Int. J. Production Economics 259 (2023) 108817

Contents lists available at ScienceDirect

International Journal of Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Impact of supply chain digitalization on supply chain resilience and performance: A multi-mediation model

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ARTICLE INFO

Keywords:
Supply chain digitalization
Supply chain resilience
Supply chain performance
Absorptive capability
Response capability
Recovery capability

ABSTRACT

The outbreak of COVID-19 has accelerated the building of resilient supply chains, and supply chain digitalization is gradually being recognized as an enabling means to this end. Nevertheless, scholars generally agree that more empirical studies will need to be conducted on how digitalization can facilitate supply chain resilience at various stages and enhance supply chain performance in a highly uncertain environment. To echo the call, this study develops a theoretical influence mechanism of "supply chain digitalization → supply chain resilience → supply chain performance" based on dynamic capability theory. The proposed relationships are validated using survey data collected from 210 Chinese manufacturing companies. The results help identify the paths digitalization and supply chain resilience can take to improve supply chain performance in a turbulent environment. The different roles of three supply chain resilience capabilities, namely absorptive capability (before the disruption), response capability (during the disruption), and recovery capability (after the disruption), which impact on supply chain performance differently, are highlighted. In addition, it is found that digitalization can bring a differential impact on these three supply chain resilience capabilities through different aspects of resource and structural adjustment measures. The findings also confirm the mediating role of absorptive capability, response capability, and recovery capability between digitalization and supply chain performance. During crisis, supply chain digitalization can increase cost-effectiveness, enhance information and communication efficiency, and promote supply chain resilience to achieve better performance. For theoretical contribution, this study enriches the research on supply chain digitalization and resilience by underpinning the relationships between the two with dynamic capability theory. For practical contribution, the research findings provide insights for enterprises to leverage digitalization to strengthen resilience in supply chain.

1. Introduction

Decentralized supply chain activities, complex supply chain networks, and volatile market environments can undermine the stability of supply chains and make them more vulnerable to disruptions and risks (Kamalahmadi and Parast, 2016; Pettit et al., 2010, 2019). For example, the sudden outbreak of the COVID-19 pandemic in such a massive scale has made it impossible for enterprises to predict in advance the extent of its impacts on business and the ripple effect. Almost all global supply chains have encountered different levels of disruptions in operation, which have severely affected the production flow of companies (Paul et al., 2021; Ivanov, 2020; El Baz and Ruel, 2021). Manufacturing industries, such as automobile, food, and pharmaceutical production, as well as service industries, such as airlines and hotels, have suffered from significant losses (Belhadi et al., 2021b; Rubbio et al., 2019; Soares et al., 2021). Take Toyota's domestic supplier, Kojima Press Industries, as an example. The company experienced problems with its internal systems due to COVID-19 and had to shut down its servers. As a result of this sudden supply disruption, Toyota's ordering system became inoperable which eventually led to complete close-down of all Toyota plants in Japan (Global. Toyota, 2022). To mitigate the impacts of disruptions caused by COVID-19 or other unexpected events, companies need to reconfigure their production systems, supply chain activities, and processes to cope. Improving supply chain resilience (SCR) is increasingly recognized by business practitioners and academics as an effective means to guard against disruptions and reduce supply chain vulnerabilities (Ivanov, 2017; Jüttner and Maklan, 2011; Pettit et al., 2013; Queiroz et al., 2022; Ivanov and Das, 2020; Naghshineh and Carvalho,

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https://doi.org/10.1016/j.ijpe.2023.108817
Received 17 April 2022; Received in revised form 19 December 2022; Accepted 19 February 2023
Available online 23 February 2023

2021; Li et al., 2022).

Despite the increased awareness, there is a need for more research on how to build SCR to risk. SCR is not only the ability to absorb disruptions but also the ability of a supply chain to respond quickly and return to its original or even better performance after disruption (Chowdhury and Quaddus, 2017. Singh et al., 2019). Realization of SCR requires firms to combine and adjust their resources, capabilities, and processes (El Baz and Ruel, 2021). However, some scholars argue that the concept of SCR is not clear enough, and the linkage with specific practical activities of enterprises is still vague. As such, future research needs to focus on how the concept of SCR with specific practical activities should be linked (Shen and Sun, 2021).

Most previous studies consider SCR a one-dimensional structure. Studies that consider it a multidimensional structure focus primarily on resilience strategies. Research covering all dimensions of SCR is limited (Alikhani et al., 2021; Parast, 2022). As such, there is a pressing need to evaluate the overall resilience capability of a supply chain. Findings from such research not only help managers understand the effectiveness of different strategies but also assist them in developing better risk response plans (Aldrighetti et al., 2021). With these considerations, this study raises the first and the second research questions as follows.

RQ1. What are the dimensions of SCR?

RQ2. How does SCR play a role in supply chain management and operation process?

Urban lockdowns, logistical disruptions, and changes in workplace and market environment have accelerated the process of supply chain digitalization (SCD), attracted widespread attention from companies, and become one of the hottest topics in operations management (Ardolino et al., 2022; Sawik, 2022; Holmström et al., 2019; Frank et al., 2019). Emergent technologies, such as big data analytics, blockchain, and artificial intelligence, have accelerated the digitalization of supply chain (Dubey et al., 2020b; Gawankar et al., 2019; Saberi et al., 2019; Song et al., 2021). Digitalization is a concept that emphasizes systematic use of data to empower production and operation activities, realize supply chain transformation and upgrading, and improve overall operational efficiency and quality development. SCD has changed the traditional supply chain operation mode and brought new products and business models (Eller et al., 2020).

Considering the advantages of digitalization, scholars have started to investigate how SCD can help companies improve SCR in crises, enabling them to recover quickly from disruptions to their original performance levels (Büyüközkan and Göçer, 2018; Stank et al., 2019; Hennelly et al., 2020). Most relevant studies have focused on discussing the role of digital technology application in resilience enhancement (Yang et al., 2021; Zouari et al., 2020; Belhadi et al., 2021c; Weking et al., 2020). However, digitally driven SCR enhancement is not only about adopting certain specific digital technologies to reduce risk but also integrating digital technologies into the whole SCR system and establishing a digital resilience management framework. Belhadi et al. (2022) state that a digitalized supply chain can promote supply chain visibility and enable flexible adjustment of structure, organization, and capabilities, improving product quality and enhancing supply chain efficiency while helping the supply chain achieve resilience. Ivanov et al. (2022) also points out that, in a digitally driven supply chain, structure and processes are dynamically changing and inherently self-adaptive. This dynamic structure can respond to the uncertainty of internal and external systems and provide higher resilience when disruption occurs. However, this digitally driven process of SCR enhancement needs to be validated by empirical studies to produce quantifiable results that can help guide enterprise resilience management practices (Hennelly et al., 2020; Ageron et al., 2020; Li et al., 2022; Seyedghorban et al., 2020; Belhadi et al., 2022).

Furthermore, some literature state that digitalization and SCR can contribute to higher performance levels. Again, empirical exploration of how supply chain performance (SCP) changes when SCD and SCR are applied to the supply chain simultaneously is needed. As such, this study raises the third and the fourth research questions as follows.

RQ3. How does digitalization contribute to SCR and SCP?

RQ4. What are the mechanisms involved?

To answer the research questions, this study firstly reviews and integrates the literature on the stages and the dimensions of SCR. Three significant dimensions of SCR, namely absorptive capability, response capability, and recovery capability, are conceptualized by combining the management practices of responding to risk at different supply chain stages. Secondly, recognizing the dynamic adaptation of supply chain digitalization and the resource requirements in developing SCR capability, an influence mechanism model depicted as "SCD→SCR→SCP" is constructed based on dynamic capability theory. Relevant hypotheses on the mechanism are proposed and a structural equation model is built to empirically analyze the data collected in a survey involving 210 Chinese manufacturing companies.

We believe that findings of this study can contribute to the existing field of research on SCR. First, by comprehensively reviewing and integrating the literature, this study establishes a system of indicators to measure the multiple dimensions of SCR. It reveals the stages of SCR and argues that SCR includes three dimensions, namely absorptive capability, response capability, and recovery capability. The study points out that the three SCR capabilities have a certain degree of independence, and as such companies can choose a flexible resilience strategy to suit their purposes. Through empirical research, the direct influence of SCD on the three SCR capabilities and SCP and the mediating role of the three SCR capabilities between SCD and SCP are thoroughly investigated. The results show that SCD during a crisis can improve absorptive capability, response capability, and recovery capability, thus achieving a better SCP. The findings demonstrate the structural changes and performance fluctuations that result from digitalization and resilience objectives taking effect at the same time. Furthermore, the findings highlight the effectiveness of response and recovery capabilities. These results extend the application of dynamic capability theory from within a firm to the entire supply chain. This study also provides practical suggestions for business managers to build digital and resilient supply chains strategically to cope with highly uncertain market conditions.

The rest of the article is arranged as follows. First, the definitions of relevant constructs are introduced. Then, the theoretical foundation and the research hypotheses are proposed. Next, the research methodology and how the data were analyzed to get results are described. Next, the findings and their theoretical and managerial implications are presented. Finally, the limitations of this paper and suggestions for future research are discussed.

2. Literature review

2.1. SCR

COVID-19 was one of the most significant disruptions in human history, severely disrupting the normal operational state of supply chains across the globe and causing catastrophic effects on companies (Ivanov and Dolgui, 2020; Queiroz et al., 2020). Global complex supply chain networks are intertwined and interdependent, making them more vulnerable to risk and uncertainty. Disruption at a supply chain node involving only a few companies can generate a ripple effect and result in the paralysis of the entire supply chain (Nikookar and Yanadori, 2022). In the current business environment, where the outbreak of the COVID-19 epidemic exacerbates uncertainty, and most businesses are unprepared, companies no longer limit their operational objectives to cost efficiency but also focus on improving their ability to cope with supply chain disruptions (Cappelli and Cini, 2020; Ivanov and Dolgui, 2020). SCR has long been regarded as a core supply chain capability to cope with disruptive events (Vanany et al., 2021). It can reduce vulnerability and help companies cope with disruptions to return to their previous operational state, if not better (Pettit et al., 2013; Sheffi and Rice, 2005). The COVID-19 epidemic has made SCR a top priority of companies and generated extensive discussions in both the academic and management circles (Gölgeci and Kuivalainen, 2020; Ketchen and Craighead, 2020; Raj et al., 2022).

SCR is a multidisciplinary concept involving psychology, engineering, ecology, and economics (Holling, 1973; Torabi et al., 2015). The definition of SCR is usually developed based on risk stages, including before, during, and after the disruptions (Sawik, 2017). Contemporary research has taken various theoretical perspectives to analyze SCR, the most popular of which is the capability perspective. From this point of view, SCR is seen as the ability of a supply chain to absorb the shock of a disruptive event, respond to the disruption, and recover quickly to its original state or to achieve a more optimal operational state (Ponomarov and Holcomb, 2009; Yu et al., 2019; Sheffi and Rice, 2005; Ali et al., 2017a). Enhanced SCR can help companies better cope with disruptions, reduce vulnerability and maintain business continuity (Vanany et al., 2021; Vali-Siar and Roghanian, 2022; Pettit et al., 2013; Sheffi and Rice, 2005). Unlike supply chain robustness, the concept of SCR highlights the response capability and recovery capability of supply chains to unknown risks (Brandon-Jones et al., 2014; Scholten et al., 2019; Ponomarov and Holcomb, 2009). Some factors, such as supply chain flexibility, redundancy, agility, visibility, collaboration, and supply chain learning, are increasingly recognized by scholars as capability elements that can enhance SCR. (Jüttner and Maklan, 2011; Hohenstein et al., 2015; Christopher and Peck., 2004; Dubey et al., 2014; Afraz et al., 2021).

Most of the previous studies treat SCR as a one-dimensional dynamic capability. However, as Parast (2022) illustrates, SCR is a multidimensional capability. The different dimensions require the development of different types of organizational resources and capabilities. Owing to the great variety of SCR capability elements, scholars are gradually conceiving a multidimensional SCR capability framework. Most of the current research regard SCR as a two-dimensional capability structure that includes proactive and reactive capabilities (Cheng and Lu, 2017; Ji et al., 2020; Wieland and Wallenburg, 2013; Llaguno et al., 2022). Proactive capability reflects the preparedness of an organization in activities before a supply chain disruption risk occurs. Reactive capability refers to the response and recovery activities after the occurrence of the risk. (Wieland and Wallenburg, 2013). Chowdhury and Quaddus (2017) develop a three-dimensional SCR framework based on dynamic capability theory comprising supply chain design quality, proactive and reactive capabilities. They analyze the role of SCR in influencing supply chain operational vulnerability and performance. Ali et al. (2017a) advocate a well-established division of SCR capabilities based on three phases: before, during, and after disruptions. Similarly, Hosseini et al. (2019) use the time attribute to identify three dimensions of SCR: absorptive capability (before the disruption), adaptive capability (during the disruption), and recovery capability (after the disruption). Furthermore, the competency elements included in the corresponding dimensions are identified. Ali et al. (2022) argue that SCR consists of three dimensions of capabilities: readiness capabilities, response capabilities, and recovery capabilities. Amalgamating the views of various scholars, this study puts forward a capability framework for SCR underpinned by dynamic capability theory and the stage characteristics of the supply chain in coping with disruption risk. Under this framework, SCR comprises three dimensions, namely absorptive capability (before disruption), response capability (during disruption), and recovery capability (after disruption). These three capabilities are independent in responding to disruptions. Because of such independency, firms need to integrate different resources to form the corresponding capabilities to respond to different types of disruptions (Parast, 2022). Absorptive and response capabilities highlight the endogenous capabilities of the supply chain while recovery capabilities reflect the exogenous capabilities (Hosseini et al., 2019). Absorptive capability emphasizes the ability of a supply chain system to absorb and withstand supply chain disruptions by using its original redundant resources and other risk preparation activities (Essuman et al., 2022; Hosseini et al., 2019). It is considered the first line of defense for supply chains to deal with disruption events (Hosseini et al., 2019).

A supply chain with absorptive capability means firms involved fully understand the state of supply chain operations and prepare accordingly before disruptive events occur (Parast, 2022). Therefore, absorptive capability reflects three SCR elements: supply chain situational awareness, redundancy, and visibility (Ivanov, 2021a,b; Mubarik et al., 2021; Ye et al., 2022). Visibility ensures that actors in the supply chain have access to timely and accurate demand and supply information (Kalaiarasan et al., 2022). Pettit et al. (2010) also mention that a supply chain should enhance visibility and perceive early risk signals to reduce supply chain disruptions. Chowdhury and Quaddus (2017) state that a supply chain should predict imminent risk before a disruptive event occurs. Early disaster prediction allows for the preparation of mitigating resources in advance, such as redundant inventory and multiple suppliers, which helps the supply chain use its resources and absorb some of the disruptions when the risk occurs (Ali et al., 2022; Knemeyer et al., 2009; Dabhilkar et al., 2016; Ivanov and Dolgui, 2018; Sheffi and Rice, 2005).

Response capability is a supply chain's ability to respond correctly to risk on time by adjusting the flow of activities and resource allocation in the face of a disruption event (Sheffi and Rice, 2005; Hosseini and Barker, 2016). Response capability is considered an essential determinant of SCR and is the second line of defense against supply chain disruptions (Hosseini et al., 2019). Response capability means that firms know what to do and can adjust their normal functions to respond to disruptions on time when faced with a highly uncertain market (Furstenau et al., 2022). Companies that respond quickly to market changes have a better chance of capturing market share and improving their position in the industry (Sheffi and Rice, 2005). Thus, response capability embodies three SCR elements of risk management decisions, agility, and collaboration (Jüttner and Maklan, 2011). A supply chain with a high level of response capability means that it can review the operational status of the supply chain promptly when the risk of disruption occurs, make rapid risk response strategies, and implement non-standardized practices to reduce disruptions (Christopher and Peck, 2004; Jüttner and Maklan, 2011).

Recovery capability refers to the ability of a firm to quickly reach its original operating or a better state by using optimal methods to resolve risk shocks quickly and cost-effectively in the later stages of risk occurrence (Chowdhury and Quaddus, 2017). Recovery capability is the last line of defense for supply chain systems against the risk of disruption. When absorptive and response capability cannot maintain the initial operational state, recovery capability needs to be urgently enhanced (Hosseini et al., 2019). Recovery capability emphasizes the reconfiguration of internal and external resources and capabilities to help the supply chain recover quickly to its initial state (Ali et al., 2022; Birkie et al., 2017; Zsidisin and Wagner, 2010). Thus, recovery capability embodies three elements of supply chain recovery efficiency, contingency planning, and knowledge management (Adobor and McMullen, 2018; Han et al., 2020; Raj et al., 2015). By integrating knowledge and information on disruption events and learning from feedback, companies can develop better plans and solutions for future supply chain operations and achieve a better operational state (Ponomarov and Holcomb 2009; Sheffi and Rice, 2005).

Companies must reconfigure their production systems, operational processes, and supply chain activities to withstand risk impact. In this regard, what factors are effective in improving SCR and how SCR can help companies improve their performance levels are areas that need to be explored in depth. (Munir et al., 2022; Queiroz et al., 2022; Ivanov and Das, 2020; Ali et al., 2017a). Scholars have begun to use empirical research to explore the antecedents and outcomes of SCR capabilities. For example, El Baz and Ruel (2021) demonstrate the role of risk management practices in influencing SCR based on a resource-based view and organizational information processing theory. Through the development and validation of theoretical model based on information process theory, Wong et al. (2020) report that SCR can positively affect risk management, market, and financial performance. Although resilience is regarded as an essential capability in a firm, it is more often considered a single-dimensional capability in previous studies. In fact, SCR is a multi-dimensional capability and the role of each dimension in the supply chain needs to be better understood. In addition, the mediating role of SCR needs further investigation to understand how SCR connects with the drivers and the outcomes (Wieland and Wallenburg, 2013; Chowdhury and Quaddus, 2017; Asamoah et al., 2020). With these objectives in mind, this study empirically investigates a whole framework of SCR capabilities to analyze the direct impact of individual SCR capabilities on SCP and their roles in mediating the impact of digitalization and performance (Ali et al., 2017b; Ivanov and Dolgui, 2020).

2.2. SCD

With the advent of the digital era, digital services for the supply chain and the analytical algorithms behind the supply chain have become the core competitive factors in the new era (Dolgui and Ivanov, 2021a,b). Especially since the outbreak of COVID-19, which caused city blockades and logistics disruptions, brought about the need for remote working, paperless operation, and supply chain structure reconstruction, which accelerated the pace of digital supply chain construction and helped companies to quickly cope with the risk of disruption (Ardolino et al., 2022). For example, the healthcare industry has pioneered the adoption of digital platform technologies and created digital operational solutions to facilitate the development of digital healthcare service processes (Chakraborty et al., 2021). Blockchain technology has also been gradually applied to the food supply chain to help core companies and other stakeholders to monitor and trace the food production process (Rogerson and Parry, 2020). To achieve the digitalization goal, companies introduce digital technologies and components, as well as other digital preparations such as digital strategy, digital organizational structure, digital culture, and digital talent (Gürdür et al., 2019; Li et al., 2022; Eller et al., 2020). The SCD driven by new technologies has also attracted more attention and research from academia and industry, observing the adjustments in business and supply chain activities brought about by SCD (Büyüközkan and Göçer, 2018; Stank et al., 2019; Hennelly et al., 2020).

SCD refers to the integration of digital technologies (such as big data, cloud computing, blockchain, Internet of Things, and artificial intelligence) into supply chain activities to form an operational process of "data-driven decision-making" (Colombari et al., 2022; Büyüközkan and Göçer, 2018; Hartley and Sawaya, 2019; Holmström et al., 2019; Caputo et al., 2021; Ageron et al., 2020). Integrating digital technologies into traditional supply chain activities generates a large amount of data and information. Leveraging the data analysis results to enhance the efficiency of specific business processes can add significant value to the supply chain. For example, Zhou et al. (2023) propose that the use of digital technologies such as smart contracts, digital storage, and intelligent labels enables traceability throughout the entire product lifecycle from raw material creation to final product delivery. This provides a digital traceability service and significantly improves the transparency and integrity of the supply chain. Unlike other related concepts such as digital transformation and digital technology adoption, SCD emphasizes the specific transformation of supply chain business processes and decision-making processes brought about by digital technology applications (Ageron et al., 2020; Richey et al., 2016). Battistoni et al. (2023) analyze the steps to achieve digitalization in enterprises and conclude that companies can extract valuable knowledge from data analysis results and improve existing operational processes through the four stages of collecting, integrating, processing, and analyzing data (Lu and Weng, 2018). Zhou et al. (2021) argue that digitalization can be categorized as either internal or external digitalization. Internal digitalization aims to reduce costs and improve the efficiency of internal operational processes. Internal digitalization includes digital information and communication technology solutions, such as video conferencing and email, as well as digital training and support for work tasks. External digitalization emphasizes reliance on digital technology to enhance interactions with stakeholders. Not only that external digitalization can reduce inter-company communication costs and facilitate partnerships with suppliers and other partners, but it can also accurately anticipate customer needs and increase customer loyalty. Colombari et al. (2022) analyze the digitalization process in digital technology application and data integration and conclude that digital technology applications can help companies optimize their operational processes and increase operational efficiency. The high level of data integration required for digitalization makes data more credible and available throughout the company, thus creating new structured processes and functions.

Proksch et al. (2021) argue that digitalization can be reflected in two main areas, namely digital products/services and digital processes. Non-digital companies offer non-digital products and services and rely mainly on manual processes. A highly digital enterprise provides complete digital products and services and operates with mature digital processes. Similarly, Truant et al. (2021) suggest that digitalization includes two aspects: (1) adding digital components to physical products to form digital products/services, and (2) empowering digital capabilities in operational processes to bring value-added products and services to the company. Kamalaldin et al. (2020) opine that digitalization contributes to the servitization (where customers pay for a service instead of buying the equipment) of manufacturing companies. Digital servitization creates a new digital business model and value-creation opportunities (Kohtamäki et al., 2019; Rachinger et al., 2018).

Existing research reveals the role of digitalization in enhancing performance levels. SCD can enhance supply chain visibility, connectivity, innovation, real-time, transparency, speed, etc., thus enabling nodal companies to better plan resources and build capabilities to meet the diverse needs of consumers (Culot et al., 2020; Frank et al., 2019). Digitalization in manufacturing can accelerate business innovation, improve resource efficiency and cost savings, and promote sustainable supply chains (Rossit et al., 2019; Haseeb et al., 2019). Ha (2022) measures digitalization from a macro perspective taking into consideration digital connectivity, internet use, e-business, e-commerce, and e-government. The findings demonstrate a positive impact of digitalization on the development of financial markets and financial institutions. Zhang et al. (2022) show that, by enhancing digital capabilities, buyer companies can improve the level of information sharing and relationship transparency between themselves and supplier firms. This can help reduce opportunistic and unethical behavior of suppliers and improve the buyer-supplier partnership.

Scholars have started to study the role of digitalization in a supply chain during crises. Studies have found that SCD can enhance SCR. Hald and Coslugeanu (2022) identify four critical resilience capabilities that can be enhanced by applying digital technologies, They include flexibility, visibility, risk management, and collaboration. Tseng et al. (2022) suggest that digital platforms can help companies gain timely insight into consumer demand, adjust sales processes and channels flexibly, and ensure business continuity during disruptions. Papanagnou et al. (2022) point out that predictive analytics, an emerging digital technology, can help supply chains quickly predict and respond to disruption risk issues and make timely risk management decisions, thereby enabling the supply chain to shift towards a complete and robust structure. Bianco et al. (2022) study the achievement of resilience in enterprises through digitalization. They conclude that application of digital technologies, such as big data, cloud computing, and the Internet of Things, in a supply chain can lead to intelligent management practices, such as improving production system autonomy and energy efficiency. Smart management practices enable the development of digital capabilities, such as digital culture and innovation capabilities, which can positively impact on SCR. Cui et al. (2022) state that digital technology adoption can impact on resilience by facilitating supply chain integration, including internal, customer, and supplier integration. Internal integration emphasizes the ability to enhance cross-functional collaboration through digital technology, which enhances internal process efficiency. External integration (including customer and supplier integration) can lead to collaboration between upstream and downstream partners, enhancing the response capability of the firm to the market. Naghshineh and Carvalho (2021) develop a detailed "AM-SCR" framework in which the disruptive digital technology of additive manufacturing (AM) will bring about a dynamic change in the state and the structure of the supply chain which can enhance SCR and mitigate supply chain vulnerability. Moreover, AM technology can facilitate the formation of duality dynamic capabilities (sensing capability, seizing capability, and reconfiguration capability) to reconcile the dilemma between SCR and supply chain efficiency (Belhadi et al., 2022).

Furstenau et al. (2022) contend that existing studies should have paid more attention to illustrating the role of digitalization in enhancing resilience capabilities in different dimensions. As such, they develop a SCR framework that identifies different dimensions of SCR, including anticipating capabilities, monitoring capabilities, responding capabilities, and learning capabilities. The aim is to analyze the differential impact of different digital technologies on these dimensions. The authors call for future research to validate these effects with large data samples. Furthermore, there also calls for further exploration of how digitalization can lead to SCP improvement in crisis scenarios (Pettit et al., 2019; Zouari et al., 2020). Achieving digitalization requires companies to gain insight into the market, remain open to new technologies and management styles, understand the opportunities presented by digital technologies, completely transform their core business, and find ways to leverage them to create value (Arias-Pérez et al., 2021). Digitalization is not restricted to adopting certain specific digital technologies to reduce risks. It also integrates digital technologies into the whole SCR process and establishes a digital resilience management framework. Therefore, the feasibility of and the extent to which SCD can contribute to improving the different SCR capabilities and SCP in various dimensions in a crisis scenario needs to be further examined empirically.

3. Theoretical background and hypothesis development

3.1. Theoretical background

3.1.1. Dynamic capability theory

Dynamic capability theory is developed from the resource-based view (RBV) (Teece et al., 1997). RBV argues that companies can achieve lasting competitive advantage because they have resources that are irreplaceable, valuable, rare, and difficult to imitate (Barney, 1991; Wernerfelt, 1984). Such resources include tangible and intangible human, financial, knowledge, and intellectual resources (Barney, 1991). The RBV perspective is constructed based on a static perspective and focuses on analyzing the competitive advantage of a firm's unique internal resources. Some scholars argue that in a dynamic environment, the original competitive dynamics may change, and the staticity of resources does not guarantee the continuity of competitive advantage (Warner and Wäger, 2019; Fainshmidt et al., 2016). Therefore, to explain strong competition in dynamic markets, scholars have developed the concept of dynamic capabilities based on the resource-based theory (Teece et al., 1997).

Dynamic capabilities are the ability of a firm to integrate, structure, and reconfigure internal and external resources and capabilities to adapt to a rapidly changing external environment (Eisenhardt and Martin, 2000; Wilden et al., 2013; Helfat and Peteraf, 2003; Teece, 2012; Winter, 2003). Compared to operational capabilities, dynamic capabilities enhance the firm's adaptability and are more difficult to replicate (Teece, 2014). Based on DCT, more is needed for companies to have scarce resources to gain a competitive advantage, but they also need to manage these resources effectively (Karimi-Alaghehband and Rivard, 2020). When the environment in which a firm operates is highly dynamic, the firm must be flexible to adjust its dynamic capabilities to respond to changes. Teece (2007) states that dynamic capabilities include perceiving opportunities and threats, seizing opportunities, and remaining competitive. Wang and Ahmed (2007) believed that dynamic capability is a comprehensive capability and identified three elements: adaptive capability, absorptive capability, and innovation capability. Wilhelm et al. (2015) also revealed three dimensions of dynamic capability: timely perception capability, learning capability, and resource reconfiguration capability. Hong et al. (2018) extended the extension of the dynamic capability to the supply chain level, including five evaluation dimensions of knowledge acquisition and absorptive capability, market-oriented perception capability, innovation capability, internal restructuring capability, and social network relationship capability.

The outbreak of COVID-19 exacerbates the environment's dynamism in which companies must collaborate, integrate, and reconfigure internal and external resources and capabilities to reduce disruptions (Ambulkar et al., 2015). SCR enables companies to perceive risk effectively before the onset of unexpected events and to quickly mobilize their resources and capabilities to respond and recover to their original level of operations in the face of unexpected events (Wieland and Durach, 2021). Companies that recover quickly can capture the market ahead of their competitors, maintain their existing competitive advantages, or create new ones (Jüttner and Maklan, 2011; Ali et al., 2017a; Kamalahmadi and Parast, 2016; Pettit et al., 2013). In conjunction with Teece (2007), dynamic capabilities are the ability of companies to perceive opportunities, seize them, and remain competitive. Consistent with the perception capability, the absorptive capability in SCR emphasizes the perception and prediction of risks and timely observation of market changes to prepare accordingly. Consistent with the ability to seize opportunities, supply chain response capability emphasizes the rapid adjustment of the supply chain's upstream and downstream resource structure. Consistent with maintaining competitiveness, SCR emphasizes the adoption of recovery means to recover quickly from disruptions and learn from disruptions to improve the competitive ability of the supply chain. Therefore, many scholars consider SCR a dynamic capability (Liu and Lee, 2018; Ruel and El Baz, 2021). Scholars have started to gradually adopt dynamic capability theory as a theoretical basis for studying SCR (Brandon-jones et al., 2014; Dubey et al., 2020b).

The arrival of the epidemic has accelerated the digitalization of companies. Digital technologies are used in supply chain processes to reduce production costs and enhance operational efficiency. However, they are standard capabilities that utilize existing resources and are insufficient to support companies to remain competitive in future markets (Warner and Wäger, 2019). The innovation of digital technology and the spreading of the epidemic have intensified the dynamism of the environment and the level of competition in the market, and companies are relying more on dynamic capabilities to integrate and reconfigure their resources in order to gain competitive advantage and high performance (Fainshmidt et al., 2019). The importance of digitalization is more reflected in the specific integration with supply chain operational processes to help develop dynamic capabilities that can adapt to the environment. SCR is seen as a dynamic capability that emphasizes timely risk anticipation, adequate resource mobilization, and reconfiguration of supply chain resources in crises to maintain competitive advantage and sustainable performance levels in a volatile environment. At this point, digitalization-driven resilience capabilities are a source of competitive advantage in a crisis environment. Companies that fail to develop these capabilities will likely be eliminated from the market. In the digital context, SCD enhances SCR in three ways: First, the application of digital technology enhances supply chain visibility and risk preparedness, helping companies analyze internal and external market information, predict risks in time, and enhance the ability to absorb disruptions (Rogerson and Parry, 2020). Second, using advanced digital technology enhances business process agility and flexibility and strengthens the collaboration of supply chain node enterprises, bringing the ability to respond to disruption risks. In addition, digitalization helps enterprises facilitate reconfiguring their internal and external resources to recover from the dynamic environment. Therefore, this paper adopts dynamic capability theory as the theoretical basis of this study to explore the relationship between SCD, SCR, and SCP in the context of digital development and epidemics.

3.2. Hypothesis development

3.2.1. SCD and SCR

Absorptive capability cannot be enhanced without adequate preparation of the supply chain before disruptive events occur, and the digitalization of the supply chain satisfies the need for risk preparation for absorptive capability. Digital technologies such as big data, IoT, and blockchain are gradually embedded in products and services, which helps companies extract a large amount of operational data and information from different supply chain members, facilitating the exchange of information among supply chain node companies (Frank et al., 2019). Moreover, blockchain technology improves the quality of data and information obtained by enterprises and provides an effective information base for supply chain visibility (Rogerson and Parry, 2020). This increase in visibility helps companies to anticipate risks and perceive changes in the environment before they occur, to more accurately forecast market demand, and to justify additional risk preparation (Yang et al., 2021; Ye et al., 2022; Wieland and Wallenburg, 2013; Chen et al., 2019). Other risk preparations such as redundant inventory and diversified procurement can be arranged in a reasonable way to enable the supply chain to absorb some of the perturbations and reduce the possibility of supply chain disruptions when risks come (Azadegan et al., 2021). At the same time, incorporating digital technologies such as artificial intelligence, machine learning, and big data into the supply chain process can better monitor and analyze supplier operations, eliminate poorly operated suppliers, and build a robust supply chain cooperation network, which will further mitigate the risk of stock-outs and enhance absorptive capability before the arrival of unexpected events (Ketchen and Craighead, 2020; Cavalcante et al., 2019). Based on these arguments, the following hypothesis is proposed.

H1a. SCD has a positive impact on absorptive capability.

The arrival of the epidemic changed the market structure, and the emergence of urban lockdowns and logistics disruptions, consumer demand shifting from non-essential to essential goods, and home-based offices exacerbated market dynamics (Ardolino et al., 2022). In order to capture market opportunities from disruption events and improve SCR, there is an urgent need for companies to improve their response capability to dynamic markets to withstand disruptions. Data analysis results generated by digital technologies such as big data and cloud computing can improve the accuracy and agility of managers' decision-making (Rajesh, 2016). Relying on digital platforms, work tasks can be quickly dispatched to various departments and segments of the enterprise, facilitating the coordination of resources, capabilities, and goals within the enterprise. Especially in urban lockdown scenarios, digital platforms can effectively address the need for telecommuting and assist in the rapid communication of corporate decisions (Munir et al., 2022). In response to changing market demands, digital manufacturing can improve supply chain resource management, reduce production and transportation costs, increase flexibility and agility in product design and production, and reduce time to market for new products, thus preventing supply chain disruptions (Christopher and Holweg, 2011). And, during a disruption event, a break in the original supply channel of the company may occur. Blockchain-driven digital business models enable diversified delivery channels, and when one channel is disrupted, the supply chain can quickly shift to other channels to deliver products and services to customers in a timely manner, enabling channel agility and response capability. Response capability cannot be improved without the collaboration of upstream and downstream partners in the supply chain. Digital platforms can define the role of each partner and improve the sharing of partner skills and information, which will optimize the effectiveness of supply chain resource allocation and provide the possibility of diverse collaboration (Tiwana, 2015; Wareham et al., 2014). Moreover, the establishment of digital platforms enables end-to-end supply chain connectivity, interweaving and integrating supply chain nodes to form a supply chain network structure that helps companies to maintain close communication with supply-capable partners in the event of disruptions (Dolgui and Ivanov, 2021a,b). At the same time, the digital platform integrates operational information of supply chain partners and enhances the level of trust, which will further facilitate resource allocation and collaboration at the whole supply chain level to achieve a high level of response capability (Dubey et al., 2020a; Yang et al., 2021). Based on these arguments, the following hypothesis is proposed.

H1b. . SCD has a positive impact on response capability.

Recovery capability emphasizes that in the late stage of disruption, enterprises can quickly and cost-effectively recover to the original or even better operation state through the re-integration of internal and external resources in the supply chain (Adobor and McMullen, 2018; Han et al., 2020; Raj et al., 2015). In the later stages of disruption, digital supply chains rely on powerful machine learning and simulation capabilities to effectively revisit the resources and capabilities within and outside the supply chain, helping companies to redefine their supply chain network development plans (Lohmer et al., 2020). This not only effectively reduces the recovery cost and recovery time of disruptions, but also reduces the scope of the supply chain in the disruption shock, which ultimately leads to a significant improvement in the recovery efficiency of the supply chain (Wang and Wei, 2007). Achieving the reconfiguration of internal and external resources and capabilities in the supply chain requires strong supply chain connectivity. Digital platforms enabling end-to-end connectivity of supply chain partners can accelerate the reconfiguration of upstream and downstream resources in the supply chain to improve SCR (Cavalcante et al., 2019). Moreover, based on the modularity advantage of the digital platform network, the open interfaces of the digital platform bring technical possibilities for flexible adjustment of the supply chain structure, helping the supply chain to introduce new partners and accelerate the integration of external resources and capabilities to achieve a better operational state. (Autio et al., 2021; Hald and Coslugeanu, 2021). In the process of synergistic resource integration with other companies, digital technologies such as blockchain can enhance trust between supply chain partners and encourage partners to exchange information, knowledge and other resources to help the supply chain reach a better operational state (Moshtari, 2016). The digital supply chain, with its strong intellectual learning capabilities, can better absorb the acquired knowledge and information and enhance the innovation capabilities of the company (Sousa and Rocha, 2019). The process of achieving innovation can bring novel ideas for supply chain restructuring, helping companies to return to their original state or to a better operating state (Cui and Idota, 2018). Based on these arguments, the following hypothesis is proposed.

H1c. SCD has a positive impact on recovery capability.

3.2.2. SCR and SCP

Increased absorptive capability reduces the volatility associated with disruptive events and safeguards the robust operation of the supply chain, giving the supply chain the opportunity and time to achieve higher profitability and greater market share (Azadegan et al., 2021). Increased absorptive capability means that supply chains can utilize redundant resources, such as redundant inventory and diversified procurement, to avoid failures and provide time for response planning, which positively impacts financial performance (Ruel and El Baz, 2021;

Wong et al., 2020; Han et al., 2020). Supply chains with high situational awareness and absorptive capability are able to quickly sense and respond to changes in the business environment and implement faster and more effective management measures, which reduces the likelihood of supply chain disruptions and leads to superior financial performance (Kamalahmadi et al., 2021; Yu et al., 2019). Context-awareness facilitates supply chain early warning strategies and business continuity planning, and identifying possible disruptions can fill supply chain gaps in time to mitigate risk shocks and maintain the original SCP (Pettit et al., 2010). Based on these arguments, the following hypothesis is proposed.

H2a. Absorptive capability has a positive impact on SCP.

Supply chain response capability emphasizes the ability of companies to quickly develop the right risk management strategies to respond to market changes when disruption events occur (Furstenau et al., 2022; Ali et al., 2022) Practitioners and scholars have demonstrated that the right risk management decisions can lead to agile and flexible responses to disruption risks, which contribute to better SCP (Dubey et al., 2022). A supply chain with stronger response capability enables rapid allocation of internal resources in an unpredictable environment, continuous improvement in product and service quality, and response capability to market demand, creating higher SCP (Han et al., 2020; Chowdhury and Quaddus, 2017). At the same time, the companies with high response capability tend to be more likely to collaborate horizontally and vertically with their supply chain partners to build more robust supply chain collaboration networks, which can reduce supply chain vulnerability (Skipper and Hanna, 2009) Meanwhile, supply chain collaboration helps supply chain partners to jointly develop business continuity plans and operational guidelines to reduce the level of endogenous risks. This will enhance the internal control of the supply chain to jointly protect against exogenous risks and improve the synergistic advantage of the supply chain, thus maintaining a steady improvement in performance levels during the disruption process (Revilla and Saenz, 2017; Shekarian and Parast, 2021). Based on these arguments, the following hypothesis is proposed.

H2b. . Response capability has a positive impact on SCP.

Improved supply chain recovery capability can reduce supply chain losses and lead to more significant operational performance (Ponomarov and Holcomb, 2009). From different dimensions of strategy, management and operations, rapid supply chain recovery enable companies to restructure their resources and capabilities to create new opportunities for value growth, thus contributing to good SCP and value creation (Carlucci et al., 2004). SCP depends to a large extent on the speed and scale of recovery actions. An increase in supply chain recovery efficiency implies a reduction in disruption time, which will reduce further threats to the supply chain from supply chain reactions and promote improved performance (Manupati et al., 2022; Han et al., 2020). In addition, improved resilience can speed up the process of developing quality services and products, facilitating the timely introduction of new products and helping companies to gain a higher market share, which has a direct impact on financial performance (Cegarra-Navarro et al., 2016; Rui et al., 2008). Based on these arguments, the following hypothesis is proposed.

H2c. Recovery capability has a positive impact on SCP.

3.2.3. SCD and SCP

SCD will bring extensive supply chain integration and increase the information sharing degree and data transparency of the entire supply chain to optimize supply chain processes, such as procurement, production, inventory management, and retail management, and ultimately improve the performance level (Bai et al., 2020; Fatorachian and Kazemi, 2020). The digital supply chain can effectively improve product quality and productivity as well as reduce production costs, thus improving supply chain operation performance (Saryatmo and Sukhotu, 2021). SCD combines digital procurement, digital production, digital sales, and digital logistics operation, which can extend the product life cycle and achieve sustainable performance improvement (Holmström and Partanen, 2014). Digitalization can integrate data from the supply chain system as well as platform and user through the strong ability of data analysis and accurate market analysis. This will accelerate the efficiency of product innovation, speed up the development of new products and services, and help enterprises occupy a larger market share, thus maintaining a leading market position and ultimately achieving a higher level of performance in a dynamic competitive environment (Hallikas et al., 2021). The application of blockchain and other digital technologies to the production and distribution of products will improve the level of product information disclosure, thus increasing the trust of sensitive consumers, stimulating their purchase desire, and increasing consumer surplus, which improves SCP accordingly (Choi et al., 2020). Based on these arguments, the following hypothesis is proposed.

H3. SCD has a positive impact on SCP.

3.2.4. Mediating role of SCR

SCR, as a special supply chain dynamic capability, plays a mediating role between SCD and SCP (Belhadi et al., 2021c). The integration of digital technologies with the existing supply chain processes of companies improves data visibility, enables digital business processes such as digital product design and manufacturing, improves operational efficiency, and reduces production costs, which can have a positive impact on SCP (Hald and Coslugeanu, 2021; Holmström et al., 2019; Ivanov, 2021). At the same time, the increased visibility brought about by digitalization facilitates risk perception and resource preparation and enhances absorptive capability (Ivanov and Dolgui, 2020). Absorptive capability is a guarantee of business continuity, allowing companies to operate robustly in the face of disruptive events and helping to translate their operational strategies into performance results (Hosseini et al., 2019). At the same time, the quantity and quality of acquired data are enhanced by digital technologies such as big data and cloud computing. Based on the powerful data analysis capability, digital supply chains can improve the response capability of companies to changes in corporate markets when disruptions come (Balakrishnan and Ramanathan, 2021). The increased response capability allows companies to maintain connections and collaboration with supply chain partners, quickly coordinate upstream and downstream supply chain resources, and ensure effective integration of SCD with supply chain business processes in the face of volatile competitive environments and high market demand uncertainty, thereby improving SCP levels (Ye et al., 2022; Munir et al., 2022). Moreover, recovery capability is the ability to quickly reconfigure supply chain resources to recover from supply chain disruptions after they occur (Hosseini et al., 2019). Digital supply chains can enhance the learning of supply chain knowledge and information to improve resilience during disruptions. Companies that recover quickly to their original state of operation or better than their competitors are able to maintain a leading competitive advantage in a volatile market, leading to long-term sustainable performance. In summary, SCD can improve absorptive capability, response capability, and recovery capability, which in turn can improve SCP. Based on these arguments, the following hypotheses are proposed:

H4. Absorptive capability mediates the relationship between SCD and SCP.

H5. Response capability mediates the relationship between SCD and SCP.

H6. Recovery capability mediates the relationship between SCD and SCP.

The digitalization of the supply chain can have a direct impact on

SCP through process efficiency improvement, and in a turbulent environment, digitalization can enhance the dynamic capability of SCR, enabling companies to achieve better performance and a competitive position in the market. Therefore, based on the dynamic capability theory and the above hypotheses, this paper establishes the analytical framework and theoretical model of "SCD→SCR→SCP" to analyze the direct impact of SCD on SCR and SCP, and the mediating role of SCR on SCP. Fig. 1 highlights the research model synthesizing the hypotheses and their relationships.

4. Research methods

In order to investigate the specific impact paths of SCD and SCR, after compiling the existing theories to derive the corresponding hypotheses, we use the survey method for empirical testing. The survey method is a self-explanatory method that relies on factual data and emphasizes the collection of empirical data and normative statistical analysis to derive a quantitative description of the variables (Flynn et al., 1990). Questionnaires are distributed mainly by e-mail, which enables data to be collected in a relatively short period of time and is considered the most economical method of data collection in empirical research (Scudder and Hill, 1998). Moreover, the researcher can design the content of the questionnaire according to his or her research questions and obtain primary data to meet the research needs (Baruch and Holtom, 2008). This method is not only able to verify existing theories, but also to combine existing theories with new fields and categories to expand the boundaries of theories and promote their development. Considering the advantages of the survey method, research in the field of supply chain management has also gradually introduced the survey method into empirical research, which has greatly contributed to the development of supply chain management theory (Zhao et al., 2008, 2013; Wong et al., 2020; Huo et al., 2014). Therefore, this paper adopts a questionnaire approach to explore the impact of digitalization on SCR and performance based on dynamic capability theory, explaining the quantitative relationship between variables and also complementing related theories to some extent.

4.1. Questionnaire design

The design of the survey questionnaire for data collection is as follows. Firstly, the research framework and the measurement indicators were derived according to the relevant theories and previous studies. Secondly, three groups of professionals in the field were invited to define the concept and adjust the semantics. The method of direct narration was adopted to avoid ambiguity in the questions of the questionnaire. Finally, 30 enterprises were selected to conduct a pre-test which was anonymous. Based on the feedback of the respondents, difficult and semantic questions with the unclear definition of constructs in the questionnaire were revised to produce the final version for use in the main survey. Table 1 shows the structure and measurement items used in this study. A 5-point Likert reflective scale is used to measure the response to the questions, where "1" stands for "strongly disagree" and "5" stands for "strongly agree".

SCD not only means the adoption of digital technology but also the application of digital technology in supply chain activities. The application of digital technology is not only reflected in the development and innovation of digital products and services, and the digitalization of supply chain processes, but also in the creation of digital business models (Weking et al., 2020). Therefore, our study established a three-item scale to measure the level of digitalization in the supply chain. Respondents were asked to indicate the extent to which their companies and supply chains adopted digital products and services, digital operation processes, and digital business models.

SCR is a comprehensive capability. Based on the viewpoints of Han et al. (2020) and Singh et al. (2019), according to different stages of SCR, this study divided the SCR into three sub-variables: absorptive capability, response capability, and recovery capability. In this study, absorptive capability was measured by three dimensions: supply chain situational awareness, supply chain redundancy, and supply chain visibility. Respondents were asked to evaluate the situational awareness, redundancy, and visibility of their company and supply chain. Response capability was measured by three dimensions: supply chain risk management decisions, agility, and collaboration. Respondents were asked to evaluate the accuracy of risk management decisions, agility, and collaboration of their company and supply chain. Recovery capability was measured by three dimensions: supply chain recovery efficiency, contingency planning, and knowledge management. Respondents were asked to evaluate the recovery efficiency, contingency planning, and knowledge management skill of their company and supply chain.

SCP can measure the overall efficiency of the supply chain (Gunasekaran et al., 2001; Beamon, 1998). SCP is not only concerned with the performance of a single enterprise but also reflects the operation status

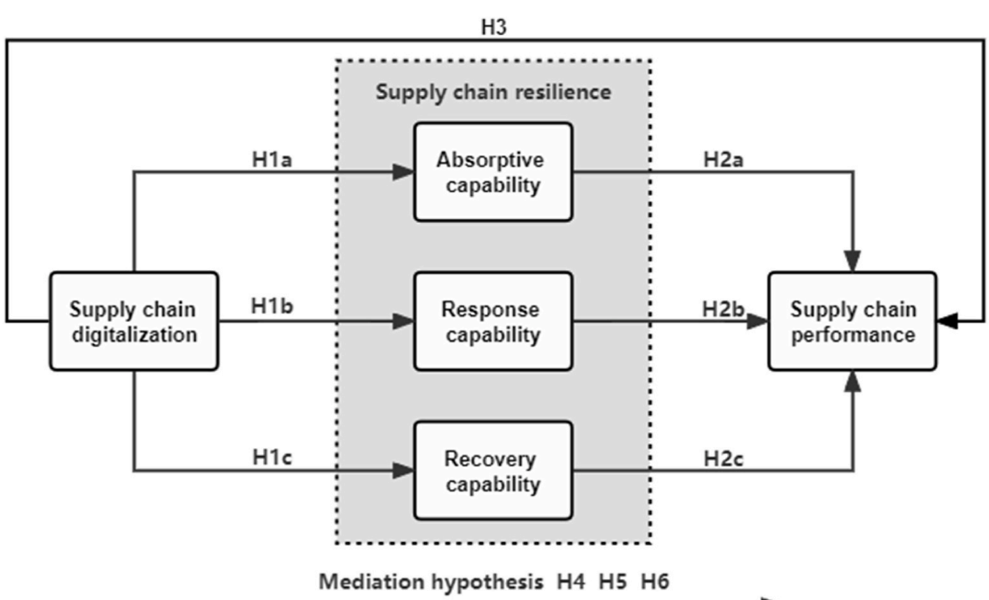

Fig. 1. Research model.

Table 1
Constructs and indicators.

Construct/Items		Definition	Indicator	Adapted from
SCD				
SCD1	Digital products and Services	Products and services based on digital technology that bring digital capabilities to consumers	We have adopted digital products and services	Ageron et al. (2020) Hallikas et al. (2021) Weking et al. (2020)
SCD2	Digital operation process	Management and operation mode based on digital technology, including digital manufacturing, digital working and so on	We have adopted digital operation management	Frank et al. (2019)
SCD3	Digital business model	Business models based on digital technology, including mass customization, product service systems, open innovation and so on	We have adopted digital business model	
Absorptive capability				
ASC1	Redundany	The excess resources in supply chains, including redundant inventory, diversified supplier selection and so on	We can have redundant resources in place prior to the onset of disruptions	Ivanov (2021) Ye et al. (2022) Mubarik et al. (2021) Adobor and McMullen (2018)
ASC2	Supply chain visibility	The ability to obtain high-quality data information reflecting supply chain operations, including supply visibility, demand visibility and market visibility	We can achieve a high level of data visibility	(Brusset and Teller, 2017)
ASC3	Situational awareness	The ability to anticipate and perceive the possible disruption risks	We were able to maintain a high level of situational awareness and crisis prediction	
Response capability				
RSC1	Correct risk management decisions	The ability of managers to make instructive risk response plans when risks arise	We are able to make the right risk management decisions at the time of disruptions	Jüttner and Maklan (2011) Singh et al. (2019) Sheffi and Rice (2005) Chowdhury and Quaddus (2017)
RSC2	Agility	The ability to respond quickly to unpredictable changes from markets and the natural environment	We are able to provide a quick response to supply chain disruptions	
RSC3	Supply chain collaboration	Collaboration means that partners at each node of the supply chain network can exchange information resources and other resources with each other to achieve benefit sharing	We are always able to maintain supply chain connectivity and collaboration at the time of disruptions	
Recovery capability				
RCC1	Recovery efficiency	The ability to return to business status in a short time and at low cost	We are able to speedily and efficiently return to normal operations after being disrupted	Han et al. (2020) Ponomarov and Holcomb (2009)
RCC2	Contingency planning	The ability to perform supply chain scenario analysis, and next phase continuous business planning with the results of disruption analysis	We were able to restructure resources and develop new supply chain continuity business plans after being disrupted	Altay et al. (2018) Ambulkar et al. (2015)
RCC3	Knowledge management	The ability to learn from interrupted feedback to gain a greater competitive advantage	We are able to extract useful knowledge from disruptions and achieve better supply chain operations after being disrupted	
SCP				
SCP1	Operating cost	Refers to the cost in the process of production and operation, including production cost, transportation cost and inventory holding cost and so on	We were able to save more on operating costs	Wamba et al. (2020) Gu et al. (2021) Katiyar et al. (2018) (Beamon, 1999)
SCP2	Return on investment	An economic return from an business investment	We can achieve a better return on investment	
SCP3	Lead time	The time period from order to delivery	We are able to achieve shorter lead times	
SCP4	Customer Satisfaction	The degree to which a customer's needs or expectations have been met, including after-sale service efficiency and out-of-stock rate	We are able to meet customers' diversified product requirements	

of the entire supply chain. Performance measurement can help enterprises to review achievements, set development goals, and determine the direction of future action (Gunasekaran et al., 2004). Gunasekaran et al. (2001) believed that SCP measurement should not only include financial performance related to cost but also comprehensively cover non-financial indicators related to output. Beamon (1999) proposed that SCP should be measured from three aspects: resource, output, and flexibility. Based on the viewpoints of Beamon (1999), SCP was measured by four dimensions: operating cost, return on investment, lead time, and customer satisfaction. Respondents were asked to evaluate the extent to which their company and supply chain fit these four items.

4.2. Sampling and data collection

The survey objects of this study are manufacturing enterprises with a certain level of digitalization located in the Yangtze River Delta region of China which are greatly affected by supply chain disruptions. Compared with other regions of China, the Yangtze River Delta region is more developed in the economy and the manufacturing industry is more concentrated. Enterprises in this region are more deeply involved in supply chain management, As the region is rapidly developing, companies therein are more inclined to adopt digital management to gain their competitive advantages. In this study, the questionnaire design, sampling process, and distribution of the questionnaire all followed strict empirical analysis steps. The questionnaires were distributed to the middle and senior management of enterprises to ensure that the collected data reflect accurately the operating conditions of the surveyed enterprises. The questionnaires were distributed through email, online survey, and on-site survey. Telephone and e-mail reminders were used to improve the response rate. In total, 976 questionnaires were distributed and 235 of which were returned. Invalid questionnaires with many missing values were removed and finally, 210 valid questionnaires were retained, with a response rate of 21.5%.

Table 2 gives a profile of the respondents. In this study, respondents included senior executives (8.1%), senior managers (22.4%), managers (18.1%), first-line managers (33.8%), and others (17.6%), which means that respondents were better equipped to solve complex supply chain system problems of their companies and had a better understanding of supply chain operations and digital technology applications (Gu et al., 2021). The survey covered a wide range of manufacturing industries, including publishing and printing, electronic products and appliances, chemicals and petrochemicals, textiles, and apparel, etc. There were different types of manufacturing enterprises, including state-owned enterprises, private enterprises, foreign enterprises joint venture enterprises, and others. In terms of company size, 82.4% of the sampled enterprises had annual operating revenue of more than CNY 10 million, and more than half of the enterprises had more than 500 employees. The sample chosen was considered representative of the population.

4.3. Common method bias and non-response bias

To ensure the reliability of the results, the sampled data were tested for any common method or non-response bias.

First, the common method bias problem was examined. Following the suggestions of Podsakoff et al. (2003), common method bias was tested before and after the questionnaire collection process. After data collection, both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) methods were used to conduct a single-factor test to check for common method deviations. First, the EFA method was used to conduct the Harman single-factor test (Podsakoff and Organ, 1986). The results showed that the first factor accounted for 44.6% of the total variance, less than the threshold of 50%, indicating that our research model was not significantly affected by common method bias. Then, CFA was applied to Harman's one-factor test and all items of the constructs were placed in a single factor. The results showed that the model fit indices of the single-factor model (CMIN/DF = 9.504, CFI = 0.584, IFI = 0.587, RMSEA = 0.202, and SRMR = 0.123) were obviously unacceptable and considerably worse than those of the original measurement model (CMIN/DF = 2.778, CFI = 0.919, IFI = 0.920, RMSEA = 0.092 and SRMR = 0.1142), indicating that all measurement items should not belong to a single factor. Therefore, based on CFA and EFA results, it was concluded that common method bias was not an issue in this study.

Second, the problem of non-response bias was examined. Referring to the method of Armstrong and Overton (1977), a comparative analysis between early and late respondents was conducted. T-test results showed that there was no significant statistical difference in the number of employees and sales ($p > 0.05$). This indicated that the problem of non-response bias did not significantly affect the data results in this study.

5. Analyses and results

5.1. Reliability and validity

EFA and CFA were used to evaluate the reliability and validity of the focal constructs. In this study, the internal reliability of the scale was tested using EFA to find out whether there was a high internal consistency between items. SPSS26.0 software was used to test the reliability of the scale. The results are shown in Table 3. Cronbach's α values are all greater than 0.75 and composite reliability is greater than 0.8, indicating that the scale has good internal consistency (Bagozzi et al., 1981; Hair et al., 2017).

Structural validity was verified using CFA. The analysis results of convergent validity and discriminant validity are shown in Table 3. All factor loadings are greater than 0.7 and all the average variance extracted values (AVE) are greater than 0.5, and the composite reliability is greater than 0.7. Therefore, this scale has high convergent validity (Bagozzi et al., 1981). Discriminant validity was confirmed by comparing the square root of the AVE value for each construct with the correlations between this construct and other constructs. When the square root of AVE on the diagonal is greater than the correlation between this construct and other constructs, it indicates that the constructs have good discriminant validity (Bagozzi et al., 1981). It can be seen from the results in Table 4 that our results meet the requirements of

Table 2
Demographics of respondents.

Characteristics of respondents (N = 210)	Frequency	Percentage (%)	Characteristics of respondents (N = 210)	Frequency	Percentage (%)
Industry			others	4	1.9
Publishing and printing	10	4.8	**Number of employees**		
Electronics and electrical	28	13.3	≤100	36	17.1
Textiles and apparel	15	7.1	101–500	64	30.5
Chemicals and petrochemicals	21	10.0	501–1000	36	17.1
Building materials	10	4.8	>1000	74	35.2
Metal, mechanical and engineering	33	15.7	**Firm sales (million CNY)**		
Wood and furniture	8	3.8	≤10	37	17.6
Food, beverage, and alcohol	19	9.0	11–50	36	17.1
Rubber and plastics	14	6.7	51–100	41	19.5
Pharmaceutical and medical	9	4.3	≥101	96	45.7
others	43	20.5	**Position**		
Firm nature			Senior executive	17	8.1
State-owned	28	13.3	Senior managers	47	22.4
Joint venture	34	16.2	Managers	38	18.1
Private	71	33.8	First-line managers	71	33.8
Foreign owned	73	34.8	others	37	17.6

Table 3
Construct reliability and validity analysis.

Construct/ Items	Loadings	Composite Reliability (CR)	Average Variance Extracted (AVE)	Cronbach's α
SCD		0.916	0.785	0.915
SCD1	0.830			
SCD2	0.905			
SCD3	0.920			
Absorptive capability		0.875	0.699	0.872
ASC1	0.858			
ASC2	0.836			
ASC3	0.814			
Response capability		0.813	0.593	0.813
RSC1	0.810			
RSC2	0.750			
RSC3	0.748			
Recovery capability		0.862	0.677	0.861
RCC1	0.787			
Construct/ Items	**Loadings**	**Composite Reliability (CR)**	**Average Variance Extracted (AVE)**	**Cronbach's α**
RCC2	0.885			
RCC3	0.793			
SCP		0.885	0.659	0.885
SCP1	0.832			
SCP2	0.860			
SCP3	0.771			
SCP4	0.781			

Table 4
Discriminant validity using AVE.

	AVE	RCC	SCP	RSC	ASC	SCD
RCC	0.677	**0.823**				
SCP	0.659	0.582	**0.812**			
RSC	0.593	0.706	0.534	**0.770**		
ASC	0.699	0.481	0.329	0.704	**0.836**	
SCD	0.785	0.566	0.520	0.492	0.462	**0.886**

Note: Supply chain digitalization (SCD); Absorptive capability (ASC); Response capability (RSC); Recovery capability (RCC); SCP (SCP).
Square roots of average variances extracted (AVEs) shown on diagonal.

acceptable discriminant validity.

A structural equation model, a method based on covariance analysis, was used to test the relationships between constructs and explore our hypothesis testing results. AMOS26.0 software was used to analyze the measurement model and the structural model. Firstly, we tested the fitness of our model, and the results showed that the measurement model provided a good fit to the sample data (CMIN/DF = 2.778, CFI = 0.919, IFI = 0.920, TFI = 0.900, RMSEA = 0.092) (Hu and Bentler, 1999). Meanwhile, SPSS26.0 software was used to conduct multiple regression analyses on the structure of our prediction model. The test results showed that the range of variance inflation factor (VIF) values was between 1.442 and 1.967, all below 2 (Hair et al., 2017). It showed that multi-collinearity was not a problem in our study. Given the complexity of our models, we examined the explanatory power of the research model based on explained variance (R^2) and predictive power based on Stone-Geisser's Q^2. The explained variance (R^2) of the endogenous variables was ASC (0.25), RSC (0.29), RCC (0.35), and SCP (0.41). It can be seen that in our model, all the values of R^2 are in the range of 0.25–0.50, which meets the empirical requirements (Hair et al., 2017). We conducted the classic Stone-Geisser's Q^2test to measure the predictive relevance (power) (Wamba et al., 2020; Stone, 1974). This test is conducted by a blindfolding algorithm, which in turn performs a determined number of resamples (Chin, 1995). Values of Q^2greater than zero are considered to have good prediction power of the research model (Hair et al., 2019). Stone-Geisser's $Q^2$for endogenous constructs are ASC (0.128), RSC (0.113), RCC (0.193), and SCP (0.241). All the values of $Q^2$are greater than zero, indicating there is an acceptable predictive relevance in our model (Peng and Lai, 2012; Hair et al., 2019).

5.2. Hypothesis testing

As shown in Fig. 2, the correlation and the significance of the structural model relationships were first evaluated using AMOS26.0 software to verify our hypotheses (H1a, H1b, H1c, H2a, H2b, H2c, H3). Fig. 2 shows the path analysis results, including standardized path coefficients, significance and the value of variance explained. Table 5 summarizes the specific statistical results of the hypothesis tests.

H1a, H1b, and H1c respectively studied the influence of SCD on absorptive capability, response capability, and recovery capability. As shown in Table 5, SCD had positive and significant effects on absorptive capability ($\beta = 0.408$; $p < 0.001$), response capability ($\beta = 0.397$; $p < 0.001$), and recovery ability ($\beta = 0.428$; $p < 0.001$). Therefore, hypotheses H1a, H1b, and H1c were all supported. At the same time, hypotheses H2a, H2b, and H2c respectively studied the effects of absorptive capability, response capability, and recovery capability on SCP. The results showed that response capability ($\beta = 0.279$; $p < 0.01$) and recovery ability ($\beta = 0.338$; $p < 0.001$) had a significant positive impact on SCP, while absorptive capability ($\beta = -0.088$; $p = 0.224$) had a negative and insignificant impact on SCP. So, hypotheses H2b and H2c were supported, while H2a was not. Meanwhile, H3 studied the influence of SCD on SCP, and the results showed that SCD ($\beta = 0.202$; $p < 0.05$.) had a significant positive impact on SCP.

H4, H5, and H6 respectively studied the mediation effect of absorptive capability, response capability, and recovery capability on the relationship between SCD and SCP. Bootstrapping application was used to test the mediating effects (Baron and Kenny, 1986). As can be seen from the above statements, the paths from SCD to resilience in three stages were all positive and significant, and the paths from the response and recovery capability to SCP were also positive and significant. Furthermore, the bootstrapping with 5000 resamples was executed to test the mediating effects of absorptive capability, response capability, and recovery capability (Preacher and Hayes, 2008). The results are shown in Table 6. The indirect impact of SCD on SCP was positive and significant through response capability (indirect effect = 0.111, SE = 0.065) and recovery capability (indirect effect = 0.145, SE = 0.069). However, the indirect effect of SCD on SCP through absorptive capability (indirect effect = −0.036, SE = 0.044) was negative and insignificant. Meanwhile, the bias-corrected 95th percentile confidence interval (CI) for the indirect influence on SCP was [0.073, 0.431], which did not contain zero. Therefore, considering the direct impact of SCD on SCP was significant and positive, it could be seen that response capability and recovery capability had a partial mediation effect, while absorptive capability did not have the mediation effect. Therefore, this study supported H4 and H5 but did not support H3.

5.3. Tests for endogeneity

We discussed possible endogeneity issues below. SCD may be endogenously affected by SCP, and such reverse causality may lead to inconsistency and bias of our results (Li et al., 2020). In order to solve this problem, this study adopted the Hausman test proposed by Davidson and MacKinnon (1993). We used firm sales as a potential instrumental variable because this variable had no significant direct effect on SCP (Yu et al., 2019). In addition, Frank et al. (2019) pointed out that larger companies were more willing than smaller ones to digitally transform their supply chains. We established the first-stage regression model with SCD as the dependent variable. The results showed that there was a significant correlation between firm sales and SCD ($\beta = 0.150$, $t = 3.73$, $P < 0.05$), and the prediction of the first-stage model

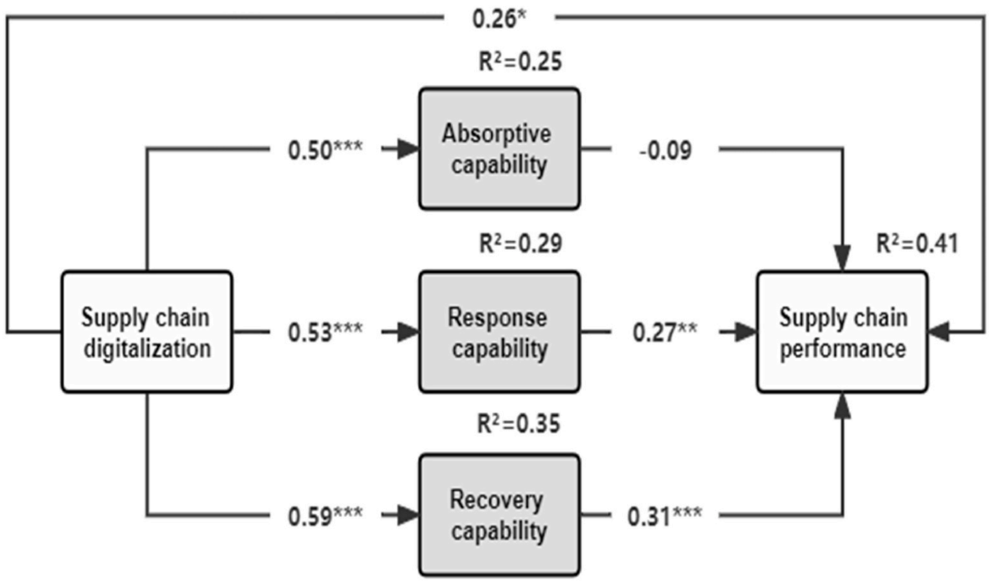

Fig. 2. Structural modeling results. + $p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 5
Summary of the hypothesis test results.

Hypothesis	Causal path	Estimate	S.E.	*p*	Hypothesis supported
H1a	SCD→ASC	0.408	0.497	***	Yes
H1b	SCD→RSC	0.397	0.534	***	Yes
H1c	SCD→RCC	0.428	0.594	***	Yes
H2a	ASC→SCP	−0.088	−0.093	0.224	No
H2b	RSC→SCP	0.279	0.265	**	Yes
H2c	RCC→SCP	0.338	0.312	***	Yes
H3	SCD→SCP	0.202	0.259	*	Yes

Note: Supply chain digitalization (SCD); Absorptive capability (ASC); Response capability (RSC); Recovery capability (RCC); SCP (SCP)+ $p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 6
Results for the mediation.

Hypothesis	Causal path	Estimate	S.E.	Bias-corrected 95%CI		
				Lower	Upper	*p*
H4	SCD → ASC → SCP	- 0.036	0.044	−0.133	0.041	0.355
H5	SCD → RSC → SCP	0.111	0.065	0.008	0.271	*
H6	SCD → RCC → SCP	0.145	0.069	0.032	0.302	*
	TOTAL	0.220	0.088	0.073	0.431	**

Note: Supply chain digitalization (SCD); Absorptive capability (ASC); Response capability (RSC); Recovery capability (RCC); SCP (SCP).
Standardized estimating of 5000 bootstrap samples.+ $p < 0.1$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

was obtained. Then, we included this residual in the second-stage regression model with SCP as the dependent variable and found that there was no significant relationship between the residual and SCP ($\beta = -0.187$, $P = 0.423 > 0.05$), which indicated that reverse causality was not a serious problem in our model setting. Therefore, it can be concluded that endogeneity is not an issue affecting the results of our study.

6. Discussion and implications

6.1. Discussion of study findings

This study investigates the quantitative relationship between SCD, SCR and SCP. By distributing questionnaires to manufacturing industries in the Yangtze River Delta region of China and using structural equations to analyze the collected data in a normative manner, the study reveals the paths and effects of SCD on SCR and SCP in a crisis situation. The specific research results will be presented in the following four aspects.

First, SCD has a positive impact on SCP. This is consistent with the results obtained by many scholars (AlMulhim, 2021; Frank et al., 2019). In the context of the digital economy, the integration of digitalization with supply chain processes helps companies to form digital operational processes, improve the efficiency of supply chain operations, and save operational costs (Ivanov, 2020). Embedding digital technologies and components into products and services can be more conducive to collecting information and data from suppliers and from consumers, and the analysis results can guide companies to conduct better product development and promotion, meet the diversified and customized needs of consumers, and improve SCP (Ivanov et al., 2022). At the same time, through the digital business model, companies implement online and offline delivery channels, which can help them create multiple revenue opportunities. At the same time, the digital supply chain maintains open interfaces to facilitate end-to-end connectivity with supply chain partners, creating an open ecosystem and improving the long-term profitability of the company.

Second, SCD has a significant positive effect on SCR. SCD had a significant positive effect on absorptive capability. This result is consistent with Liu et al. (2013). Supply chain absorptive capability emphasizes the use of a firm's own resources and capabilities to absorb a portion of shocks when disruptive events occur. By establishing a digital business development model that shifts product and supply chain operations from offline to online, supply chain visibility can be greatly enhanced, thus maintaining information sharing between upstream and downstream of the supply chain and achieving good risk preparedness (Ivanov, 2021a,b; Li et al., 2022). At the same time, digital supply chains can enable the capture of risk signals, maintain a high degree of situational awareness, reduce the likelihood of supply chain disruptions, and improve absorptive capability (Kache and Seuring, 2017; Wagner et al., 2009). With powerful data analysis capabilities, digital supply chains can develop sound inventory management strategies that can fully mobilize inventory and enhance the risk-absorptive capability of the supply chain when risks come. (Cavalcante et al., 2019). Meanwhile, existing digital technologies such as blockchain can bring smart contracts into the transaction process (Manupati et al., 2022). The speed, transparency, and high reliability of smart contracts also facilitate the establishment of cooperative relationships among supply chain partners, improve the robustness of supply chain networks, and enhance resistance to risk (Lohmer et al., 2020; Saberi et al., 2019). Therefore, this study provides empirical support for the facilitative effect of SCDs on absorptive capability.

SCD has a significant positive effect on response capability. This result is consistent with Dolgui an Ivanov (2021a,b). Response capability emphasizes the ability to make quick risk response decisions when risks occur, mobilize resources flexibly, communicate with partners in a timely manner, and optimize overall supply chain resource allocation (Cabral et al., 2012). Digital platforms can help internal departments and supply chain partners to communicate online, even in the case of urban lockdown (Frank et al., 2019). Through digital technologies such as big data analytics and artificial intelligence, the supply chain can integrate operational and environmental data to quickly generate effective, visual decisions in response to disruptions (Ivanov et al., 2019). This can be more objective and accurate than traditional risk response plans based on managers' personal experience and judgment (Singh and Singh, 2019). At the same time, a digital supply chain has the advantages of streamlined operational processes and efficient collaboration, which greatly increases the efficiency of employees and managers, thus improving the efficiency of resource integration when risks occur (Ganbold et al., 2020). At the same time, companies upstream and downstream of the supply chain can effectively share data on resources, operating conditions, environmental conditions, and risk indices after digitalization (Ivanov et al., 2022). This allows companies in the supply chain to make joint decisions about new technologies, new production lines, and new products when they face risks, ensuring supply chain flexibility (Shukor et al., 2020). Therefore, this study provides theoretical support for the positive impact of supply chain sustainability on supply chain response capability.

SCD would also have a significant positive impact on recovery capability. This assertion is in line with Chen et al. (2019). Recovery capability emphasizes the ability of a supply chain to quickly return to its original level of operation, or even better after the interrupt event has occurred (Chowdhury and Quaddus, 2017). By adding digital technology into existing management, supply chains can quickly and effectively develop operational strategies and integrate resources, thus minimizing the shortcomings of traditional supply chains that are costly and inefficient (Carlucci et al., 2004). At the same time, the digital supply chain advocates win-win cooperation and benefit sharing, which will effectively promote supply chain partners to agree on common risk preparation and cooperative planning. The integration of existing risk data into the original decision database through digital technology can guide managers to better make more rational management decisions and business plans (Belhadi et al., 2021a). In addition, supply chain information and knowledge sharing bring an increased level of learning to the supply chain. Upstream and downstream companies in the digital supply chain can extract knowledge, exchange knowledge, and learn knowledge from disruptions, thus promoting innovation in the supply chain and achieving better business status (Rui et al., 2008). Therefore, this study also provides an empirical explanation for the positive impact of SCD on recovery capability.

Third, SCR has a significant positive effect on SCP. Absorptive capability does not promote the improvement of SCP, and may even have a negative impact, while response and recovery capability have a significant positive impact on SCP. Response and recovery capability reflect the ability of the supply chain to respond in time, allocate resources reasonably, recover quickly and achieve better business conditions when the risk occurs (Chowdhury and Quaddus, 2017; Sheffi and Rice, 2005). Obviously, the more responsive and resilient the supply chain is, the less likely the supply chain will suffer from disruption loss, which will have a positive impact on SCP (Tukamuhabwa et al., 2015). However, absorptive capability does not have a significant positive effect on SCP, which is inconsistent with previous scholars' views. For this result, this paper argues that absorptive capability emphasizes that companies use their existing resources and capabilities to resist risk shocks. However, supply chains with higher absorptive capability tend to store more redundant inventory and cash flow, arrange diversified procurement rather than single procurement, and invest more resources in risk perception and visibility, which are contrary to the business objectives of lean production and cost minimization (Govindan et al., 2013; Pettit et al., 2013). Excessive SCR preparation will erode profits to a certain extent, and thus have a certain negative impact on the supply chain level, which is consistent with the view of Fraccascia et al. (2020). Therefore, the impact results of the three resilience capabilities on SCP in this study also provide empirical support for the impact of SCR on SCP.

Fourth, different SCR capabilities have different mediating roles. This study supports the mediation effect of response and recovery capability. However, it does not support the mediation effect of absorptive capability, which particularly explains the mechanism among SCD, SCR, and SCP. It concludes that the establishment of SCD will not only have a direct impact on SCP but also enhance risk response efficiency and risk adaptability of a supply chain by improving response and recovery capability, thus bringing a stronger improvement to SCP (Chowdhury and Quaddus , 2017; Chen et al., 2019), 2016. As for the mediation path of absorptive capability, this study believes that the improvement of SCD can indeed enable the supply chain to fully mobilize redundant inventory and improve visibility and situational awareness accuracy. However, the elements building of the absorptive capability, such as visibility and redundancy, also requires additional infrastructure support, such as digital development costs, inventory management costs, and supply chain visual network construction costs (Govindan et al., 2013). The increase in these costs can erode SCP and therefore this intermediary path is not supported.

6.2. Theoretical implications

This study takes 210 manufacturing companies as the research objects, builds an inner influence mechanism of "SCD→SCR→SCP" based on the dynamic capability perspective, and analyzes the specific digitalization process to enhance SCR and SCP as well as the mediating role of SCR through structural equation modelling. The findings of this study contribute to the extant SCR literature.

First, many of the SCR elements, such as visibility, agility, and recovery efficiency, are complex and widely used in research on complete risk cycle. As such, there is a strong need to develop a comprehensive SCR framework linking them together with solid theoretical support. This study analyzes the various SCR dimensions in detail. It develops a comprehensive SCR framework based on a dynamic capability perspective and validates it empirically, thereby extending the current quantitative research of SCR. The study also points out that improvement of SCR depends on the combined effect of the three identified capabilities, namely absorptive, response and recovery capabilities. Compared with other studies that consider SCR as a unidimensional capability, this study comprehensively explores the building process and the performance impacts of different SCR capabilities. It considers SCR a complex dynamic capability to cope with risks and emphasizes the integration process of resources and capabilities throughout the internal and external parts of the supply chain. As such, it provides a reference for future quantitative research in this regard that can help companies examine the weaknesses of their SCR according to their unique circumstances.

Next, this study explores digitalization as an antecedent helps the formation of SCR. It argues that realization of SCR requires companies to adjust their infrastructure, break down the information barriers between departments and partners, and achieve risk prediction and planning, agile response, and rapid recovery through process optimization and resource reorganization. As a driving factor, SCD includes the application of digital technology and the overall innovation of business processes, products and services, and business models brought by the application of technology. Digitalization enables enterprises to reconstruct their value-creation logic and achieve flexibility, agility, and efficiency. Therefore, digitalization of the supply chain has a certain degree of consistency with the strategic objectives and realization process of SCR. Digitalization can effectively help build different dimensions of SCR capabilities. This study extends the SCD research focus from a single digital technology to the whole digital management process. The research perspective focuses on digital supply chain activities with digital technology adoption as the underlying logic and integrated use of digital technologies as the approach. This study extends the scope of research in digitalization from conventional to crisis scenarios, enriching the research context in the field of digitalization.

Finally, this study enriches the research on the mediating role of supply chain resilience in SCD and SCP. Previous studies in this regard mainly focus on the relationship between SCD and SCP, as well as SCR and SCP. Research on how SCR and SCD jointly affect SCP in a turbulent environment is limited. This study integrates these three variables into a theoretical framework of "SCD→SCR→SCP" based on dynamic capability theory. The results highlight that new resources, capabilities, and models brought by SCD have helped shape SCR, a complex capability required to maintain business continuity in a highly uncertain market. This dynamic process helps the supply chain achieve better performance outcomes. In short, this study has successfully responded to the call for research to build dynamic supply chain capabilities in crisis scenarios (Ambulkar et al., 2015).

6.3. Managerial implications

In addition to theoretical contributions, the findings of this study provide some valuable managerial insights for companies. The results show that digitalization enables the reorganization of existing products and services, business processes, and business models to improve SCP through the dynamic capability of SCR to fully unleash the digital driving effect in times of crisis. Specific management implications for managers and practitioners are as follows.

First, our study highlights the combined effect of absorptive capability, response capability, and recovery capability in resisting supply chain disruption. Changes in the external environment, such as natural disasters, political interventions, and the complexity of supply networks, can lead to unexpected supply chain disruptions. Our research shows that improving SCP in highly volatile market environments relies on the building of resilience capabilities. It requires firms to enhance their abilities in forecasting the internal and external environment and achieving dynamic management of redundant resources (Namdar et al., 2018; Pettit et al., 2013). The findings of this study echo the view of Ivanov et al. (2022) that redundant assets are resources "waiting" to be used in crisis scenarios. Using them only to respond to emergencies may be inefficient and will not significantly improve performance levels. Especially for SMEs with limited resources and capability, the costs of stocking redundant inventory and arranging diversified purchases are also high. As SCR has become a decisive factor for enterprises to ensure business continuity, enterprises should strengthen the collaboration with different partners to expedite development of joint risk mitigation plans and quickly respond to changes in the market environment. At the same time, enterprises should accelerate the construction of a diversified supply chain network. Advocating win-win cooperation and benefit sharing can extend the advantages of resources and capabilities of individual enterprises to the entire supply chain to achieve more sustainable development.

Next, our results show the differential roles of supply chain digitalization in building SCR at different stages. SCD can achieve absorptive capability by increasing the effectiveness of supply chain risk preparedness. It can improve the response capability and recovery capability through the reconstruction of internal and external resources by intelligent operational processes and digital business models. Differences such as the industry sector, the risk stage, and the current state of resilience building can determine the priorities for developing different SCR capabilities (Cohen et al., 2022). Managers can use our SCR framework to examine their current supply chain weaknesses and build the required resilience. They need to re-examine their resilience and digital resource base to align their digital strategies with their resilience capabilities at different stages. Using the digital tools flexibly to re-plan enterprise structure, process, and business model is important. Starting with resilience capability that needs to be improved most, managers can improve the SCR levels of their companies from point to point. Considering the mediating role of SCR, managers should further stimulate the potential of digitalization by combining digital management with the dynamic capability of the enterprise. Companies need to recognize the inherent mechanisms of SCD, develop a digital strategy aligned with their development in times of crisis, and undertake a more profound digital transformation. They need to advance their SCD process purposefully and directionally. At the same time, companies need to recruit digital talents, develop digital skills of their employees, and actively adjust the digital supply chain structure to ensure the success of supply chain digitalization.

7. Conclusion, limitations, and future research

Contemporary SCR research has noted the significant role of digitalization in enhancing supply chain resilience in different dimensions, but this impact needs to be validated through empirical analysis. Moreover, the mediating role of SCR as a multi-dimensional dynamic capability between SCD and SCP in crisis scenarios requires further exploration. To meet these needs, this study focuses on the specific impact paths of SCD affecting SCR and performance. First, the study develops a full-stage SCR framework based on dynamic capability theory and the disruption stages (before, during, and after), which includes three significant dimensions, namely absorptive capability, response capability, and recovery capability. Then, this study integrates the outcome variables of supply chain performance. It constructs the framework of "SCD→SCR→SCP" by combining dynamic capability theory to observe the fluctuations of SCP when SCD and SCR are combined. Finally, the structural equation model depicting the framework was validated using questionnaire data collected from 210 manufacturing enterprises in China's Yangtze River Delta region. The study shows that digitalization directly impacts on SCR and SCP, and the three SCR capabilities play different degrees of mediating roles in the relationship between SCD and SCP. The findings not only extend the boundary of dynamic capability theory research from within a firm to the entire supply chain but also enrich the existing empirical research on the antecedents of SCR. The study systematically reveals the information, resource, structure, and process changes brought about by digitalization in crisis scenarios and promotes the different dimensions of capability enhancement. The results provide theoretical and practical support for enterprises to selectively and step-by-step develop resilience capabilities using digital tools to help them recover quickly from risks.

The limitations of this study may also be the direction for future research. This study constructs the theoretical analysis framework of the relationship between SCD, SCR, and SCP and conducts an empirical test using the structural equation modeling method. Future studies can conduct case studies to further explore and verify this path from the perspective of longitudinal enterprise practice. In addition, our research primarily collects data from the manufacturing enterprises in the Yangtze River Delta region of China, which is also one of the limitations. Different environmental and cultural factors may reduce the representativeness and universality of the findings. Future studies may examine these relationships by collecting data from other countries, regions, and industries. In addition, the current study did not involve group discussions of large-scale and small-scale enterprises. Control variables as such firm size and years of establishment would need to be considered in future studies. Subsequent research may design the antecedents of SCD to understand which factors hinder or promote the implementation of digitalization. Recent research opines that SCR focuses more on sudden disruptions. In contrast, risk factors such as epidemics have long-term and unpredictable impacts on the supply chain, shifting the research perspective from SCR to supply chain viability (Ivanov, 2020). Supply chain viability not only considers resilience but also incorporates sustainability and adaptability considerations. Therefore, exploring the impact of digitalization on supply chain viability in further studies can further help supply chains achieve sustainable performance.

Declarations of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Acknowledgement

This research was sponsored by Shanghai Talent Development Funds (#2020134) and Soft Science Research Funds of Science and Technology Innovation Action Plan Shanghai.

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