Article

The Impact of Digital Transformation on Supply Chain Capabilities and Supply Chain Competitive Performance

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Abstract: In the current highly uncertain external environment for businesses, maintaining a single competitive advantage in the supply chain is difficult in the long run. There is an urgent need to acquire a more comprehensive and sustainable competitive advantage, and the thriving digitalization is reshaping the industry structure and competitive dynamics. This study, based on data from 255 survey responses, employs a structural equation model to examine the relationships among environmental uncertainty, digital transformation, supply chain capabilities, and sustainable competitive performance in the supply chain context. Our findings reveal the significant role of digital transformation in enhancing supply chain capabilities, which in turn positively influence sustainable competitive performance. A further analysis shows that supply chain capabilities mediate the relationship between supply chain digital transformation and sustainable competitive performance. Moreover, environmental uncertainty can serve as a driving force for digital transformation, stimulating supply chains to enhance their exploration of digitalization. This research provides valuable insights into exploring sustainable competitive performance in the supply chain context. It addresses the gap in empirical literature regarding digital transformation research and enriches the field of the contingency theory.

Keywords: digital transformation; supply chain capability; sustainable competitive performance; contingency theory

1. Introduction

With the rapid development of digital technologies such as big data, cloud computing, artificial intelligence, the Internet of Things, blockchain, and 5G, coupled with the interconnected global economy and the high level of uncertainty in the external environment, risks and opportunities are exerting immeasurable impacts on the sustainable development and competitive performance of supply chains. For instance, during the COVID-19 pandemic, the digital economy flourished with online shopping, remote work, online education, telemedicine, and other digitalized activities. Companies that embraced digital transformation in these areas gained a competitive advantage, while those that failed to adapt to the digital shift faced a passive position in the market competition. Given the influence of digital technology development and the uncertain external environment on supply chain competitive performance, developing resilient and sustainable supply chains through leveraging digital technologies has become a top priority for organizations. There is an urgent need for research and practical implementation of digital transformation in supply chains to enhance their competitive performance at the organizational level [1].

Supply chain competitive performance (CP) refers to the effective coordination, collaboration, and communication among different entities within a supply chain, enabling organizations to achieve better performance, enhance customer satisfaction, and maintain

competitiveness in the fast-paced business environment [2]. With the continuous development of digital technologies, the logic of value creation in supply chains has undergone profound transformation, reshaping the industrial landscape and supply chain competitive dynamics. Clarifying the factors and mechanisms influencing supply chain competitive performance in the new external environment holds practical significance and has garnered significant attention from both academia and industry.

Supply chain capability (SCC) refers to an organization's ability to identify, utilize, and absorb internal and external resources/information to facilitate the activities of the entire supply chain [3]. Previous research has shown that different dimensions of supply chain capability can impact different aspects of supply chain performance. For example, market sensing, supply chain agility, and adaptability can influence the dual flexibility of the supply chain [4]. Due to the multi-dimensional nature of supply chain capability and the dependence of supply chain competitive performance on different dimensions of supply chain capability in different industries, the relationship between supply chain capability and supply chain competitive performance is complex and many-to-many. Especially in the process of supply chain digital transformation, organizations not only need to adapt to the turbulent external environment but also experience dynamic changes in the internal environment. To further enhance organizational competitive performance and secure future development while maintaining their current competitive position, it is necessary to cultivate and build supply chain capability. Therefore, this study explores the role of four-dimensional supply chain capability in the relationship between digital transformation and supply chain competitive performance from the perspective of supply chain digital transformation.

Digital transformation (DT) is a series of value creation activities driven by enterprise technological innovation, relying on open sharing and efficient utilization of data resources to reconstruct business processes and business models with the aim of improving user experience [5]. The digital economy is an economy that operates through digital technology, including technical facilities and e-commerce [6]. The digital economy is an important support for high-quality economic development. With the rise of the digital economy, optimizing current business processes through digital technology has become the mainstream choice for many organizations to undergo digital transformation. In recent years, an increasing number of companies have regarded digital transformation as a crucial means to shape competitive advantages [7]. Consequently, research on digital transformation has received widespread academic attention and has become an important backdrop for studying organizational strategic change.

Environmental uncertainty (EU) is referred to as the task environment characterized with changing customer demands, unforeseeable competitor actions, a fluctuating sales volume, and unpredictable customer preferences [8]. Environmental uncertainty describes the volatility and unpredictability of an organization's external environment [9]. Many supply chain management studies suggest that the impact of resources or capabilities on performance is moderated by environmental uncertainty [10]. These studies indicate that an organization's requirements for resources and capabilities depend on the level of environmental uncertainty. Building on this line of thought, this study explores whether there is a moderating effect of environmental uncertainty on the relationship between digital transformation and supply chain competitive performance.

Based on this, this study constructs a theoretical model to clarify the relationship between digital transformation, supply chain capabilities, environmental uncertainty, and supply chain competitive performance. Using survey data from 255 respondents in China, the theoretical model is examined using structural equation modeling (SEM). This study contributes to the literature on digital transformation and supply chain competitive performance in several aspects. Firstly, the current views on digital transformation research are mainly based on a few normative studies and have not yet received widespread empirical support. This study fills the gap in the empirical literature. Secondly, it provides empirical evidence for improving and maintaining sustainable supply chain competitive performance.

This study constructs a model of the mechanism through which digital transformation affects supply chain competitive performance, including the antecedent variable (digital transformation), the mediating path (supply chain capabilities), the determining factor (environmental uncertainty), and the economic consequence (supply chain competitive performance). It establishes connections between different theories, examines the relationship between digital transformation and supply chain competitive performance, and provides a new perspective for unlocking the "black box" of supply chain competitive performance in the digital economy. Thirdly, it reveals the value realization path of digital transformation in the supply chain and the advancement mechanism of supply chain capabilities. It demonstrates that digital transformation is an important antecedent variable for cultivating supply chain capabilities. Moreover, this study, based on the scenario of digital transformation, selects four dimensions of supply chain capabilities, providing insights for future supply chain research in digital contexts. Fourthly, it analyzes the contingency factors of supply chain digital transformation and reveals the moderating effect of environmental uncertainty on the relationship between digital transformation and supply chain competitive performance. It offers a new perspective for the study of digital transformation, enriches the research on the moderating mechanisms between digital transformation and supply chain competitive advantage, and develops the application scenarios of the contingency theory. Finally, this study responds to the call for more empirical research on digital transformation [11] and supply chain competitive performance [12].

The remainder of this paper is structured as follows. In Section 2, an analysis of the research status and relationships among the research objects, including supply chain competitive performance, digital transformation, supply chain capability, and the contingency theory, is presented. Section 3 proposes the research hypotheses, while Section 4 introduces the sample characteristics and research methodology employed in this study. The empirical results and analysis are presented in Section 5, followed by a discussion of the findings and implications at both theoretical and practical levels in Section 6. Finally, Section 7 provides a summary of the study's conclusions and highlights its limitations.

2. Theoretical Background

2.1. Supply Chain Competitive Performance

Supply chain competitive performance refers to the comprehensive qualities of a supply chain to surpass competitors in the competitive market by effectively allocating resources and delivering value to the market, thereby winning more opportunities for development [13]. Establishing a supply chain with sustained competitive performance is a crucial strategic approach for organizations to survive and achieve sustainable development in a dynamic global market. The term sustainable competitive advantage (SCA) was initially introduced by Porter, who regarded competitive advantage as the core of organizational performance in a competitive market, representing enduring performance that surpasses competitors [14]. Hoffman further defined sustainable competitive advantage as the long-term benefits achieved by implementing unique strategies that cannot be implemented or replicated by current or potential competitors [15]. Achieving supply chain competitive performance is the ultimate goal of core enterprises in leading supply chain activities [16]. Supply chain competitiveness is characterized by its systemic nature, stability, and value creation, representing the ultimate objective of transformative activities by enterprises [17]. Given this, the study of how to build sustainable supply chain competitiveness has attracted research attention.

Supply chain management scholars have proposed various strategies to enhance supply chain competitive performance. Based on different sources of competitive performance, the academic community has developed three classic theories: endogenous, exogenous, and integrative perspectives. The research on approaches to improving supply chain competitive performance has mainly followed this path, starting from early focus on internal supply chain management, achieving integration among various processes within the supply chain enterprise, gradually shifting attention to the impact of the external environ-

ment on competitive performance, and ultimately evolving into the integration of internal and external supply chains to identify, explore, and construct elements that contribute to competitive performance and pathways for its enhancement [18]. Accordingly, this paper reviews the most discussed strategies in the existing literature from three perspectives.

The first category is internal strategies. The resource-based theory emphasizes the endogeneity of competitive advantage, suggesting that enduring competitive advantage originates from an organization's unique resources and capabilities formed on the basis of these resources, highlighting the heterogeneity of resources, capabilities, or knowledge [19]. Resources and capabilities with distinctive attributes form the foundation of organizational competitive advantage, and it is the differentiation in organizational resources and capabilities that leads to differences in competitive performance [2]. Therefore, it is necessary to utilize digital technology to build organizational digital resources and digital capabilities, thereby establishing internal competitive advantages.

The second category is external strategies. The SCP (Structure–Conduct–Performance) paradigm of the industrial organization theory proposes exogenous strategies for competitive advantage, asserting that differences in firms' competitive performance are determined by market structure and market conduct [20]. Porter emphasizes analyzing the impact of external market environments, such as interactions between firms and industries, cooperative competition between firms, and interactions among related industries, as well as interactions between firms and suppliers, customers, and peers, on competitive advantage [21]. This aligns well with strategic practices in the digital economy environment. In this context, it is necessary to explore new strategic competitive models that align with the current digital environment and build external competitive advantages for organizations.

The third category is cross-organizational and cross-functional supply chain strategies, which integrate resources and capabilities across the entire supply chain, leading to sustained competitive advantages that individual firms and external firms cannot possess [18]. The integrative perspective emphasizes that the integration of internal and external resources and capabilities, along with the accumulation of historical capabilities, is fundamental to achieving competitive advantage in a dynamic market environment, explaining the sources of organizational competitive advantage [17].

In conclusion, exploring how to improve supply chain competitive performance is of paramount importance, and there are three strategies for enhancing competitive performance: internal, external, and integration strategies. As demonstrated by Ma Gang et al., organizational competitive advantage is not only determined by high-performance practices shaped by processes and positions within the organization, but it is also influenced by technological opportunities [21]. Digital technology, being the most advanced and continuously evolving technology, can play a role in each of these strategies. Internally, digital transformation can be utilized to build organizational digital resources and capabilities, leading to internal competitive advantage. Externally, digital technology can be leveraged to reduce transaction costs and create a more favorable external environment. Integration-wise, digital platforms and other tools can be utilized to integrate resources and capabilities, achieving a synergistic effect where the sum of competitive advantages is greater than its individual parts. Therefore, this study aims to enrich this research context by examining the impact of digital transformation on supply chain competitive performance.

2.2. Supply Chain Capability

The key to supply chain capabilities lies in integrating various technological means, improving the level of digitalization in the supply chain, achieving supply chain collaboration and sharing, and promoting the development of a networked, intelligent, and sustainable supply chain [16]. Building upon the research of Fang Wu, Rui Bi, and others, we adopt a two-tier structure to conceptualize supply chain capabilities, which includes four dimensions: information exchange, activity coordination, business integration, and supply chain responsiveness [22,23]. These four dimensions were chosen because they represent important activities involved in the supply chain process, and each dimension

reflects the cross-functional and cross-organizational capabilities required in supply chain management [22], aligning with the digital context of network collaboration. Previous studies have demonstrated the impact of supply chain capabilities on organizational performance, with supply chain capabilities representing a higher level within the hierarchy of organizational capabilities, which are more difficult to achieve and enjoy higher levels of protection against competitive imitation [24]. Supply chain capabilities have a positive impact on organizational performance, including financial and marketing performance [25]. Most empirical studies have analyzed supply chain capabilities using a general conceptualization without further differentiation. However, due to the diverse nature of critical capabilities in the supply chain, their impact on performance varies across different organizations. Moreover, the general concept of supply chain capabilities is too abstract, making it challenging for enterprises to identify suitable starting points for their cultivation. Therefore, future research on supply chain capabilities should consider the integration of these dimensions instead of isolating specific types of capabilities within the supply chain [4]. In this regard, we consolidate the four dimensions of supply chain capabilities and explore the role of digitally related capabilities in determining competitive advantage, as suggested by Alessandro and others [26].

2.3. Digital Transformation

The field of digital transformation stems from the continuous development of digital technologies, characterized by their availability, scalability, and openness [27], which enable sustainable improvements in market efficiency and empower both macro and micro contexts. Over time, a considerable amount of academic research has emerged around the theme of digital transformation, with 134 different definitions of digitization found in high-quality journals [28]. According to the latest research by Wang Hecheng et al., digital transformation, at the organizational level, refers to the process where enterprises require new technological applications, ecological positioning, business models, and business and organizational processes, as well as a favorable corporate culture, leadership, and risk tolerance. It aims to enhance relationships between organizations and employees, customers, suppliers, partners, and stakeholders, enabling more effective competition in the ever-changing digital economy [29]. This definition reflects the focus of digital transformation on building deep integration networks among participants in the industry chain, with the aim of achieving sustainable competitive performance. Currently, research on digital transformation can be categorized into two main types. The first type focuses on studying the antecedents and consequences of digital transformation, which is also the most relevant research type to this study. The second type of research is conducted on different subjects or entities, exploring digital transformation in specific contexts or industries.

The first type involves the continuous refinement of research on the effects of digital transformation. Digitalization in the supply chain refers to an information and data-driven management approach that places the customer at the center. It involves recording and analyzing the entire process of product procurement to delivery using digital technologies. Existing research has demonstrated that digital transformation can have an impact at both the organizational and supply chain levels. At the organizational level, digital transformation has a significant effect on enhancing the supply chain capabilities of weaker members [30]. At the supply chain level, the ongoing application of digital technologies optimizes product development, warehouse management, logistics visibility, and quality traceability, leading to effective improvements in the supply chain network and business processes [31]. It also promotes collaboration among supply chain participants, creating synergy and stability throughout the entire supply chain, thereby enhancing financial performance [32], innovation performance [33], new product development performance [34], and more.

The second category involves the expanding scope of digital-driven collaboration. Research on digital transformation has been evolving from individual organizations to a broader context. Earlier studies on digital transformation focused on individual orga-

nizations, exploring the driving factors [35], transformation mechanisms [36], and transformation effects [31,37] of digital transformation within a single organization. With the continuous development of digital technologies, research on digitization has deepened its focus on collaborative efforts within the industry value chain. Numerous scholars have studied the entities that rely on digitization for collaboration, models that enable digitization to empower the industry value chain, and pathways for integrating digital technologies to achieve industry collaboration [38]. Wang Hecheng and others found that organizations at the forefront of digital transformation are in a leading position in terms of business and digital technology applications, which drives the construction of an industry ecosystem [29]. Scholars have also conducted research on understanding the characteristics of value co-creation in business ecosystems and their evolution under the influence of the digital economy [39].

While these studies have enriched our understanding of the facilitating factors and multifaceted benefits of digitalization, most research indicates the need for further empirical investigations into the antecedents and outcomes of digital transformation [40]. This paper seeks to contribute to this research by elucidating the impact of digital transformation on supply chain capabilities and competitive performance.

2.4. Contingency Theory

The contingency theory refers to the need for organizations to make corresponding adjustments when external environments, technologies, scales, strategies, and other contextual factors change [41]. Achieving the optimal match between an organization and its contextual factors enables the organization to adapt best to its environment [42]. Information technology is one of the most critical contingency variables in the external environment. Zhu Xiaowu et al. pointed out the importance of aligning IT infrastructure with the organizational structure to enhance organizational adaptability. In reality, this involves improving the organization's information processing capabilities and providing robust support platforms for organizational transformation [42]. The alignment of information technology and the organizational structure can promote the improvement of organizational performance. Alexander and Randolph proposed a research framework for the relationship between the alignment of technology and organizational structure and performance. Their definition of alignment refers to the match between technology and the organizational structure, and they concluded that the alignment between technology and the organizational structure better predicts organizational performance [43]. Siggelkow pointed out that the purpose of studying alignment is to gain a better understanding of organizational performance [44].

Currently, on one hand, new digital technologies such as blockchain, cloud computing, and Internet of Things (IoT) platforms are changing the structure of organizations. Organizations now have the ability to rapidly expand or contract their operations at a speed and cost that was not possible a decade ago. On the other hand, the pervasive nature and generative capabilities of these digital technologies mean that building an adaptive organizational structure is crucial for broader organizations such as supply chains. Research by Lawrence et al. emphasizes the need to study the relationship between the "fit" between the organizational structure and contextual factors in the contingency theory and organizational effectiveness [45]. Along this research direction, considering the disruptive nature of digitalization, we believe that the contingency framework provides a powerful perspective for examining the digital transformation of supply chains. Supply chains need to undergo organizational adjustments through digital transformation in order to establish supply chain capabilities that align with the current digital environment, including more efficient information exchange, activity collaboration, business integration, and supply chain responsiveness. This leads to organizational effectiveness and enables them to remain competitive in the emerging digital economy. There is limited existing literature that examines the digital transformation of supply chains from a contingency perspective, and this paper aims to expand the research perspective on digital transformation.

In the global process of digitalization, the structure of supply chains is being reshaped by digital technologies. The leadership of supply chain entities is shifting from those with a large business scale to those with high levels of digitization. The digitization of supply chain elements, the intelligence of supply chain processes, and the platformization of supply chain organizations have led to a strong dependence of supply chain participants on digital technology resources, resulting in fundamental changes in the structure of supply chains. This has triggered considerations of the impact of digital transformation on supply chain competitive performance.

In the literature on international digital transformation, there is still a relatively small proportion of research on digital transformation in the Chinese context. Although China started relatively late in digital transformation, with rapid economic growth and strong government support, digital transformation has experienced rapid development in the country. China possesses significant advantages in terms of a large market, transaction cost advantages, and a complete industry chain [46]. It is becoming one of the driving forces in the application of digital transformation and an ideal environment for researching digital transformation issues. Previous studies have shown that studying digital transformation in the context of China can provide important insights for enterprises in the new stage of high-quality development [47].

3. Hypothesis Development

3.1. Digital Transformation and Supply Chain Competitive Performance

Belhadi et al. have pointed out that digitalized supply chains can improve supply chain visibility, enable flexible adjustments in the structure, organization, and capabilities, enhance product quality, and improve supply chain efficiency [48]. Xue et al. found in their research that companies can eliminate organizational barriers, integrity culture barriers, employee quality barriers, and managerial talent barriers in supply chain value management through digital transformation [49]. Shin and Namchul's study demonstrated that digital technology can enhance the coordination of economic activities and improve firm productivity [50]. Marko's research showed that companies can significantly improve customer service performance through digital transformation [32]. Huixiang Zeng et al. found that digital transformation can promote financial performance [51]. Additionally, Elisa Truant et al.'s study indicated that organizations can create new forms of value through digital transformation [37]. Based on the above research findings, it can be observed that the digitally transformed supply chain is more flexible and competitive. Therefore, it can be inferred that digital transformation undoubtedly strengthens supply chain competitive performance.

H1. *Digital transformation has a positive impact on supply chain competitive performance.*

3.2. Supply Chain Capability and Supply Chain Competitive Performance

This study evaluates supply chain capability from four dimensions: information exchange, activity integration, collaboration, and responsiveness. These four elements are considered to assess the impact of supply chain capability on supply chain competitive performance.

Information exchange refers to the ability of enterprises to share knowledge with supply chain partners in an effective and efficient manner [52]. Information exchange capability is a new organizational capability and a new source of competitive advantage in the digital age [53]. Effective information exchange has been identified as one of the fundamental capabilities in supply chain processes [52]. Efficient information exchange capability can enhance operational efficiency among supply chain partners, and improving information sharing strategies can enhance overall supply chain performance [54].

Supply chain collaboration can be understood as the ability of enterprises to coordinate transaction-related activities with supply chain partners [50]. It encompasses all collaborative behaviors based on the structural strategy of facilitating process integration

among partners [55]. Increasing structural collaboration among supply chain stakeholders leads to improved performance [55].

Supply chain activity integration (AI) is conceptualized as the degree to which a company collaborates with its supply chain partners and coordinates the management of processes within and between organizations to achieve effective integration of physical, information, and financial flows [56]. AI is an important area that involves strategic adjustments of functions and processes within organizations and among supply chain members [57]. Cross-functional boundary integration of processes and activities, including suppliers and customers within the supply chain, can reduce transaction costs, reduce information asymmetry, optimize allocation of supply chain resources, and achieve low-cost and efficient fulfillment of customer demands [58,59], which is crucial for the development of nodal enterprises [60].

Supply chain responsiveness (RS) refers to the ability of the supply chain to respond to market demands due to unpredictable demand and constantly shrinking product lifecycles. It focuses on the capability of the supply chain to quickly respond to unpredictable demand, manufacture products according to customer requirements, and ensure timely distribution [61]. Supply chain responsiveness highlights the dynamic nature of supply chain capabilities, enabling companies to develop and update their specific capabilities and better respond to environmental changes [22], thus having a sustained impact on the dynamic competitive performance of the supply chain.

Therefore, strengthening supply chain capabilities can support companies in achieving higher competitive performance on the supply chain. Based on the above arguments, this study proposes the following hypotheses:

H2a. *Information exchange capability in the supply chain has a positive impact on supply chain competitive performance.*

H2b. *Activity integration capability in the supply chain has a positive impact on supply chain competitive performance.*

H2c. *Collaboration capability in the supply chain has a positive impact on supply chain competitive performance.*

H2d. *Responsiveness capability in the supply chain has a positive impact on supply chain competitive performance.*

3.3. Digitization Transformation, Supply Chain Capabilities, and Supply Chain Competitive Performance

Digital transformation promotes the construction of a digitally enabled end-to-end supply chain, expands the boundaries of supply chain services, and facilitates the formation of a supply chain ecosystem, which contributes to the emergence of a responsive supply chain and drives the value expansion of supply chain collaboration and integration [62]. Therefore, it can be inferred that digital transformation enhances the ability of supply chain activity integration and responsiveness. Furthermore, digital transformation enhances the visibility of the supply chain, reduces information asymmetry among supply chain members, and can be predicted to strengthen the information exchange capability of the supply chain. Lastly, sharing contracts such as profit sharing can lead to better supply chain performance through incentivizing collaboration between parties compared to other types of contracts [63]. Therefore, this study hypothesizes the following:

H3a. *Digital transformation has a positive impact on information exchange capability in the supply chain.*

H3b. *Digital transformation has a positive impact on activity integration capability in the supply chain.*

H3c. *Digital transformation has a positive impact on collaboration capability in the supply chain.*

H3d. *Digital transformation has a positive impact on responsiveness capability in the supply chain.*

Previous research has found that supply chain capabilities supported by digital technologies are organization-specific and difficult to replicate across organizations. These capabilities can serve as catalysts for transforming digital resources into higher value for companies [22]. Factors influencing supply chain capabilities can enhance the improvement of supply chain competitive performance [55]. Therefore, it is evident that supply chain capabilities play a crucial role in the relationship between digital transformation and competitive performance. Based on the above, this study concludes that digital transformation can enhance the capabilities of supply chain information exchange, activity integration, collaboration, and responsiveness, thereby contributing to supply chain competitive performance.

H4a. *Information exchange capability in the supply chain mediates the relationship between digital transformation and supply chain competitive performance.*

H4b. *Activity integration capability in the supply chain mediates the relationship between digital transformation and supply chain competitive performance.*

H4c. *Collaboration capability in the supply chain mediates the relationship between digital transformation and supply chain competitive performance.*

H4d. *Responsiveness capability in the supply chain mediates the relationship between digital transformation and supply chain competitive performance.*

3.4. The Moderating Role of Environmental Uncertainty

Supply chains have a higher demand for stable competitive performance under high environmental uncertainty compared to low environmental uncertainty. However, in high uncertainty external environments, existing supply chain competitive performance is often more prone to loss or decline. In high uncertainty environments, maintaining supply chain competitive performance requires organizations to have stronger information processing capabilities. Digital transformation can enable more efficient data collection, processing, analysis, and dissemination, making it easier to meet the increased demand for information processing resulting from environmental changes [64]. Therefore, as the level of environmental uncertainty increases, digitally transformed supply chains exhibit a more significant advantage in maintaining and enhancing competitive performance. Based on these assertions, this study infers that digital transformation strengthens the ability of supply chains to maintain competitive performance in environments with increased uncertainty.

H5. *Environmental uncertainty moderates the relationship between digital transformation and supply chain competitive performance.*

3.5. Control Variables

Controlling for company size is beneficial for stability, and more stable companies are more likely to focus on the development of sustainable competitive performance. Cash flow and total assets can influence the relationship between digitization and higher performance. Annual revenue can reflect the current business situation of a company and its current market competitiveness [32]. Following the articles by Song et al. [65], the following variables that have essential impacts on competitive performance are controlled.

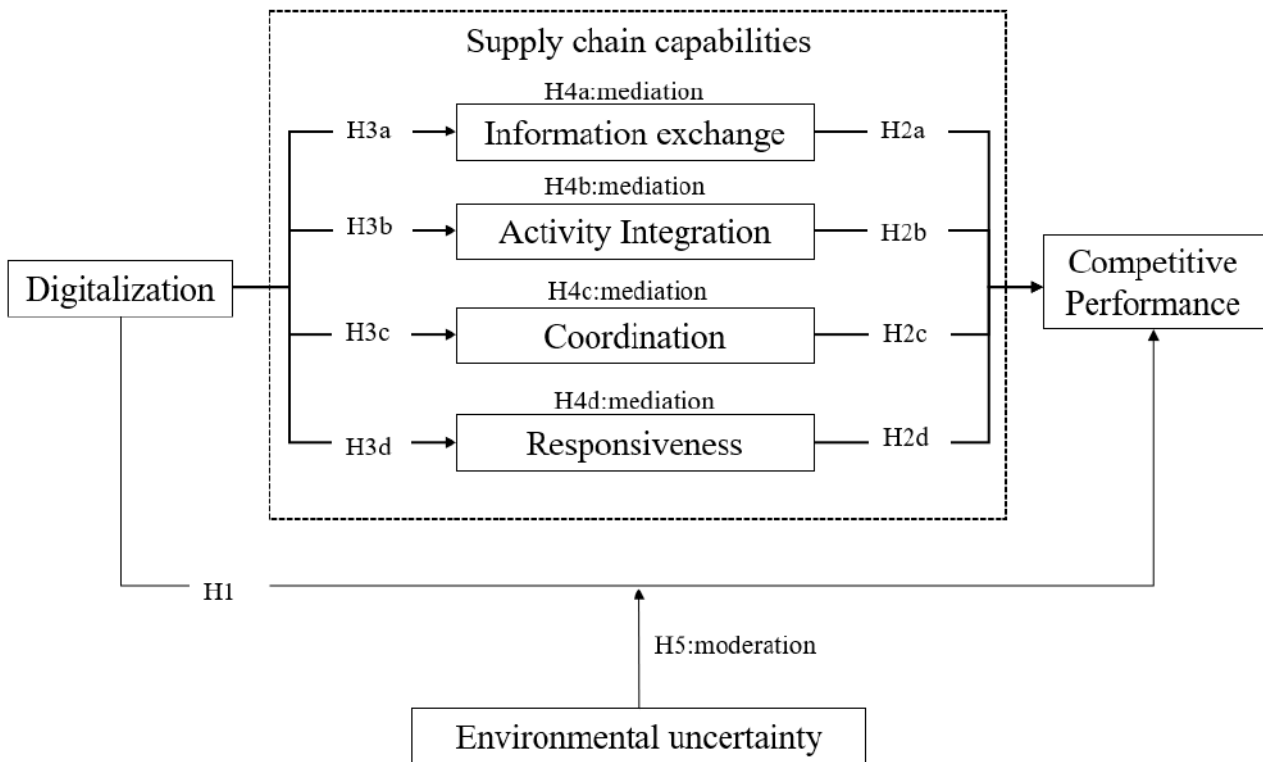The conceptual framework of this study is illustrated in Figure 1.

Figure 1. Conceptual framework.

4. Methodology

4.1. Measurement Scales

Digitalization (DT), supply chain capabilities (SCC), environmental uncertainty (EU), and competitive performance (CP). To be specific, items of digitalization were adapted from studies of Chi et al. [34] and Singh et al. [66]. The scale of supply chain capabilities was based on studies of [22,23,56,67]. Items of environmental uncertainty were drawn from studies of [68–71]. Items of competitive performance were drawn from studies of [16,71,72]. All the indicators were measured with a seven-point Likert scale (ranging from 1, "strongly disagree" to 7, "strongly agree"). Given that the most measurement scales were drawn from the English literature while the informants are Chinese, a professor in the field of the supply chain was invited to translate the original English scale into Chinese and then employ another professor to back-translate it into English. There were no significant differences between the translated English version and the original English version. Thus, the study was not influenced by deviation caused by cultural differences. To further refine the measurement, the questionnaire was issued to 30 companies for the pilot test. Based on their feedback, the questionnaire was modified and improved for large-scale distribution. The final constructs and items are shown in Table 1.

Table 1. Constructs and items.

Constructs	Indicator
Digital Transformation (DT) [34,66]	Our company is operating business processes based on digital technology.
	Our company is integrating digital technology to transform our business processes.

Table 1. *Cont.*

Constructs	Indicator
	Our company unanimously believes that adopting digital technology and digital management is beneficial for the development of the enterprise.
Supply Chain Information Exchange Capability (IE) [22]	The information exchanged between our company and partners is greater than that between competitors and their partners.
	My company benefits more from information exchange with partners compared to our competitors.
	The information exchange between our company and partners is superior to that between competitors and their partners.
Supply Chain Collaboration Capability (CO) [22,23,67]	Our company demonstrates more efficient coordination activities with partners compared to competitors.
	Our company is able to carry out transactional activities with partners more efficiently compared to competitors.
	Our company requires less time to coordinate transactions with partners compared to competitors.
	Our company develops strategic plans to enhance collaboration with partners.
Supply Chain Activity Integration Capability (AI) [56]	Our company actively collaborates with partners in forecasting and planning.
	Our company collaboratively engages with partners in projects and plans for future demands.
	Collaborative demand forecasting and planning with partners is a regular practice in our company.
	Our company consistently engages in collaborative forecasting and planning activities with partners.
Supply Chain Responsiveness (RS) [56]	Our supply chain responds faster and more effectively to the constantly changing demands of customers and suppliers compared to our competitors.
	Compared to our competitors, our supply chain is capable of responding more quickly and effectively to changes in their strategic plans.
	Our supply chain is effectively competing in most markets.
Competitive Performance (CP) [16,71,72]	Lower communication costs, order management costs, inventory costs, warehouse management costs, transportation costs, logistics management costs, etc.
	Customers are highly satisfied with our services.

Table 1. *Cont.*

Constructs	Indicator
	Our company performs well in terms of sales revenue growth compared to key competitors.
	Our company performs well in terms of market share compared to key competitors.
Environmental Uncertainty (EU) [68–71]	Rapid changes in customer demand for products or services.
	The performance of our suppliers is difficult to predict.
	Actions taken by competitors in marketing and promotion are unpredictable.
	Sales volumes in our industry fluctuate significantly year after year.
	Our company uses constantly changing core production technologies.
Control Variables [65]	Operation duration of the company
	The number of employees in the company
	Annual sales of the company
	Total assets

4.2. Sample Selection and Data Collection

This study conducted a survey among Chinese enterprises for the following reasons. Firstly, starting from 2015, the Chinese government has issued a series of policies to accelerate the construction of a digital China, emphasizing the development of the digital economy and the deep integration of the digital and physical economies, with the goal of creating internationally competitive digital industry clusters [73]. Secondly, in recent years, the scale of China's digital economy has grown at an average annual rate of 11.24%, becoming an important driving force behind economic growth [74]. Thirdly, China is one of the most prominent emerging economies and is often considered as a "laboratory" for supply chain researchers [69]. Fourthly, Chinese enterprises have shown great enthusiasm for digital transformation and actively seek to incorporate it into their supply chain practices.

The measurement of each variable used mature scales that were validated for their validity and reliability. The final determination of each scale was based on at least two existing scales to ensure a comprehensive evaluation of each construct. Some questions that did not fit the current context were removed, such as the question in the information sharing construct scale regarding "communication with partners through emails", ensuring the quality of the questionnaire. Additionally, based on the author's own experience of encountering difficulties in understanding certain questionnaire items, efforts were made to translate the items into plain and understandable language without altering the original meaning of the scales, ensuring the reliability of the questionnaire survey results.

Overall, 300 questionnaires were distributed, and 278 were returned. After excluding questionnaires with obvious errors (such as giving the same answer for all questions), 255 valid questionnaires were retained, resulting in an effective response rate of 85 percent. Table 2 presents the distribution structure of the samples.

Table 2. Sample distribution.

Constructs	n	%
Number of employees		
0–50	23	9.4%

Table 2. *Cont.*

Constructs	n	%
51–100	110	43.1%
101–300	85	33.3%
301–500	30	11.8%
Above 500	6	2.4%
Operation duration		
1–3 years	19	7.5%
3–8 years	73	28.6%
8–15 years	122	47.8%
Above 15 years	41	16.1%
Annual sales (million RMB)		
Below 5	30	11.8%
5–30	68	26.7%
30–100	96	37.6%
100–300	51	20.0%
Above 300	10	3.9%
Total assets (million RMB)		
Below 5	15	5.9%
5–50	29	11.4%
50–150	58	22.7%
150–50	89	34.9%
Above 500	64	25.1%

Note: N = 255.

5. Results

5.1. Nonresponse Bias and Common Method Bias

In survey-based research, examining nonresponse bias and common method bias (CMB) is crucial. Following the study by Scott and Terry [75], this study assessed nonresponse bias by comparing early responses and late responses using independent sample *t*-tests. The *t*-test results showed no significant difference between early responses and late responses, indicating the absence of nonresponse bias in this study.

Furthermore, as the data were collected from managers, it was necessary to examine the presence of common method bias [76]. To ensure that the interpretation of the results was not affected by CMB, several remedial measures were implemented during the questionnaire development process. These measures included using pre-validated scales, providing introductory information, ensuring respondent anonymity, using simple language, balancing the order of questions, and employing a midpoint anchor for measurements. Additionally, two statistical techniques were used to test for the presence of CMB. One technique was Harman's single-factor analysis, conducted using SPSS 26.0. The results indicated that the first factor explained 35.348% of the total variance, which is less than the standard threshold of 40%, suggesting the absence of severe common method bias. Additionally, the correlation coefficient and the square root of AVE (average variance extracted) presented in Table 3 demonstrated that the inter-correlations among constructs were significantly lower than 0.9, further supporting the conclusion that there is no CMB issue in this paper.

5.2. Reliability and Validity Testing

The internal consistency reliability coefficients (Cronbach's α), composite reliability (CR), and average variance extracted (AVE) were calculated using SPSS 26.0 and Mplus 8 for the seven variables. The results are presented in Table 4. It can be observed that all variables achieved Cronbach's α coefficients and CR values above the standard threshold of 0.7, and the AVE values exceeded the standard threshold of 0.5, indicating good reliability of the data in this study.

Table 3. The correlation coefficient and the square root of AVE.

Variable	Mean	SD	DT	EU	IE	CO	AI	RS	CP
DT	5.509	0.892	0.807						
EU	4.936	0.789	0.513 **	0.758					
IE	5.273	0.901	0.604 **	0.123 *	0.780				
CO	5.358	0.776	0.509 **	0.234 **	0.556 **	0.807			
AI	5.230	0.886	0.589 **	0.456 **	0.609 **	0.671 **	0.796		
RS	5.346	0.791	0.409 **	0.431 **	0.612 **	0.589 **	0.566 **	0.804	
CP	5.313	0.810	0.496 **	0.453 **	0.689 **	0.497 **	0.601 **	0.701 **	0.792

Notes: N = 255; the value on the diagonal italics is the square root χ^2 = 260.216, df = 254, RMSEA = 0.01, TLI = 0.989, CFI = 0.978, SRMR = 0.019; * $p < 0.05$, ** $p < 0.01$.

Table 4. Reliability and Validity Analysis of the Measurement Model.

Constructs	Item	Factor Loading	Cronbach's α	CR	AVE
Environmental Uncertainty (EU)	EU1 EU2 EU3	0.842 0.714 0.710	0.796	0.801	0.574
Digital Transformation (DT)	DT 1 DT 2 DT 3 DT 4	0.815 0.809 0.741 0.860	0.881	0.882	0.652
Information Exchange (IE)	IE 1 IE 2 IE 3	0.808 0.764 0.768	0.820	0.823	0.609
Collaboration (CO)	CO1 CO2 CO3 CO4	0.829 0.767 0.827 0.802	0.881	0.882	0.651
Activity Integration (AI)	AI 1 AI 2 AI 3 AI 4	0.785 0.743 0.854 0.799	0.870	0.874	0.634
Responsiveness (RS)	R 1 R 2 R 3	0.826 0.782 0.805	0.845	0.846	0.647
Competitive Performance (CP)	CP 1 CP 2 CP 3 CP 4	0.762 0.826 0.812 0.765	0.868	0.870	0.627

Note: N = 255.

Table 4 shows that all factor loadings are above the threshold of 0.7, and all AVE values meet the requirement of being above 0.5. Additionally, the square root of AVE for each variable in Table 3 is greater than the correlation coefficients between variables, indicating that the constructs in this study exhibit high discriminant validity [77].

5.3. Hypothesis Testing

5.3.1. Proposed Structural Model and Main Effect Hypotheses Testing

The SEM was applied to estimate the relationship between the constructs. The SEM estimates were generated by running Mplus 8 with a maximum likelihood method. SEM is a popular and impressive statistical technique that can be used to test the cause and effect relationship [73]. Numerous high-quality scientific studies have run SEM in Analysis of Mplus8 to validate their theoretical model and hypotheses. The fit indices for the model of this study were χ^2 = 260.216, df = 254, χ^2/df = 1.024 < 3, RMSEA = 0.01, TLI = 0.989 > 0.9,

CFI = 0.978 > 0.9, and SRMR = 0.019 < 0.05, suggesting that the SEM depicted a good fit to the data. Figure 2 is the path analysis diagram and Table 5 presents the results of the standardized path coefficients of the SEM. H1, H2a, H2b, H2c, and H2d, respectively, propose that DT and SCC play a positive role in CP. Both hypotheses are supported because the corresponding coefficients are significant ($\beta1 = 0.24$, $p < 0.01$; $\beta2a = 0.18$, $p < 0.01$; $\beta2b = 0.14$, $p < 0.05$; $\beta2c = 0.27$, $p < 0.001$; $\beta2d = 0.17$, $p < 0.01$).
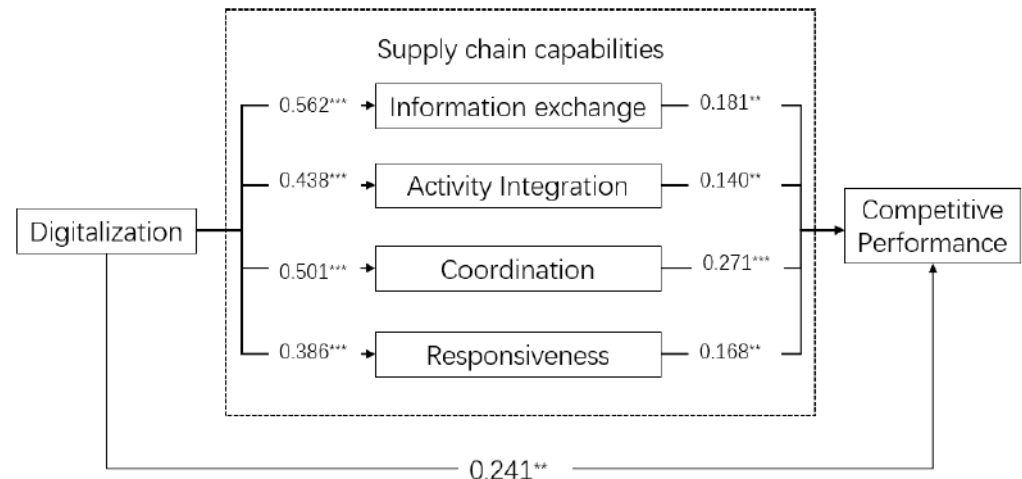
Figure 2. Structural equation diagram: path analysis. ** $p < 0.01$, *** $p < 0.001$.

Table 5. The results of hypotheses testing.

Path	Parameter Estimate	SE	*p*-Value	Decision
DT→CP	0.241 **	0.046	<0.01	H1: Accepted
IE→CP	0.181 **	0.063	<0.01	H2a: Accepted
CO→CP	0.140 *	0.067	<0.05	H2b: Accepted
AI→CP	0.271 ***	0.063	<0.001	H2c: Accepted
RS→CP	0.168 **	0.061	<0.01	H2d: Accepted
DT→IE	0.562 ***	0.035	<0.001	H3a: Accepted
DT→CO	0.438 ***	0.038	<0.001	H3b: Accepted
DT→IAI	0.501 ***	0.033	<0.001	H3c: Accepted
DT→RS	0.386 ***	0.041	<0.001	H3d: Accepted

Notes: N = 255, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

H3a, H3b, H3c, and H3d, respectively, propose that DT plays a positive role in SCC. Both hypotheses are supported because the corresponding coefficients are significant ($\beta3a = 0.56$, $p < 0.001$; $\beta3b = 0.44$, $p < 0.001$; $\beta3c = 0.50$, $p < 0.001$; $\beta3d = 0.39$, $p < 0.001$).

5.3.2. Testing the Mediating Effect of SCF

This paper employed the bias-corrected bootstrapping approach to validate the mediation hypotheses. The results of the mediation analysis are presented in Table 6. H4a, H4b, H4c, and H4d state that SCC plays a mediating role in the relationship between DT and CP. The results suggest that the indirect effect of DT on CP through SCF is 0.157, 0.135, 0.245, and 0.159 and statistically significant, thus providing support for H4a, H4b, H4c, and H4d, respectively. To conclude, DT improves CP indirectly via SCC.

5.3.3. Testing the Moderating Effect of Environmental Uncertainty

A hierarchical regression analysis was applied to test the moderation hypotheses and the results are presented in Table 7. H5 posits that environmental uncertainty moderates the relationship between DT and CP. This hypothesis is supported by the increased R-square and the significant interaction effects. As shown in Table 7, adding the interaction terms to

the direct model significantly increased the R-square for supply chain resilience, from 0.806 to 0.820. In addition, the interaction effect of DT and environmental uncertainty on CP is significant (β = 0.225) with a *p*-value of 0.01. This study plotted the relationship between DT and CP under high and low (1 standard deviation above or below the mean) levels of environmental uncertainty, as shown in Figure 3. Figure 3 illustrates that environmental uncertainty changes the strengths of the associations between DT and CP. The association between DT and CP at a high level of environmental uncertainty is higher than that at a low level of environmental uncertainty. Together, these results provide support for H5 and suggest that the positive effect of DT on CP is stronger when environmental uncertainty is high than when it is low.

Table 6. Results of mediation analysis.

Path	Parameter Estimate	SE	Lower 95% CI	Upper 95% CI	Decision
DT→IE→CP	0.157	0.054	0.046	0.260	H3a: Accepted
DT→CO→CP	0.135	0.065	0.011	0.264	H3b: Accepted
DT→AI→CP	0.245	0.058	0.138	0.361	H4c: Accepted
DT→RS→CP	0.159	0.058	0.046	0.274	H4d: Accepted

Notes: N = 255; bootstrapping iterations are 5000.

Table 7. Results of Hierarchical Regression Analysis.

|	Dependent Variable: Supply Chain Competitive Performance			
Constructs	Model 1	Model 2	Model 3	Model 4
		Control variable		
Number of employees	0.390 ***	0.051	0.041	0.005
Number of employees	0.265 ***	0.092	0.077	0.057
Annual sales	0.012	0.020	0.037	0.031
Total assets	0.369 ***	0.082	0.038	0.020
Independent variable				
DT		0.478 ***	0.428 ***	0.387 ***
EU			0.279 ***	0.219 ***
DT × EU				0.225 ***
F-statistics	68.237 ***	180.786 ***	171.772 ***	160.765 ***
R2	0.522	0.784	0.806	0.820
ΔR2	0.522	0.262	0.022	0.014

Notes: N = 255; *** *p* < 0.001.
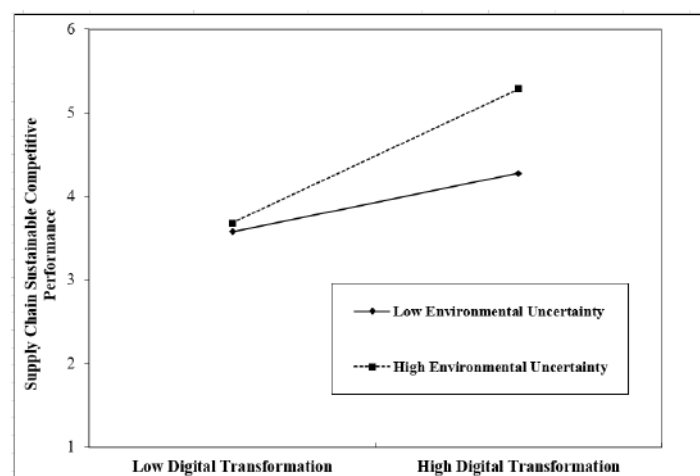
Figure 3. Moderation effect of environmental uncertainty on the relationship between digital transformation and supply chain competitive performance.

6. Discussion

6.1. Discussion of Results

This study proposed a research model based on the contingency theory to investigate the relationship between digital transformation, supply chain capabilities, environmental uncertainty, and supply chain competitive performance. The theoretical model was validated using survey data from 255 respondents in China.

Firstly, digital transformation can lead the supply chain in new directions of competition, making it a current research hotspot. However, the integration of digital transformation and supply chain management still lags behind in theoretical research compared to practical development. The digital transformation of the supply chain involves a digital revolution in technology, business models, organizations, processes, services, and operations. Deconstructing the antecedents and consequences of digital transformation helps reveal the process by which the supply chain reconstructs itself to survive, develop, and adapt to the digital environment. It also provides theoretical support for the continuous cultivation of supply chain capabilities based on digital transformation in a constantly changing environment.

Secondly, this study explored the mediating role of supply chain capabilities in the relationship between digital transformation and supply chain competitive performance, revealing the mechanism "black box" of this causal chain. Previous studies have discussed the relationship between supply chain dynamic capabilities and competitive advantage or organizational performance, but they often treat supply chain capabilities as independent variables, overlooking their sources. In this study, while delving into the impact of digital transformation on supply chain competitive performance, it was found that digital transformation indirectly affects competitive performance through four dimensions of supply chain capabilities, clarifying the causal path of digital transformation in supply chain competitive performance. The findings of this study validate the behavioral logic starting point and micro-level origin of supply chain capabilities as constituted by digital transformation, expanding the antecedent research of supply chain capabilities and providing a theoretical basis for building supply chain capabilities in the digital economy.

Therefore, based on supply chain management principles and the contingency theory, this study linked digital transformation and supply chain competitive performance through the dimensions of information exchange, activity integration, collaboration, and responsiveness. The conclusions of this study not only fill the theoretical gap in understanding the mechanisms of digital transformation and supply chain competitive performance but also provide reference for future research on supply chain capabilities from the perspective of the digital economy.

Third, environmental uncertainty moderates the relationship between digital transformation and supply chain competitive performance. Specifically, in situations of high external uncertainty, supply chains with higher levels of digital transformation achieve better competitive performance. This finding is consistent with previous conclusions in the field of supply chain management, indicating that environmental uncertainty, as an important contingency variable, significantly moderates the relationship between supply chain capabilities and performance [71]. This finding implies that when organizations are unable to effectively respond to environmental changes and experience a decline in competitive performance, they can effectively address the situation through digital transformation.

6.2. Theoretical Implications

First, this study attempts to empirically examine the impact of digital transformation on supply chain competitive performance in emerging economies. On one hand, there is limited empirical research on how digital transformation affects supply chain competitive performance. On the other hand, Elisa Truant et al. argue that it is necessary to enrich the understanding of the consequences of digital transformation from multiple perspectives [37]. This study aims to address these gaps by empirically examining the impact of digital transformation on supply chain competitive performance.

Second, this study enriches the understanding of the relationship between digital transformation and supply chain competitive performance by introducing supply chain capabilities as a mediating variable. This study also complements the knowledge base on antecedents of supply chain solutions by identifying the positive impact of digital transformation on supply chain capabilities. Furthermore, previous research that linked digital transformation and supply chain capabilities only focused on general and broad capabilities, whereas this study reveals the influence of digital transformation on more granular aspects of supply chain capabilities such as information exchange, activity integration, responsiveness, and collaboration.

Third, the ongoing conflict between Russia and Ukraine and the gradual fading of the COVID-19 pandemic in 2023 have made scholars and practitioners realize the urgency of advancing research on supply chain capabilities and competitive performance in dynamic environments, in order to validate more strategies for addressing environmental uncertainty and help organizations cope with unpredictable risks [31]. Additionally, in the field of supply chain capabilities, most contributions are conceptual or based on mathematical models, often lacking empirical evidence. In response to these calls, this study collected rich primary data to provide empirical evidence for explaining the relationship between digital transformation, supply chain capabilities, and supply chain competitive performance under different levels of environmental uncertainty. By revealing the moderating role of environmental uncertainty, it further deepens the understanding of the relationship between digital transformation and supply chain competitive performance and expands the contingency theory by highlighting the importance of digital transformation in organizational contingencies.

6.3. Managerial Implications

First, this study provides management insights to enhance supply chain capabilities. As the research results confirm, digital transformation contributes to the improvement of supply chain capabilities and competitive performance. Therefore, efforts need to be made at various levels of society to promote digital transformation. 1. Enterprises should develop digital transformation strategies based on their resource endowments. They should systematically plan how to fully integrate digital technologies into their organizational processes and address issues such as an insufficient depth of resource integration by changing organizational structures and business processes. 2. Supply chain partners should widely accept and apply digital technologies. Promoting intra- and inter-organizational collaboration plans within the supply chain enables synchronous perception and sharing of information among supply chain partners. Close collaborative relationships in the supply chain further enhance partners' willingness to share information, creating a virtuous cycle. 3. Industry associations can take measures to enhance the digital transformation of enterprises. For example, they can encourage key enterprises in various industry chains to initiate digital transformation and lead the way. The design of digital systems should focus on high compatibility and open interfaces. This way, small-scale enterprises in the supply chain that lack resources to actively pursue digital transformation can also acquire supply chain capabilities such as information exchange, activity integration, business collaboration, and rapid response by joining existing digital platforms. 4. At the national level, efforts should be made to continuously upgrade digital infrastructure and focus on key areas of digital technology—accelerating the construction of information network infrastructure, enhancing the R&D capabilities of digital technology foundations, and promoting the inclusive power of scientific and technological innovation.

Furthermore, this study contributes to a better understanding among managers of the role of information exchange, activity integration, collaboration, and responsiveness—the four dimensions of supply chain capabilities—in organizational supply chain management. Enhancing these four aspects of supply chain capabilities helps build a relationship network characterized by high security, resilience, and deep integration, thereby strengthening the supply chain's competitive performance. This reminds organizations to efficiently

coordinate logistics, commercial flows, fund flows, and information flows along the supply chain by utilizing digital planning externally. Internally, business managers, operational managers, and financial managers should closely collaborate to integrate and manage business information, enabling enterprises to dynamically optimize supply chain capabilities and substantially enhance competitive performance.

Lastly, managers should recognize that the impact of digital transformation on improving supply chain competitive performance is influenced by environmental uncertainty. The higher the level of uncertainty in the environment, the more important it is to engage in digital transformation to enhance the stability of supply chain capabilities. Therefore, companies should be acutely aware of environmental changes, properly understand environmental uncertainties, and choose appropriate digital transformation strategies. Additionally, industry associations and government entities should provide a conducive institutional environment for the sustainable and healthy development of industrial supply chains. Optimal adjustments and improvements to institutional policies should be made to ensure that supply chains with high competitive performance are integrated while those with low competitiveness are strengthened, thereby promoting the efficient development of different industry supply chains as a whole.

7. Conclusions and Implications

The current research on supply chain capabilities has recognized the impact of digitization on enhancing supply chain competitive performance across different dimensions. However, this influence needs to be empirically analyzed and validated. Additionally, the multi-dimensional mediating role of supply chain capabilities (SCC) between digital transformation (DT) and competitive performance (CP) requires further exploration. Moreover, the moderating effect of environmental uncertainty on the relationship between digital transformation and supply chain competitive performance remains unclear. To address these research needs, this study was conducted.

First, a comprehensive framework of supply chain capabilities was applied in this study, which included four important dimensions: information exchange capability, collaboration capability, activity integration capability, and responsiveness capability. Then, the framework "DT→SCC→CP" was constructed for observation. Finally, a structural equation model was validated using questionnaire data collected from Chinese companies that described this framework.

The research findings indicate that digital transformation directly influences supply chain capabilities and supply chain competitive performance, with the four dimensions of supply chain capabilities playing a mediating role between digital transformation and competitive performance. Furthermore, the uncertainty of the external environment influences the impact of digital transformation on supply chain competitive performance. Specifically, under high external environmental uncertainty, digital transformation plays a more significant role in sustaining the competitive advantage of the supply chain. These findings not only expand the boundaries of digital transformation theory research from within organizations to the entire supply chain but also enrich the empirical research on the antecedents of supply chain competitive performance.

This study systematically reveals the process of capability changes brought about by digital transformation, leading to enhanced competitive performance and deepening the understanding of the theory of contingencies. The research results provide theoretical and practical support for the selective and gradual development of supply chain capabilities, helping companies achieve sustainable competitive advantages.

This study has certain limitations and provides avenues for future research. Firstly, the sample size and the industries and regions involved in this study were limited. The insufficient sample size may impose restrictions on the interpretation and generalizability of the results. Future research should aim to expand the sample size, collect more data from a broader range of regions and industries, and further validate the findings of this study to enhance the generalizability of the results. Secondly, this study argues that digital

transformation strengthens the dependence on and provision of supply chain capabilities in enhancing the supply chain ecosystem. However, it did not measure the reasonable degree of interdependence. It is encouraged that future research conducts measurement studies by comparing marginal costs and benefits. Thirdly, this study uses a cross-sectional dataset to test the relationships between hypotheses, which is limited in inferring causality. Future research can further validate the hypotheses' causal relationships by collecting longitudinal data.

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