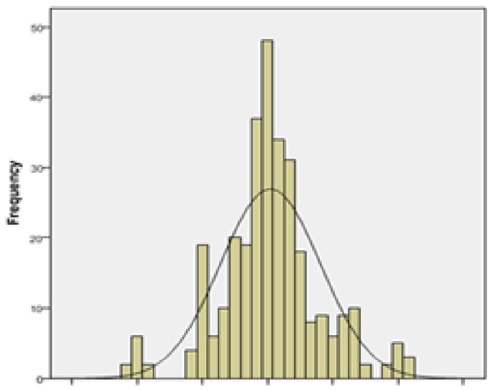

Figure 5: Histogram of supply chain operational performance

Table 2 shows results of multicollinearity test and ensures that independent variables were not highly correlated with each other and for this Variance Inflation Factor (VIF) and tolerance values were used. Results showed that all VIF values were below 5 and tolerance values were above 0.20, meaning there is no multicollinearity problem in the data. Measurement model was assessed to ensure reliability and validity of the constructs. Results summarized in table 3 showed that indicator reliability using factor loadings, where values above 0.6 were considered acceptable (Hair et al., 2014; Chin, 2010). All items met this requirement. Internal consistency was tested using Cronbach's alpha and composite reliability, both of which were above the recommended level of 0.70 (Nunnally, 1994; Hair et al., 2011), confirming good reliability.

Table 2: Results of Multicollinearity test

Constructs	Tolerance	VIF
Supply Chain Management Practices (Information Sharing)	0.347	3.24
Information Technology Capabilities	0.368	3.68
Cultural Capabilities	0.321	2.53
Technology Adoption	0.357	2.47
Supply Chain Operational Performance	0.386	2.85

Convergent validity was assessed using Average Variance Extracted (AVE), with values ranging from 0.621 to 0.736, which is above the acceptable threshold of 0.50. This confirms that the indicators properly measure their constructs (Barclay et al., 1995).

Table 3: Items loading summary

Constructs	Items	Loading	AVE	CR	Alpha
Supply Chain Management Practices (Information Sharing)	IS1	0.654	**0.644**	**0.783**	**0.749**
	IS2	0.756			
	IS3	0.789			
	IS4	0.741			
	IS5	0.753			
	IS6	0.689			
	IS7	0.673			
Information Technology Capabilities	ITC1	0.741	**0.686**	**0.747**	**0.875**
	ITC2	0.753			
	ITC3	0.751			
	ITC4	0.758			
	ITC5	0.619			
	ITC6	0.694			
Cultural Capabilities	CC1	3714	**0.736**	**0.814**	**0.865**
	CC2	0.721			
	CC3	0.716			
	CC4	0.735			
	CC5	0.762			

Technology Adoption	TA1	0.735	**0.621**	**0.833**	**0.821**
	TA2	0.783			
	TA3	0.698			
	TA4	0.812			
	TA5	0.845			
	TA6	0.795			
Supply Chain Operational Performance	SCOP1	0.755	**0.683**	**0.811**	**0.796**
	SCOP2	0.816			
	SCOP3	0.716			
	SCOP4	0.726			
	SCOP5	0.738			
	SCOP6	0.818			

Further to above; results of discriminant validity test are grouped in table 4; using the Fornell-Larcker criterion (1981). The results showed that each construct shared more variance with its own indicators than with other constructs, confirming that the variables are distinct and valid.

Table 4: Discriminant validity results

S/N	**Variables**	**1**	**2**	**3**	**4**	**5**
1	Supply Chain Management Practices (Information Sharing)	**0.802**				
2	Information Technology Capabilities	0.341	**0.828**			
3	Cultural Capabilities	0.281	0.331	**0.857**		
4	Technology Adoption	0.265	0.286	0.196	**0.788**	
5	Supply Chain Operational Performance	0.316	0.271	0.268	0.351	**0.826**

Summary of results in table5 shows predictive relevance of the model by using cross-validation redundancy. All values were above zero (0.521 to 0.621), showing that the model has good predictive ability (Fornell & Cha, 1994). These results confirm that the measurement model is reliable, valid, and suitable for further hypothesis testing and structural analysis.

Table 5: Result summary for the model quality

Construct	**Cross Validity communality**	**Cross Validity Redundancy**
Supply Chain Management Practices (Information Sharing)	0.541	0.321

Information Technology Capabilities	0.521	0.358
Cultural Capabilities	0.621	0.369
Technology Adoption	0.532	0.294
Supply Chain Operational Performance	0.582	0.347

Table 6: Results summary of hypotheses testing

Hypotheses	Propositions	Coefficients	t values	Decision
H1	ITC-->SCOP	0.268	4.258	Accepted
H2	CC-->SCOP	0.247	2.359	Accepted
H3	CC-->SCTA	0.351	3.39	Accepted
H4	CC-->SCTA	0.362	7.21	Accepted
H5	SCTA-->SCOP	0.269	9.36	Accepted
H6	ITC-->SCTA-->SCOP	0.481	6.38	Accepted
H7	CC-->SCTA-->SCOP	0.299	6.53	Accepted

Information technology capabilities (ITC) and cultural capabilities (CC) both have a positive and significant effect on supply chain operational performance (SCOP). ITC improves SCOP (β = 0.268, t = 4.258) by helping firms use data, automation, and real-time monitoring systems. Cultural capabilities also improve SCOP (β = 0.247, t = 2.359) by promoting trust, teamwork, and shared goals. These findings show that both technology and organizational culture are important for better supply chain performance. Second, technology adoption (SCTA) also has a significant positive impact on SCOP (β = 0.269, t = 9.360). This means firms that adopt modern supply chain technologies achieve higher efficiency, faster operations, and better coordination. Third, IT capabilities, and cultural capabilities all significantly influence technology adoption as IT capabilities (β = 0.351–0.412 range in models) and cultural capabilities (β = 0.351). This shows that firms with strong communication, better IT systems, and supportive cultures are more likely to adopt new technologies. Most importantly, technology adoption acts as a mediator between these capabilities and supply chain performance. The results show that IT capabilities, and cultural capabilities improve performance more strongly when they lead to technology adoption (e.g., ITC → SCTA → SCOP, CC → SCTA → SCOP). This confirms that technology is a key mechanism that converts organizational capabilities into better performance outcomes. Overall, all hypotheses (H1–H7) are supported. The study concludes that supply chain performance improves not only through direct effects of IT capabilities, and culture, but also indirectly through technology adoption. This highlights that technology adoption is central to improving efficiency, responsiveness, and overall supply chain success in the Chinese cold storage sector.

DISCUSSION

The findings of this study highlight the important roles of information technology capabilities (ITC), cultural capabilities (CC), and supply chain technology adoption (SCTA) in improving supply chain operational performance (SCOP) in the Chinese cold storage industry. The results show both direct and indirect effects, confirming that these factors work together to enhance efficiency, coordination, and responsiveness in supply chain operations. Information technology capabilities have a significant positive impact on supply chain operational performance (β = 0.268, t = 4.258). This means that firms with stronger IT systems are better able to use data, automate processes, and support faster and more accurate decision-making. In the cold storage sector, IT systems are especially important for monitoring temperature, tracking inventory, and ensuring timely delivery, which are all essential for maintaining product quality. Supporting studies such as Dubey et al. (2021) confirm that IT capabilities improve supply chain integration and visibility, which leads to better performance. Similarly, Queiroz et al. (2020) found that digital technologies increase efficiency and resilience, especially in uncertain environments. From a managerial perspective, this suggests that companies should invest in modern IT infrastructure such as cloud computing, IoT, and data analytics, as well as develop employees' digital skills. However, a limitation of the study is that it does not distinguish between different types of IT systems. Future research could explore which specific technologies contribute most to performance.

Cultural capabilities also significantly improve supply chain operational performance (β = 0.247, t = 2.359). This shows that organizational values such as trust, collaboration, adaptability, and shared goals are essential for effective supply chain operations. In cold storage operations, where coordination between multiple partners is critical, a strong organizational culture supports smooth communication and teamwork. Prior research by Zhang et al. (2020) and Huo et al. (2019) also supports this finding, showing that trust and cooperation improve supply chain integration and performance. Practically, firms should focus on building a collaborative culture through training, communication, and shared performance goals. However, this study treats cultural capability as a single overall concept. Future research could examine specific cultural dimensions such as innovation or trust in more detail.

Supply chain technology adoption has a strong positive effect on operational performance (β = 0.269, t = 9.36). This indicates that firms that actively adopt and use modern technologies achieve better efficiency, speed, and coordination. In cold storage, technologies help in real-time temperature monitoring, inventory tracking, and timely deliveries, all of which are critical for product quality. Studies such as Ivanov and Dolgui (2020) and Queiroz et al. (2020) also confirm that technology improves supply chain resilience and visibility. Managers are therefore encouraged to adopt technologies such as IoT, tracking systems, and digital platforms. At the same time, employee training is necessary to ensure effective use of these systems. A limitation is that the study does not assess the level of technology maturity, which could be explored in future research.

The study also finds that IT capabilities significantly influence technology adoption (β = 0.351, t = 3.39). This means that firms with strong IT infrastructure and skilled employees are more likely to adopt new supply chain technologies. Similarly, cultural capabilities also positively affect technology adoption (β = 0.362, t = 7.21), showing that organizations with innovative, flexible, and collaborative cultures are more willing to embrace technological change. These findings are supported by studies such as Dubey et al. (2021), Saberi et al. (2019), Wamba et al. (2020), and Hofmann and Ruesch (2017), which emphasize the importance of IT readiness and organizational culture in digital transformation. Managers should therefore invest in both technology infrastructure and cultural development, encouraging innovation, learning, and openness to change.

The study confirms that supply chain technology adoption acts as a key mediator between IT capabilities, cultural capabilities, and supply chain performance. The mediation effect of ITC on SCOP through SCTA is strong (β = 0.481, t = 6.38), and similarly, cultural capabilities also show a significant mediated effect (β = 0.299, t = 6.53). This indicates that IT and cultural strengths improve performance mainly when they lead to effective technology adoption. In other words, having capabilities alone is not enough; they must be translated into actual technology use to achieve performance gains. This is supported by recent literature showing that digital transformation improves agility, integration, and operational outcomes. The study concludes that supply chain performance in the cold storage industry is improved through a combination of IT capabilities, cultural strengths, and technology adoption, with technology adoption playing a central mediating role.

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