

IMPACT OF SUPPLY CHAIN DIGITIZATION ON SUPPLY CHAIN PERFORMANCE: THE MEDIATING ROLE OF QUICK RESPONSE (QR) AND EFFICIENT CONSUMER RESPONSE (ECR)

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Abstract: In recent years, supply chain Digitization has become a subject of concern for logistics and management as it is an important indicator of operational effectiveness. However, most research in China focuses on the frequency of operational activities in specific sectors or the influence of a single factor, with a lack of studies on the effects of multiple factors and their influencing mechanisms. Supply chain digitization, defined as the integration of digital technologies in supply chain processes, has been linked to improved efficiency and responsiveness, potentially affecting overall Digitization. There are no empirical studies examining the influence of supply chain digitization on Digitization.

The study employs a quantitative research methodology to analyze the current status of supply chain digitization across various sectors, examine differences in digitization between different company sizes and industries, and explore the influence of supply chain digitization on digitization, analyzing the mediating role of QR and ECR. Data was collected from 707 companies in China, investigating supply chain digitization levels, digitization efforts, and the implementation of QR and ECR strategies across multiple sectors, including manufacturing and retail. The results indicate:

Supply chain digitization varies by sector, with manufacturing, retail, and logistics showing different levels of digitization. There are industry differences, with the highest digitization in the manufacturing sector and the highest implementation of QR and ECR strategies in the retail sector.

There is a significant positive correlation between supply chain digitization and supply chain engagement across all sectors. Supply chain digitization positively impacts the supply chain engagement through Quick Response (QR) and supply chain digitization positively impacts the supply chain engagement through Efficient Replenishment (ECR).

Keywords: Supply Chain Digitization, Supply Chain Engagement, Quick Response (QR), Efficient Consumer Response (ECR).

Introduction

In recent years, the level and manner of supply chain digitization have received widespread

attention. Characteristics of supply chain digitization in China include low frequency of collaboration, lack of active participation, and insufficient interaction among supply chain partners. Research indicates that the current state of supply chain digitization is less than satisfactory, with companies avoiding collaboration, engaging infrequently, and often participating passively. Supply chain digitization refers to companies' cognitive involvement with supply chain objectives and tasks, as well as their behaviors in communicating and collaborating with others. Studies have shown that a crucial measure of supply chain effectiveness is the degree of Digitization and collaboration; active participation in the supply chain engagement promotes operational efficiency, innovation, and overall business performance. Therefore, researching supply chain digitization is of great significance. Improving the level of digitization is not only the starting point for enhancing supply chain quality but also the foundation for promoting overall business development.

Research on supply chain digitization in China mainly analyzes individual and environmental factors. Individual factors include company size, technological capabilities, financial resources, management attitudes, etc.; environmental factors include market demand, regulatory policies, technological infrastructure, cultural differences, etc. Scholars have often explored the impact of supply chain digitization on Digitization from perspectives such as technology adoption, process automation, data analytics, and digital communication tools. However, there has been a lack of in-depth exploration from the perspective of specific strategies like Quick Response (QR) and Efficient Consumer Response (ECR).

Supply chain digitization refers to the positive integration and application of digital technologies in supply chain processes. It involves using technologies such as the Internet of Things (IoT), blockchain, artificial intelligence (AI), and advanced data analytics to enhance visibility, coordination, and decision-making across the supply chain. Digitization affects both companies and their partners. Digitally engaged companies not only improve their operational efficiency and responsiveness but also foster positive relationships and collaboration within the supply chain. These companies also appear to be more competitive, innovative, and better prepared to respond to market changes.

In China, there are numerous factors influencing supply chain digitization, but empirical research is limited, with many new perspectives yet to be explored, making the research incomplete and not thorough enough. By reviewing Chinese literature and summarizing the existing information on factors affecting supply chain digitization among Chinese companies, this study proposes the following questions:

Firstly, research subjects are primarily focused on companies within specific industries or supply chain stages, lacking comprehensive attention across various sectors throughout the entire supply chain. Existing literature shows that research perspectives on supply chain digitization are singular, mainly concentrated in the field of business management, with relatively few studies in the

field of operations research. Therefore, considering the context of supply chain management in China, this study proposes the first research question: What is the status of supply chain Digitization among Chinese companies?

Secondly, while research mostly emphasizes individual factors affecting companies, there remain unexamined variables among external environmental factors, such as digitization in supply chain strategies. Existing research evidence indicates that supply chain digitization significantly impacts Digitization. However, as an aspect of supply chain strategy, digitization has not been directly explored in relation to Digitization. Based on this, the study proposes the second research question: What is the correlation between supply chain digitization and Digitization?

Lastly, research methods predominantly focus on descriptive statistics, with few studies establishing mediation models to analyze large sample data and reveal specific internal mechanisms. Research points out that there is a close relationship between supply chain digitization, QR, ECR, and Digitization. Both digitization and strategies like QR and ECR may significantly influence Digitization. However, whether these conclusions hold true for Chinese companies remains to be verified. Therefore, this study proposes the third research question: How do QR and ECR mediate the effect of supply chain digitization on Digitization?

Research Objectives

- 1) To examine the state of supply chain digitization in supply chain digitization among companies.
- 2) To examine the relationship between supply chain digitization and supply chain.
- 3) To examine the mediating role of Quick Response (QR) and Efficient Consumer Response (ECR).

Literature Reviews

Supply Chain Digitization

Supply chain digitization has long been recognized as a critical factor influencing operational efficiency and overall supply chain performance. Digitization in supply chain management can be defined as the adoption of digital technologies to enhance the visibility, integration, and automation of supply chain processes (Hofmann & Rüsçh, 2017). This digitization is not only a technological advancement but also a transformative process that can significantly affect the responsiveness and agility of supply chains (Ivanov et al., 2019). In supply chain management, understanding the dynamics of how digitization impacts supply chain engagement is essential for developing effective strategies that promote efficient and collaborative operations (Christopher & Holweg, 2017).

Studies have demonstrated that digitized supply chains tend to create more efficient and transparent operations, which can lead to higher levels of collaboration and engagement among supply

chain partners (Wang et al., 2016; Kamal & Irani, 2014). This enhanced operational environment is crucial for fostering quick response (QR) and effective replenishment (ECR), which are key determinants of a supply chain's ability to meet market demands and reduce lead times (Fisher, 1997). Moreover, the impact of supply chain digitization can vary across different industries and contexts, suggesting that contextual factors may moderate the relationship between digitization and supply chain engagement (Gunasekaran et al., 2017; Zhai & Xie, 2021).

Supply chain digitization refers to the integration of digital technologies into supply chain processes, including activities such as real-time tracking, data sharing, and automated replenishment (Hofmann & Rüscher, 2017). Research has indicated that supply chain digitization is a multifaceted construct influenced by technological, organizational, and environmental factors (Ivanov et al., 2019). Studies have shown that higher levels of supply chain digitization are associated with better operational outcomes and enhanced supply chain performance (Gunasekaran et al., 2017; Wang et al., 2016).

In the context of supply chain management, digitization has been extensively studied in terms of its impact on efficiency and responsiveness (Christopher & Holweg, 2017; Kamal & Irani, 2014). However, comprehensive research examining the combined effects of multiple factors, particularly those related to quick response (QR) and effective replenishment (ECR), remains limited (Feng, Yao, & Zhao, 2021; Zhai & Xie, 2021).

Research has shown that supply chain digitization positively influences operational performance and overall supply chain efficiency (Gunasekaran et al., 2017; Wang et al., 2016). For instance, organizations utilizing Quick Response (QR) and Efficient Consumer Response (ECR) strategies are more likely to achieve better coordination and performance (Zhai & Xie, 2021; Feng, Yao, & Zhao, 2021). These digital strategies enable real-time data exchange, improve inventory management, and enhance the agility of supply chain processes, thus ensuring that supply chain activities are aligned with market demands (Zhai, 2021).

Supply Chain Engagement

Supply chain engagement involves the active participation of all stakeholders in the supply chain process, including behaviors such as timely data sharing, collaborative planning, and joint problem-solving (Lambert & Cooper, 2000). Research indicates that supply chain engagement is a multifaceted construct influenced by individual, organizational, and technological factors (Mentzer et al., 2001). Studies have shown that higher levels of supply chain engagement are associated with better operational outcomes and enhanced customer satisfaction (Christopher, 2016; Flynn et al., 2010).

In the context of Chinese supply chains, engagement has been extensively studied in terms of frequency and the impact of specific factors, such as technological adoption and organizational culture (Liu, 2018; Zhou & Chen, 2020). However, comprehensive research examining the combined effects of multiple factors, particularly technology-related factors, remains limited (Feng, Yao, & Zhao, 2021).

Quick Response (QR) and Efficient Consumer Response (ECR)

Quick Response (QR) and Efficient Consumer Response (ECR) are strategies designed to improve supply chain responsiveness and efficiency by leveraging real-time data and collaborative practices (Kurnia & Johnston, 2001). QR focuses on reducing lead times and improving inventory turnover, while ECR emphasizes the synchronization of production and demand to minimize inefficiencies (Zhao, 2014). Both strategies aim to enhance supply chain agility and customer satisfaction by ensuring timely and accurate replenishment of products (Sun, 2017).

Research has demonstrated that QR and ECR positively influence supply chain performance by fostering a more integrated and responsive supply chain network (Zhai & Xie, 2021; Feng, Yao, & Zhao, 2021). For instance, studies have found that supply chains implementing QR and ECR strategies achieve better coordination, reduced stockouts, and improved customer service levels (Zhao & Gao, 2017; Shen et al., 2015).

Supply Chain Digitization and Supply Chain

Research has consistently shown a positive relationship between supply chain digitization and engagement, which in turn affects overall supply chain performance (Ivanov et al., 2019; Reeve, 2012). Digitized supply chains can create an engaging and collaborative environment that encourages stakeholders to actively participate in supply chain activities (Gunasekaran et al., 2017; Wang et al., 2016). This relationship has been demonstrated in various contexts, including manufacturing, retail, and logistics (Hofmann & Rüscher, 2017; Flynn et al., 2010).

A study by Ivanov et al. (2019) found that supply chain digitization is associated with higher levels of stakeholder engagement and collaboration, which are critical components of supply chain performance. Similarly, Zhai and Xie (2021) highlighted that digitization positively impacts supply chain responsiveness and efficiency, leading to increased engagement and better operational outcomes. These findings underscore the importance of supply chain digitization in promoting an active and collaborative supply chain environment.

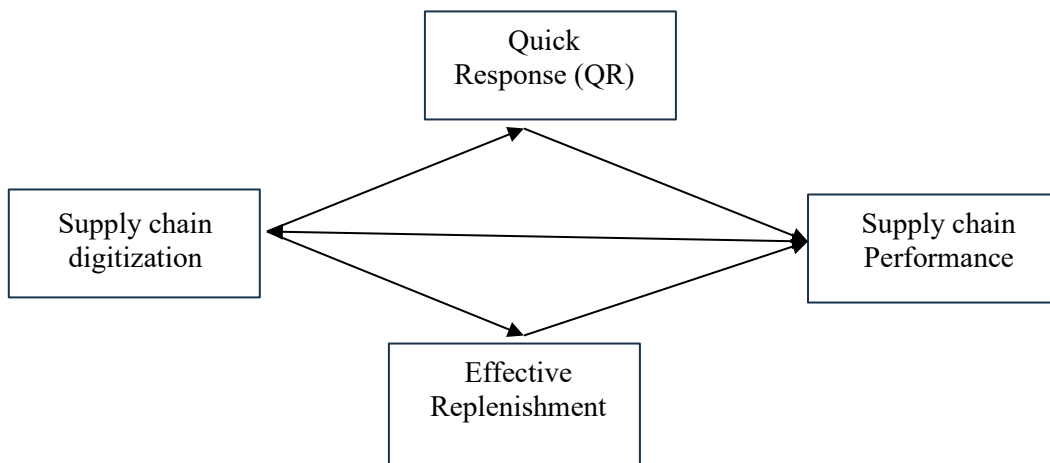
Quick Response (QR) and Efficient Consumer Response (ECR) as Mediators

QR and ECR have been identified as key mediators in the relationship between supply chain digitization and engagement (Kurnia & Johnston, 2001; Feng, Yao, & Zhao, 2021). These strategies encompass various practices aimed at improving supply chain responsiveness and efficiency, which can influence stakeholder engagement differently (Zhai, 2021).

Studies have shown that supply chain digitization can enhance the implementation of QR and ECR, thereby increasing stakeholder engagement (Gunasekaran et al., 2017; Wang et al., 2016). For example, Zhao (2014) demonstrated that supply chains utilizing QR and ECR strategies were more likely to achieve higher levels of engagement and collaboration, leading to better operational performance. Conversely, when digitization is low, supply chains are more likely to experience inefficiencies and reduced engagement (Sun, 2017).

Conceptual Framework

In response to the challenges posed by contemporary supply chain dynamics, this study adopts a novel perspective and approach, aiming to examine the factors affecting supply chain performance within various operational contexts. Particular attention is given to the differences in industry sectors, company sizes, and the impact of digital technologies both internally and externally. The study focuses on the effects of supply chain digitization and the mediating role of strategies like Quick Response (QR) and Efficient Consumer Response (ECR) on overall supply chain performance. By exploring the mediating role of QR and ECR in the relationship between supply chain digitization and engagement, supported by the supply chain management and digital transformation theories, this research seeks to develop a deeper theoretical understanding of the mechanisms driving supply chain efficiency and responsiveness. The conceptual framework aims to provide a theoretical basis and practical guidance for enhancing supply chain performance in modern business practices. The conceptual framework is illustrated below:



Picture 1: Conceptual Framework

Hypotheses

- H1: Supply chain performance varies by industry sector and company size.
- H2: Supply chain digitization has a positive effect on supply chain performance across different operational contexts.
- H3: Quick Response (QR) and Efficient Consumer Response (ECR) mediate the relationship between supply chain digitization and supply chain performance.
- H4: Quick Response (QR) has a positive effect on Supply chain performance.
- H5: Efficient Consumer Response (ECR) has a positive effect on Supply chain performance.

Methodology

Quantitative research methods were adopted, and SPSS was used to organize and analyze the

collected data, as well as to carry out the commonly used methods of bias test, descriptive statistics, correlation analysis and mediation effect test on the data.

This study takes Chinese small and medium-sized enterprises (SMEs) as the research object and adopts the questionnaire survey method, 800 questionnaires were distributed and 734 questionnaires were recovered, among which 707 questionnaires were valid.

Results

The overall Cronbach's Alpha value for the survey questionnaire, as shown in Table 1, is 0.926, indicating excellent internal consistency reliability of the scales used in this study.

Table 1: Results of Reliability Analysis

Number of questions	Cronbach 's α
29	0.926

The Cronbach's Alpha values for each variable's scale were measured, as detailed in Table 2. It can be observed that all α values for the scales in this study are above 0.7, indicating high reliability of the scales for each variable in this study.

Table 2: Results of Reliability Analysis for Each Variable

Variable	Number of questions	Cronbach 's α
Supply Chain Digitization	3	0.877
Effective Replenishment (ECR)	6	0.834
Quick Response (QR)	8	0.867
Supply Chain	12	0.856

The data were subjected to a discriminatory process of suitability for factor analysis and the results are shown in Table 3.

Table 3: KMO and Bartlett's Test^a

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.973
Bartlett's Test of Sphericity	Approx. Chi-Square	4656.172
	df	560
	Sig.	0.000

From Table 3, the overall KMO value of the questionnaire is $0.973 > 0.9$ and the Bartlett's test Sig value is 0.000. this indicates that the scale is suitable for factor analysis and can be tested in the next step.

The basic picture of Supply Chain Performance of SEMs in each subject was derived from descriptive statistics of the data in each subject of the Supply Chain Scale and the results are shown in

Table 4.

Table 4: Descriptive Statistics of Supply Chain in SEMs

Name	Mean	SD	Post hoc comparison
Supply Chain Resilience	4.064	0.602	Supply Chain Resilience > Sustainable Supply Chain Management > Agility in Supply Chain
Sustainable Supply Chain Management	3.665	0.664	
Agility in Supply Chain	3.669	0.729	

The data in Table 4 shows that the supply chain performance scores were all above 3.6, indicating that the SMEs were at an intermediate to high level of engagement. The results of repeated measures ANOVA showed that there was a significant difference between the levels of participation in each segment (including purchasing, production, inventory, and transportation), $F=89.07$, $p<0.001$.

Post hoc comparisons showed that the scores of participations in each segment were, in descending order, inventory, transportation, purchasing, and production. A one-way ANOVA was conducted to analyze the program participation (assessment, tracking, and reliability) in each link, and the results are shown in Table 5.

Table 5: Tests of Grade Level Differences in High School Students' Supply Chain Performance in Various Subjects

Grade level (mean ± standard deviation)	Assessment	Tracking	Reliability
Purchasing (n=294)	4.13±0.57	3.69±0.63	3.68±0.73
Production (n=314)	4.05±0.61	3.70±0.70	3.71±0.75
Inventory & Transportation (n=99)	3.93±0.63	3.48±0.62	3.51±0.64
F	4.407	4.342	2.983
<i>p</i>	0.013*	0.013*	0.051

Note: * $p < 0.05$ ** $p < 0.01$, below.

Table 6: Test of Gender Differences in Supply Chain Performance of High School Students in Various Subjects

level (mean ± standard deviation)	Supply Chain Performance	Supply Chain Performance	Inventory & Transportation Supply Chain Performance
Male (n=304)	4.05±0.65	3.61±0.68	3.71±0.73
Female (n=403)	4.07±0.57	3.70±0.65	3.64±0.73
F	-0.417	-1.766	1.431
<i>p</i>	0.677	0.078	0.153

The data in Table 5 shows that there is a significant difference in the level of involvement of employees in different SMEs in each segment, and the post hoc test found that the main supply chain involvement in the inventory segment was significantly higher than the remaining two grades; there is also a significant difference in the level of involvement of employees in different segments in the procurement segment, and the post hoc test found that the assessment in the procurement segment was

higher than that of the remaining two grades; however, there is no significant difference in the level of involvement in tracking in different segments. differences. The results of the cubic sample t-test for the reliability of the supply chain for each link are shown in Table 6.

The data in Table 6 shows that there is no significant difference in Quick Response (QR) and Effective Replenishment (ECR) participation among employees in different departments. Pearson's cumulative difference correlation analyses were conducted on the assessment, tracking, and reliability dimensions of quick response (QR) and effective replenishment (ECR), and the results are shown in Table 7.

Table 7: Correlation Analysis of Supply Chain Digitization, Supply Chain Performance and Achievement Motivation of High School Students in Various Subjects

Variables		Mean	SD	Supply Chain Performance	Supply Chain Digitization	Speed and Agility	Data Integration and Visibility	Collaboration and Coordination
Purchasing	Supply Chain Performance	4.064	0.602	1				
	Supply Chain Digitization	4.393	0.588	0.616**	1			
	Speed and Agility	4.056	0.674	0.396**	0.437**	1		
	Data Integration and Visibility	3.729	0.834	0.236**	0.260**	0.475**	1	
	Collaboration and Coordination	3.277	0.921	0.394**	0.315**	0.370**	0.525**	1
Production	Supply Chain Performance	3.665	0.664	1				
	Supply Chain Digitization	3.999	0.738	0.564**	1			
	Speed and Agility	3.127	0.805	0.427**	0.379**	1		
	Data Integration and Visibility	2.426	0.788	0.184**	0.147**	0.397**	1	
	Collaboration and Coordination	2.222	0.697	0.177**	0.116**	0.224**	0.424**	1
Inventory & Transportation	Supply Chain Performance	3.669	0.729	1				
	Supply Chain Digitization	3.932	0.831	0.539**	1			
	Speed and Agility	3.146	0.834	0.432**	0.287**	1		
	Data Integration and Visibility	2.639	0.886	0.197**	0.135**	0.452**	1	
	Collaboration and Coordination	2.316	0.793	0.160**	0.086*	0.273**	0.457**	1

The data in Table 7 shows that there is a significant positive correlation between two and two on the assessment, tracking, and reliability dimensions of Quick Response (QR) and Effective Replenishment (ECR) in each section.

One of the objectives of this study was to examine the mediating effect of the three dimensions of quick response between supply chain digitization and supply chain performance. After controlling

for demographic variables, the mediating variables between supply chain digitization and supply chain performance were added to the three dimensions of Quick Response (QR) and Effective Replenishment (ECR), i.e., the three dimensions of Speed and Flexibility, Data Integration and Visibility, and Collaboration and Coordination of Quick Response (QR), as well as the three dimensions of Inventory Management, Supply Chain Synchronizations, and Customer-Centricity under Effective Replenishment (ECR) strategy and examine their mediating effects. Specific results are presented in Tables 8 and 9.

Table 8: Results of the test analysis of the mediating effect of Quick Response (QR) and Efficient Replenishment (ECR) between supply chain digitization, supply chain performance and across sectors

Variables		Supply Chain Digitization		Mastery Goal		Data Integration and Visibility Goal				Collaboration and Coordination Goal	Supply Chain Digitization	
		B	t	B	t	B	t	B	t	B	t	
Purchasing	Supply Chain Digitization	0.595	19.514**	0.400	11.031**	0.283	5.210**	0.396	6.870**	0.510	15.784**	
	Mastery Goal									0.120	3.659**	
	Data Integration and Visibility									-0.061	-2.485*	
	Collaboration and Coordination									0.137	6.249**	
	<i>R</i> ²	0.467		0.397		0.118		0.186		0.507		
	<i>F</i>	76.337		57.362		11.688		19.911		64.948		
Production	Supply Chain Digitization	0.538	20.161**	0.426	11.897**	0.172	4.225**	0.119	3.262**	0.471	16.443**	
	Mastery Goal									0.144	4.872**	
	Data Integration and Visibility									-0.011	-0.396	
	Collaboration and Coordination									0.066	2.214*	
	<i>R</i> ²	0.435		0.307		0.060		0.033		0.462		
	<i>F</i>	67.179		38.690		5.537		2.959		54.355		
Inventory & Transportation	Supply Chain Digitization	0.488	17.917**	0.313	9.140**	0.139	3.492**	0.046	1.274	0.416	15.058**	
	Mastery Goal									0.231	7.378**	
	Data Integration and Visibility									-0.008	-0.261	
	Collaboration and Coordination									0.034	1.131	
	<i>R</i> ²	0.363		0.231		0.082		0.037		0.420		
	<i>F</i>	49.721		26.274		7.842		3.358		45.829		

The data in the above two tables show that the value of the direct effect of supply chain digitization on supply chain performance is 0.510, with the paths "Supply Chain Digitization => Quick Response (QR) => Supply chain performance" and "Supply Chain Digitization => Effective Replenishment (ECR) => Supply chain performance," where the path "Supply Chain Digitization => Achievement => Supply chain performance" partially mediates the effect. Additionally, the path "Supply Chain Digitization => Achievement => Supply chain performance" masks it.

Table 9: Summary of test results on the mediating effects of Quick Response (QR) and Efficient Replenishment (ECR) between supply chain digitization and supply chain performance across sectors

	Path	Effect Value	(Boot SE)	(95% Boot CI)	Test Findings	Percentage of effect
Purchasing	Supply Chain Digitization => Mastery => Supply Chain Digitization	0.048	0.014	0.021 ~ 0.075	Partially Mediated	8.069%
	Supply Chain Digitization => Data Integration and Visibility => Supply Chain Performance	-0.017	0.008	-0.035 ~ -0.003	Avoidance Effect	3.360%
	Supply Chain Digitization => Collaboration and Coordination => Supply Chain Performance	0.054	0.011	0.033 ~ 0.075	Partially Mediated	9.093%
Production	Supply Chain Digitization => Mastery => Supply Chain Performance	0.061	0.017	0.036 ~ 0.102	Partially Mediated	11.386%
	Supply Chain Digitization => Collaboration and Coordination => Supply Chain Performance	-0.002	0.006	-0.015 ~ 0.011	Mediated Not significant	0%
	Supply Chain Digitization => Collaboration and Coordination => Supply Chain Performance	0.008	0.005	0.001 ~ 0.019	Partially Mediated	1.467%
Inventory & Transportation	Supply Chain Digitization => Mastery => Supply Chain Performance	0.072	0.016	0.052 ~ 0.116	Partially Mediated	14.814%
	Supply Chain Digitization => Collaboration and Coordination => Supply Chain Performance	-0.001	0.006	-0.014 ~ 0.011	Mediated Not Significant	0%
	Supply Chain Digitization => Collaboration and Coordination => Supply Chain Digitization	0.002	0.003	-0.003 ~ 0.010	Mediated Not Significant	0%

Note: Masking effect if a and b are significant and c' is significant and a*b is heteroscedastic with c'.

Discussion

This study investigated the differences between supply chain engagement and industry sectors in different companies. The results confirm that there is no significant difference in supply chain engagement across industry sectors, which is contrary to the existing view and hypothesis H1 of this study. Some studies may suggest that certain economic or operational factors may influence the engagement activities of firms in different industry sectors, e.g., manufacturing firms may be more active in supply chain collaboration than service firms. However, due to advances in supply chain technology and globalization of business practices, these factors are likely to promote standardization and equality, thus encouraging all types of firms to actively participate in supply chain digitization.

The findings suggest that supply chain digitization is a key factor in promoting engagement and efficiency in various operational contexts, which is generally consistent with Hypothesis H2 of this study. Supply chain digitization not only reflects the extent of technology adoption and operational optimization, but also influences engagement and responsiveness within the supply chain. Therefore, the advancement of supply chain digitization can improve both operational capability and overall efficiency, which is consistent with the results of previous studies.

This study conducted a mediation test on supply chain engagement, supply chain digitization,

quick response (QR) and efficient consumer response (ECR) and found that supply chain digitization has a direct impact on supply chain engagement. This direct effect exists across different operating environments, validating this study's hypothesis H2. The cross-contextual consistency of supply chain digitization on engagement further underscores its importance. Supply chain digitization can have an indirect effect on engagement through QR and ECR, i.e., QR and ECR partially mediate the relationship between supply chain digitization and engagement. This result suggests that digitization not only affects supply chain engagement directly, but also indirectly through the activation of QR and ECR strategies, a finding that is consistent with previous research on supply chain optimization.

In order to better explore the impact of supply chain digitization and engagement in an internal and systematic way, this study also examines the mediating effects of QR and ECR between supply chain digitization and engagement in different operational contexts. It was found that there is a complex correlation between supply chain digitization, engagement, and the QR and ECR dimensions, which is consistent with Hypothesis H3 of this study. Hypotheses H4 and H5 are also tested.

Conclusions

This study examined the impact of supply chain digitization on engagement and operational efficiency within various industries, focusing on the mediating roles of Quick Response (QR) and Efficient Replenishment (ECR). Three dimensions of supply chain engagement—real-time data integration, responsiveness, and collaboration—acted as partial mediators or masking effects between supply chain digitization and overall operational efficiency. The three pathway models accounted for the effects of 8.069%, 3.360%, and 9.093%, respectively. This shows that for industries with high responsiveness needs, supply chain digitization can significantly increase operational efficiency, which is inconsistent with previous researchers' findings that traditional supply chain methods negatively impact efficiency. It may be because some companies in the modern supply chain context prioritize real-time data and rapid responsiveness, focusing less on traditional metrics and more on dynamic operational adjustments.

Supply chain digitization provides them with positive feedback and support, increasing their motivation to engage in real-time supply chain activities. However, for companies focused on long-term strategic goals, digitization produces a masking effect, consistent with previous scholars' studies. These companies already have enough intrinsic motivation for strategic planning and do not rely heavily on external incentives and feedback to support their operations. They focus more on the intrinsic value and significance of their operational processes rather than just rapid responsiveness, and for these companies, supply chain digitization may not have much effect.

This study found that both real-time data integration and responsiveness partially mediated the relationship between supply chain digitization and engagement in small and medium-sized enterprises (SMEs), with mediating effects accounting for 11.386% and 1.467% of the total effect. This result

suggests that SMEs are more likely to influence supply chain engagement through real-time data integration under the influence of digitization. SMEs typically engage more actively in the supply chain because they aim to achieve high efficiency or receive positive evaluations from partners. This may occur because SMEs in the modern supply chain context are often required to develop agility, resilience, and adaptability. These companies are usually more appreciated and recognized by the market for their excellent performance in a competitive environment, especially in sectors led by technology and innovation, an explanation consistent with the findings of some previous studies. The generally low mediating effect of responsiveness on supply chain digitization and engagement in SMEs compared to larger firms may be due to the fact that in the context of the broader market environment, SMEs perceive immediate responsiveness to be less critical than long-term strategic integration, and therefore are less motivated to focus solely on rapid responses, which may lead to a weaker mediating effect of responsiveness on supply chain engagement.

The present study added engagement in physical distribution as one of the observational objects to explore the differences between the three dimensions of engagement for physical distribution as an outdoor activity and other supply chain activities in terms of supply chain digitization and overall operational efficiency. It was found that only real-time data integration partially mediated the difference between supply chain digitization and physical distribution engagement, accounting for 14.814% of the total effect. Motivation for real-time data integration reflects companies' desire to develop competence or improve their logistics and distribution processes. This finding suggests that, on the one hand, companies equipped with real-time data integration capabilities are more likely to actively engage in distribution activities when their supply chains are digitized. On the other hand, responsiveness and collaboration did not mediate significantly between supply chain digitization and engagement in physical distribution, which may indicate that engagement in physical distribution may not be as influential for companies focusing on rapid responsiveness or collaborative efforts as it is for companies focusing on their own logistics development or improving distribution processes. Of these, real-time data integration appears to be the strongest mediator when compared to other supply chain activities, suggesting that companies motivated to integrate real-time data tend to be more actively engaged in distribution activities when they implement digitized supply chains. The results of companies' engagement in physical distribution accounted for a somewhat higher effect ratio compared to engagement in other activities, possibly due to the fact that distribution is often conducted outdoors, and companies feel the impact of digitization more strongly in this context, which also increases their motivation to achieve and thus influences overall engagement.

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