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Supply Chain Digitalization and Agility: How Does Firm Innovation Matter in Companies?

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ABSTRACT

This study investigates the impact of supply chain digitalization on agility through the lens of innovation within firms. Employing a resource-based view and dynamic capabilities approach, we analyze the relationship between supply chain digitalization and agility. This exploration is essential for fostering an agile supply chain capable of addressing challenges post COVID-19. The empirical data were gathered through a survey administered in the Emirates. Factor analysis was performed to validate the measurement models and structural equation modeling techniques were employed to test the hypotheses. Further, the study analyses the mediating role of firm innovation between digitalization and supply chain agility within companies. The findings suggest that firm innovation serves as a significant mediator. Moreover, a multigroup analysis was conducted to examine the moderating effects in the research models, revealing that firm innovation plays a pivotal role in elucidating the mechanism between supply chain digitalization and agility. This study offers valuable insights into supply chain agility and resilience post COVID-19 and makes a significant contribution to the literature on supply chain digitalization.

1 | Introduction

Digitalization is becoming increasingly crucial in logistics and supply chain (SC) operations (Coreynen, Matthyssens, and Van Bockhaven 2017; Seyedghorban et al. 2020). Digitalization—the utilization of digital technologies to facilitate the digital transformation of businesses (Brennen and Kreiss 2016; Coreynen, Matthyssens, and Van Bockhaven 2017)—has changed the competitive dynamics of industries (Cichosz, Carl Marcus, and Knemeyer 2020; Hess et al. 2016). It provides opportunities for industries to apply new technologies to optimize business operations (Coreynen, Matthyssens, and Van Bockhaven 2017; Holmström et al. 2019). In an era of globalization and the advancement of emerging technologies, SCs have emerged as a crucial success factor in the global market competition (Verbeke 2020). Businesses with effective and efficient SCs can reduce costs, offer lower prices and better services, and attract more customers. Furthermore, digitalization enables firms to optimize SC operations, create value and improve business models (Ritter and Pedersen 2020; Vial 2019), and allows firms to attain flexibility and agility, when developing SC strategies (Seyedghorban et al. 2020; Shih 2020). It is crucial to understand the underlying mechanism of digitalization and SC capabilities (Nambisan, Wright, and Feldman 2019). This study provides a nuanced understanding of how SC digitalization influences SC agility, offering insights into the strategies and mechanisms that companies can employ to navigate the complexities of the post-pandemic era effectively.

Digitalization has become an important topic of Industry 4.0 (also known as the Fourth Industrial Revolution) and

provides significant research opportunities in SC management (Holmström et al. 2019; Ritter and Pedersen 2020). Prior studies mainly focus on antecedents of digitalization, such as how dynamic capabilities and business strategies contribute to digitalization (Reuschl, Deist, and Maalaoui 2022; Vial 2019), but lack a comprehensive understanding of the effect of digitalization at an organizational level (Hess et al. 2016). Additionally, there has been limited research conducted from an interdisciplinary perspective on digitalization (Nambisan, Wright, and Feldman 2019). This study focuses on the digitalization of SC at the organizational level.

Some authors argue that digitalization may bring new opportunities for both radical and incremental innovation (Huang et al. 2017; Lorenz et al. 2020) and SC operations (Cole, Stevenson, and Aitken 2019; Holmström et al. 2019). However, there have been few empirical studies that address these inquiries. Therefore, this article employs a resource-based view (RBV) and dynamic capabilities approach to conduct an empirical investigation based in the UAE. Digitalization in the UAE is expected to grow, with 99% of the population having access to the internet, the UAE boasts the high level of digitalization (Cabral 2023). Companies across industries in the UAE have an opportunity to create an advantage in SCs by leveraging digitalization. However, digitalization research on these SCs is scarce. Moreover, in the aftermath of the COVID-19 pandemic, businesses encounter a myriad of unique challenges and alterations in the operational environment. SC disruptions, fluctuating consumer demands, and the need for rapid adaptability have become paramount concerns for organizations worldwide. Companies need to boost digital transformation in their SCs to enable the effective use of technology and improve their responses to change (Wang et al. 2021). This study seeks to address this gap in the literature by exploring the effect of SC digitalization on SC agility via firm innovation. This leads to the following research question:

RQ. How does SC digitalization influence SC agility through firm innovation?

This study offers contributions to the existing body of literature. By shedding light on the interplay between SC digitalization, innovation, and SC agility, our research equips practitioners and policymakers with valuable knowledge to develop resilient and responsive SCs. We also compare this interplay within companies of different sizes, across various industries, including both dynamic and static sectors. An understanding of these interactions is crucial for businesses so that they can thrive in the evolving landscape shaped by the aftermath of COVID-19; it will help them to proactively address challenges and seize opportunities for sustainable growth and competitiveness.

This article is structured as follows: The theoretical background of the study is presented first, followed by an explanation of the conceptual framework and hypotheses used for the research. This article then moves on to look at the research methodology, and then next there is an examination of the data analysis and research results. Finally, the research findings and implications are discussed.

2 | Theoretical Background

2.1 | SC Digitalization

Industry 4.0 drives digitalization (Seyedghorban et al. 2020). This phenomenon has gained popularity across various industries (Bertoni et al. 2022; Kraus et al. 2021). Holmström et al. (2019) propose that digital technologies offer opportunities to reassess decision-making, interorganizational and intraorganizational processes, and architectures. Digital technologies have significant impacts on business performance. Perano et al. (2023) argue that digital technologies can influence SC performance through their effects on business processes. Successful companies in the digital economy will provide customer value and scale and efficiency (Ross 2017; Wang and Prajogo 2024).

To maximize the benefits of digital technologies, Henderson and Venkatraman (1993) argue that organizations must consider strategic alignment to realize value through technology. In addition, Hess et al. (2016) found that firm size significantly determined the level of digital diversification in media companies. Therefore, it is important to consider firm size when implementing SC digitalization. Vial (2019) suggests that digital transformation is a process in which firms respond to environmental changes by applying digital technologies to enhance their value-creation processes. This transformation must be supported by management and leaders, who play a crucial role in fostering collaboration and driving change within organizations.

Digitalization in the SC has attracted growing attention in recent decades, it changed the way organizations strategize their SC operations (Seyedghorban et al. 2020). SC digitalization focuses on the adoption of digital technologies in firms to enhance SC operations (Wang and Prajogo 2024). The use of digital technology facilitates firm innovation (Huang et al. 2017; Wang, Chen, et al. 2020) and enables agility and ambidexterity (Seyedghorban et al. 2020; Vial 2019). Technology can improve SC capabilities (such as flexibility and agility) through information visibility (Gligor and Holcomb 2012; Wang and Wei 2007). Thus, a measurement of SC digitalization may involve the adoption of digital technologies (Vial 2019), standardizing processes (Ross 2017), simplifying the operating process (Childerhouse and Towill 2003), and IT and SC integration (Gligor and Holcomb 2012; Subramani 2004; Swafford, Ghosh, and Murthy 2008; Wang and Wei 2007). In this study, we define "SC digitalization" as the application of digital technology to business SC operations (Brennen and Kreiss 2016; Ritter and Pedersen 2020; Vial 2019).

2.2 | Firm Innovation

Innovation has garnered significant attention within the realms of business, SC, and organizational management (Tidd and Bessant 2013; Wang, Asian, et al. 2020). Azadegan and Dooley (2010) define innovativeness as the capability to develop new products, services, or processes. In this study, firm innovation may refer to a firm's capability to detect and manage opportunities for innovation activities. Firm innovation may encompass the creation, adoption, and execution of

novel concepts, procedures, products, or services (Calantone, Cavusgil, and Zhao 2002). These activities may include both explorative and exploitative innovations (Ahsan et al. 2022). Explorative innovation involves pursuing new products, services, or business models, whereas exploitative innovation involves seeking improvement by using existing resources and improving existing products, services, or business models (Wang, Chen, et al. 2020). Calantone, Cavusgil, and Zhao (2002) emphasize that a firm must be innovative to survive in turbulent environments. In addition, firm innovation provides a sustainable competitive advantage (Khazanchi, Lewis, and Boyer 2007; Wang 2020).

The implementation of digitalization has a positive impact on innovation endeavors (Nambisan, Wright, and Feldman 2019; Wang, Chen, et al. 2020). Advancements in technology have a profound impact on creativity and innovation by providing new ways to create, collaborate, and communicate. Vial (2019) argues that digital technologies offer enhanced connectivity and computational power, presenting a vast potential for fostering innovation within firms. Technology serves as a significant driver of innovation in SC digitalization (Seyedghorban et al. 2020). However, technologies alone cannot influence firm innovation (Vial 2019), but rather people, organizational culture, and atmosphere for innovation play a key role in the firm innovation process (Khazanchi, Lewis, and Boyer 2007; Koufteros, Vonderembse, and Jayaram 2005; Prajogo and Ahmed 2006; Vial 2019). It is important to note that firm innovation may also lead to adverse outcomes. Firm innovation may encounter failure or risk (Jeong, Oke, and Choi 2022); for example, when a firm undertakes innovation, it involves creating new products, services, processes, or business models. This innovative activity is inherently uncertain, meaning there is a risk that the expected outcomes may not be achieved. Risks associated with firm innovation can include market risk—the new product or service may not be positively received by the market; and financial risk—the costs of developing and implementing the innovation may exceed the budget or not lead to the expected financial returns. This highlights the necessity for managers and leaders to embrace risk-taking when fostering an innovative culture. Additionally, organizations should actively support firm innovation. Prajogo and Ahmed (2006) suggest that the empowerment of employees facilitates the transformation of ideas into innovations. Furthermore, Shih (2020) emphasizes the importance of companies seeking out creative technologies and innovative solutions to address challenges in SC management. This can help contribute to the development of an agile SC.

2.3 | SC Agility

SC agility is a research frontier subarea in the SC digitalization discipline (Seyedghorban et al. 2020). According to the RBV and dynamic capabilities approach, SC agility is a firm's capability to respond rapidly to unexpected changes and transform changes into business opportunities (Braunscheidel and Suresh 2009; Swafford, Ghosh, and Murthy 2008; Teece, Peteraf, and Leih 2016). It is a dynamic capability that enables companies to gain a competitive advantage and withstand uncertainties in their SCs (Aslam et al. 2020; Teece, Peteraf, and Leih 2016). According to the concept of "order qualifiers" and "order winners" (Hill 2000), SC agility plays a crucial role in both market qualifiers and market winners (Christopher and Towill 2001). Moreover, SC agility is closely linked to SC resilience. It has emerged as a critical capability for both agile and resilient SCs (Gligor et al. 2019). Wang, Jie, and Frederico (2024) argue that SC agility involves not only responding to internal and external changes but also having the capability to resolve issues within the SC.

Technology is a key enabler of agility (Gligor and Holcomb 2012; Shashi et al. 2020; White, Daniel, and Mohdzain 2005) and information technology plays a vital role in achieving SC agility (Swafford, Ghosh, and Murthy 2008). Russell and Swanson (2019) highlight that the synergy between SC agility, information processing, and new technologies addresses the conversion of information into agility. Wang et al. (2021) argue that digital technologies (such as blockchain) provide a new paradigm for SC operations. In a virtual organization, where suppliers are considered partners, production planning is collaboratively conducted with suppliers across functional boundaries within the agile SC (van Hoek, Harrison, and Christopher 2001). These technologies enable companies to collaborate more effectively and respond to changes more efficiently, thereby enhancing SC agility. Wamba et al. (2020) argue that big data analytics can help enhance SC agility. Lim et al. (2021) stress that blockchain technology can eliminate intermediaries and quickly locate problematic products. Likewise, Shashi et al. (2020) argue that the adoption of information technologies to share information between SC partners is essential to help forecast and meet market demand in the virtual-based SC.

In addition, SC agility has become an essential capability for companies to remain competitive in the digital era (Seyedghorban et al. 2020; Vial 2019). Businesses are increasingly dependent on their SCs to ensure the efficient and timely delivery of products and services to their customers (Gligor et al. 2019). This dependency has grown more pronounced in recent years with the surge of e-commerce, globalization, pandemic, and geopolitical conflicts (Wang, Childerhouse, and Abareshi 2024). Moreover, SC uncertainties have amplified the complexity and challenge of SC management (Wang 2018). Organizations with effective SC agility are better positioned to effectively respond to unforeseen events (Swafford, Ghosh, and Murthy 2008; Wang and Wang 2023).

Braunscheidel and Suresh (2009) stress that firms must work closely with their suppliers and customers to adapt or respond rapidly to marketplace changes. Flexibility constitutes a fundamental aspect of SC agility (Christopher 2000; van Hoek, Harrison, and Christopher 2001). Both agility and flexibility revolve around the capacity for change (Swafford, Ghosh, and Murthy 2006). Given the nature of SC agility (Christopher 2000; Swafford, Ghosh, and Murthy 2006; Wang and Wei 2007), collaboration between SC partners is essential in addressing issues and eliminating barriers, thereby enhancing responsiveness between firms. Responsiveness can be seen as the outcome of organizational adaptations to an ever-changing environment (Richey et al. 2022; Wang et al. 2024). Consequently, post COVID-19, organizations can leverage their SC agility to address challenges, reconfigure operational processes, and adapt to changes, thereby bolstering their SC performance (Ivanov 2022; Wang and Wang 2023; Wulandhari et al. 2023).

3 | Conceptual Model and Hypotheses

This research delves into the influence of SC digitalization on the agility of SCs, specifically through the means of firm innovation. The research conceptual model, depicted in Figure 1, proposes that firm innovation plays a mediating role in the effect of SC digitalization on SC agility. Moreover, the research model examines the moderating effects of firm size and industry on the relationship between SC digitalization, firm innovation, and SC agility.

Digital technologies may contribute to SC agility (Shashi et al. 2020; Swafford, Ghosh, and Murthy 2008; Vial 2019). Leveraging digital technologies enhances virtualization and can streamline information flow and collaboration between business partners (Lim et al. 2021; Shashi et al. 2020). For example, the smart capabilities of blockchain technology can automatically execute processes and shorten response time (Lim et al. 2021). Wang and Wei (2007) stress that information technology can lead to SC flexibility and agility through information visibility between firms. Digitalization offers digitally technology-enabled business transformations, which help firms compete effectively and improve agility and ambidexterity (Gligor and Holcomb 2012; Seyedghorban et al. 2020; Vial 2019). SC digitalization often involves collaboration with external partners, such as suppliers, distributors, and logistics providers. Through digital platforms and technologies, firms can exchange information, collaborate on joint initiatives, and share best practices more effectively. This collaborative environment fosters SC agility. Thus, we proposed the following hypothesis:

H1. *SC digitalization positively influences SC agility.*

Digitalization is an integral driver of firm innovation (Hess et al. 2016; Nambisan, Wright, and Feldman 2019; Tidd and Bessant 2013) as it introduces new technologies, processes, and approaches within a firm's operations. These changes can spark innovative solutions to existing challenges. There is a close association between the use of new technology and innovation (Venkatesh et al. 2003), but new technology alone cannot improve business performance, it must fit with companies (Lim et al. 2021). Hess et al. (2016) argue that firms need to find ways to innovate with digital technologies and Reuschl, Deist, and Maalaoui (2022) stress that firms must reconsider their value creation and proposition in digitalization—this may also help stimulate firm innovation. In addition, Hess et al. (2016) see information technology as a fundamental part of digitalization and that it will help foster innovation. Technologies do not only create new products and business processes but also change the rules of competition (Prajogo and Ahmed 2006). Furthermore, the literature highlights that digitalization can generate innovations that can modify value propositions and enable the creation of new customer value (Huang et al. 2017; Vial 2019; Wang, Chen, et al. 2020), and it can facilitate different types of service innovation (Coreynen, Matthyssens, and Van Bockhaven 2017). For example, Netflix used digital technologies to develop new video streaming services and generated disruptive innovations. Specifically, SC digitalization acts as a catalyst for firm innovation by providing access to data-driven insights, optimizing processes, fostering collaboration, and enhancing agility. By leveraging digital technologies and capabilities, firms can unlock

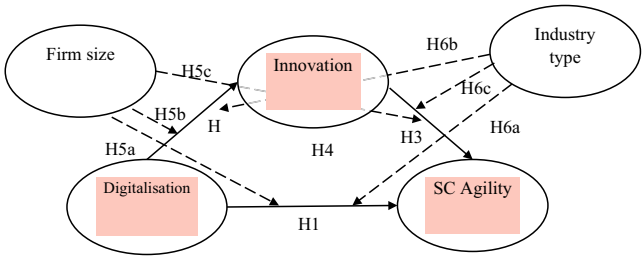

FIGURE 1 | Conceptual model showing that firm innovation plays a mediating role in the effect of SC digitalization on SC agility.

new opportunities for innovation, driving business success and growth in an increasingly digital and interconnected world. Thus, the following hypothesis is proposed:

H2. *SC digitalization positively influences firm innovation.*

Firm innovation is the main antecedent to SC agility and Teece, Peteraf, and Leih (2016) argue that innovation capability is necessary for fostering agility. Innovation is often driven by a culture of continuous improvement, encouraging creativity, experimentation, and risk-taking among employees and fostering a dynamic and adaptive organizational culture. This culture of continuous improvement enables firms to identify and capitalize on opportunities for innovation throughout the SC, driving ongoing enhancements in agility and responsiveness (Wang 2016). In addition, innovation can significantly increase SC resilience (Shih 2020). Innovation enables firms to explore new ways to respond to changes and resolve unexpected problems. It can often lead to the development of more efficient and effective processes across the SC. These innovations may involve the adoption of new technologies, the implementation of novel strategies, or the introduction of innovative products or services. By improving and optimizing internal processes, firms enhance their overall operational agility, enabling them to respond more quickly and effectively to changes in demand, supply disruptions, or market dynamics. Kim and Chai (2017) argue that supplier innovativeness may positively influence SC agility. Additionally, drawing from the dynamic capability approach, innovation is a dynamic capability that can influence SC agility (Iddris, Awuah, and Gebrekidans 2016; Teece, Peteraf, and Leih 2016; Wang 2020). Furthermore, the customer's role in fostering innovation within the organization is pivotal—SC agility may be enhanced through firm innovation, which facilitates both customer and supplier integrations (Koufteros, Vonderembse, and Jayaram 2005). As a result, we formulated the following hypothesis:

H3. *Firm innovation positively influences SC agility.*

According to the RBV and technology–organization–environment framework, firm innovation is viewed as a mediator variable between SC digitalization and SC agility. Firms with superior dynamic capabilities, such as innovation capability, can obtain more favorable efficiency/agility tradeoffs (Teece, Peteraf, and Leih 2016). Digital technologies alone cannot achieve a dynamic capability (Vial 2019). Innovation capability plays a crucial role in fostering agility within new business processes (Teece, Peteraf, and Leih 2016). Furthermore, technologies can bring many opportunities for innovation, which may facilitate SC agility (Kim and Chai 2017). SC digitalization leads

to increased innovation within the firm, and this innovation can create new value propositions for customers and stakeholders. Whether through the development of innovative products, services, or business models, firms can differentiate themselves in the market and better meet the evolving needs of customers and changes. This would facilitate the firm's ability to adapt, respond, and maneuver swiftly in its SC operations, thereby enhancing its overall SC agility. As discussed above, firm innovation capability is strongly associated with digitalization and SC agility. Thus, we propose the following hypothesis:

H4. *Firm innovation mediates the relationship between SC digitalization and SC agility.*

The study incorporated control variables, including firm size and industries, to further examine relationships in the research model. Prior studies suggest that firms' digitalization may be affected by their size (Hess et al. 2016). According to the RBV and dynamic capabilities approach, resources are necessary to achieve capabilities and dynamic capabilities require internal and external resources to address changes (Teece, Pisano, and Shuen 1997). Larger organizations may have more resources, such as digital technologies, ERP systems, skilled and qualified staff, and good IT support and, therefore, these resources offer them more advantages in their capability development.

SC digitalization holds significant potential to improve SC agility and innovation for a wide range of enterprises, although the extent of its impact may vary based on specific organizational contexts. As discussed, large firms often possess greater resources, capabilities, and organizational complexity compared to small- and medium-sized firms. As a result, they may be better positioned to leverage SC digitalization to enhance innovation and SC agility. These resources may be allocated toward developing and implementing innovative technologies, processes, and strategies that enhance agility across the SC. Thus, we propose the following hypotheses:

H5a. *The relationship between SC digitalization and SC agility differs between large-sized firms and small and medium-sized firms.*

H5b. *The relationship between SC digitalization and innovation differs between large-sized firms and small- and medium-sized firms.*

H5c. *The relationship between innovation and SC agility differs between large-sized firms and small- and medium-sized firms.*

Firms should embrace digitalization to gain competitive advantages (Fitzgerald et al. 2014). One of the important objectives of SC digitalization is to compete in industries. We adopted Fine's (1998) industry classification to split the research sample into two industry types—dynamic and static industries. Dynamic industries are those with short product life cycles and high competition, whereas static industries are those with slow product change and long product life cycles, and the price is sensitive in purchase decisions (Fine 1998; Wiengarten, Pagell, and Fynes 2012). Firms in dynamic and static industries may face different pressures of competing in business environments, and high competition, and short product life cycles may stimulate those firms in dynamic industries to invest in flexibility and agility (Wiengarten, Pagell, and Fynes 2012). It may be argued that SC digitalization and firm innovation play a more influential role in those firms situated in dynamic industries, compared to those in static industries. Thus, this perspective leads to the following hypotheses:

H6a. *The relationship between SC digitalization and SC agility differs between firms situated in dynamic industries and those in static industries.*

H6b. *The relationship between SC digitalization and innovation differs between firms situated in dynamic industries and those in static industries.*

H6c. *The relationship between innovation and SC agility differs between firms situated in dynamic industries and those in static industries.*

4 | Methodology

4.1 | Instrument Development

To verify the research models and test the hypotheses, we gathered empirical data from the seven emirates of the UAE and used a questionnaire as our primary research tool. We developed multi-item scales to assess the constructs, these included SC digitalization, firm innovation, and SC agility. Each was measured reflectively on a Likert scale—strongly disagree = 1; strongly agree = 7. The 7-point Likert scale offered more options for the respondents (compared to the 5-point scale), and it is comparable for both factor analysis and structural equation models (Dawkes 2008). The use of multi-item scales is a much more effective way to explain the target construct's variance (Hair 2010).

Following the existing literature, we developed a measurement model of SC digitalization to assess the use of digital technologies in an individual firm. The scale of SC digitalization includes observable variables measuring the use of digital technologies in business operations, such as process optimization, SC integration, delivery, payment, and customer service (Wang, Hill, and Hwang 2022). The measurement items of firm innovation were developed to assess the levels of the firm's ability to manage innovation (Wang 2016). The measurement items of SC agility were derived from previous studies (Braunscheidel and Suresh 2009; Wang and Wei 2007; Wang and Wang 2023) (see Appendix A). We measured all the scale items on a 7-point Likert-type scale. As some items were introduced for this study, we conducted an exploratory factor analysis (EFA) to confirm the underlying theoretical structure and validate the measurements before proceeding with the structural equation modeling (SEM) analysis. The results are reported in Section 5.

To ensure the research instrument's reliability and validity, we used a pilot study to refine the research questionnaire. We conducted the pilot study prior to initiating large-scale data collection. First, we invited five managers and three academics from the UAE to review the questions and statements. As the survey questions were being used for the first time in an Arabic business context, some were slightly modified to ensure the content

validity of the measurement items. We then distributed the survey questionnaire to 25 participants and the respondents' data were used to examine the instrument's reliability and validity before we conducted the full-scale study. The pilot study results illustrated that the instrument was reliable and valid.

4.2 | Sample

The trend of SC digitalization is present in many industries (Vial 2019), and our study attempts to understand the impact of SC digitalization across industries. Thus, we did not target any specific industry or sector in this study. Instead, we conducted a multigroup analysis (MGA) to test whether parameters differ significantly between groups, in terms of static and dynamic industries (see Table 1). We obtained a list of businesses from within the UAE, including contact information, from the Yellow Pages UAE and LinkedIn. Approximately 1150 firms, across seven emirates, were invited to participate in the research (and we deliberately included key industries in the UAE). The majority of respondents were from Abu Dhabi and Dubai. We also received responses from: Sharjah, Ajman, Umm Al Quwain, Ras Al Khaimah, and Fujairah. Respondent profiles aligned with the UAE demographics. All participants received a cover letter with the survey, to ensure they understood the study's objectives and research questions. The letter outlined the purposes of the research project and informed the participants that their involvement was voluntary and anonymous. The letter also stipulated, that to take part in the research, participants should possess SC knowledge and experience within their organizations. It also emphasized that participants could withdraw from the project at any time. We provided our contact information and the survey link was distributed by email to the management of each firm.

We collected data at the firm level throughout March and April 2022, with follow-up reminders sent to prompt survey completion. We applied a force response rule to the survey questions; this required the respondents to answer all the questions before submitting the survey. Consequently, our dataset is devoid of missing values. We eliminated the cases with obvious errors. A total of 271 valid respondents were adopted in this research. This provides, approximately, a 23% survey response rate. Over 70% of the respondents have worked for more than 2 years in their current organization. In addition, over 70% of the respondents hold managerial positions. This shows that the quality of data is satisfactory. The sample size is an important consideration for SEM, but more is not always better. Our sample size ($n = 271$) is adequate (see Wolf et al. 2013; Zhang, Dawson, and Kline 2021). Table 1 illustrates the sample characteristics in our study.

TABLE 1 | Sample characteristics ($n = 271$).

Dimension	Category	*N*	%
Position	Senior Manager/ CEO, Director	80	29.5
	Manager/Supervisor	113	41.7
	Staff	68	25.1
	Others	10	3.7
Working experience	Less than 2 years	73	26.9
	2–5 years	87	32.1
	More than 5 years	111	41
Size (revenues)	< US $0.8 million	54	19.9
	US $0.8 million to US $13.6 million	80	29.5
	> US $13.6 million to US $68 million	58	21.4
	> US $68 million	79	29.2
Location	Abu Dhabi	53	19.6
	Dubai	163	60.1
	Others	55	20.3
Industry type	Oil and Gas[a]	16	5.9
	Construction[a]	31	11.4
	Manufacturing[a]	30	11.1
	Trading[a]	30	11.1
	Public administration[a]	7	2.6
	Warehousing and transportation[a]	10	3.7
	Insurance and finance[b]	11	4.1
	Education services[b]	16	5.9
	Tourism and hospitality[b]	13	4.8
	Healthcare and pharmaceuticals[b]	12	4.4
	Other services[b]	95	35.1
	Total	271	100

[a]Static industries.
[b]Dynamic industries.

4.3 | Nonresponse Bias and Common Method Variance

Nonresponse bias is a significant concern in survey studies (Dillman 1991; Wagner and Kemmerling 2010). To mitigate this issue in our study, several techniques and procedures were employed to enhance response rates and minimize the potential for nonresponse bias (Clottey and Grawe 2014). For example, samples were carefully selected and a detailed cover letter was attached to the online survey to help increase response rate. In addition, we used follow-up reminders and emphasized the anonymity of responses (Dillman 1991).

To assess nonresponse bias, an analysis was conducted by comparing early respondents (the first 20% to complete the survey) with late respondents (the last 20% to complete the survey) (Wagner and Kemmerling 2010). This comparison allowed us to evaluate whether there were any significant differences between the two groups, and if this indicated the presence of nonresponse bias. As we observed no significant differences, we did not consider nonresponse bias as a major concern in this study.

Additionally, we compared respondents' industry types and firm sizes to those of the overall population to further assess potential nonresponse bias (Wagner and Kemmerling 2010). The distribution of respondents across industry types (e.g., manufacturing, finance, healthcare) and firm size (e.g., small, medium, large enterprises) was statistically similar to the overall population ($p > 0.05$), indicating that nonresponse bias is unlikely to be a significant concern in this study. This suggests that the findings are broadly representative of the target population.

To address common method variance, we conducted Harmon's single factor test as the empirical data were obtained from a single respondent in this study (Podsakoff et al. 2003). After identifying several factors, we found that the first factor did not account for most of the variance (if a single factor emerged that accounted for a substantial portion of the variance—usually 50% or more—it would have suggested the presence of common method bias). The outcome indicates that common method variance was not a significant concern in our study. We also employed the marker variable technique to identify potential bias (Lindell and Whitney 2001). This method entails examining the pairwise correlations among the primary variables within the dataset. In this technique, a "marker variable" is designated as a variable that is theoretically unrelated to at least one variable in the study. If a marker variable shows significant relationships with other study variables, particularly those measured using the same method, it suggests the presence of a common method bias. We utilized several variables as proxies for common method bias, and there was no discernible basis to suggest significant common method bias in our study.

5 | Data Analysis and Results

We designed the research with careful plans and rigorous strategies (Zhang, Dawson, and Kline 2021). Two statistical software packages—IBM SPSS Statistics (version 27) and IBM SPSS Amos 27—were used for the data analysis. To test the models, we utilized the maximum likelihood method. First, we performed EFA in the SPSS version 27. Then, we employed a two-step SEM approach to examine models in our research. The measurement and structural model underwent separate validation processes (Hair 2010; Zhang, Dawson, and Kline 2021). Measurement models were used to examine the reliability and validity of the measures, the overall structural model fit and the hypothesized relationships test were performed in a structural model. Additionally, we employed an SEM approach to assess the mediating effect in the model.

5.1 | Exploratory Factor Analysis

Before commencing the factor analysis, we performed the Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity to verify if the data could be meaningfully compressed through factor analysis. The KMO test was conducted to measure the sampling adequacy in the factor analysis (Fabrigar 2012). A commonly accepted guideline is that a KMO statistic above 0.80 indicates that the sample is adequate for factor analysis. The KMO measure of sampling adequacy is 0.958, which was satisfactory. We performed Bartlett's test of sphericity to check whether the variables are orthogonal; the null hypothesis showed that they are. The results of the Bartlett's test were significant (approximately chi-square = 5996.743, df = 300, p-value < 0.001), but the correlation matrix was not an identity matrix.

To develop validated scales, we conducted EFA with principal component and varimax rotation to assist in the interpretation of the dimensions. Varimax is the most popular rotation method (Kaiser 1958). The EFA was performed with an initial 25 items. Six items were removed from the analysis because they showed significant loadings on multiple constructs, which is known as cross-loading (Fabrigar 2012). Appendix A lists all the items included in this research survey. The results reveal three components extracted from the dataset; they explain approximately 71% of the variance of the data. Table 2 displays the pattern coefficients of the items for the three dimensions identified, which have eigenvalues greater than 1. *SC Digitalization* has 8 items, *Innovation* has 6 items, and *SC Agility* has 5 items. In addition, we used a scree-plot in the selection of the number of factors. Figure 2 shows the scree-plot in EFA. The reliability of the measurement scale was tested using Cronbach's alpha coefficient. A Cronbach's alpha coefficient greater than 0.7 shows acceptable internal consistency. Cronbach's alpha for *SC Digitalization* was found to be 0.91, *Innovation* was found to be 0.92, and *SC Agility* was found to be 0.93. The results offer evidence of the reliability of the instrument.

5.2 | Measurement Model

This section presents our measurement model analysis, which involved conducting confirmation factor analysis using IBM Amos version 27 (Hair 2010). We first verified the measurement items from the EFA. The poor factor loading items (less than the threshold of 0.7) have been eliminated from *Digitalization*, and one item was deleted from the measurement items of *Innovation*. Item loadings should surpass the 0.7 threshold (Fornell and Larcker 1981). Table 3 shows the details of each item in the measurement models. We evaluated construct reliability and validity by calculating Cronbach's alpha (the recommended threshold > 0.7) and composite reliability (the suggested measurement models). Three items were deleted from the measurement items of SC (threshold > 0.7) and average variance extracted (AVE) (the suggested threshold > 0.5) (Fornell and Larcker 1981; Hair 2010). The convergent validity was examined by the reliability coefficient for each item and all constructs met the suggested thresholds. According to the Fornell–Larcker criterion, discriminant validity among constructs is confirmed when the square root of the AVE for each construct exceeds the correlations between different constructs, and the indicators have higher loadings on their respective constructs in the model (see Table 4). The recommended model fits the value of the chi-square (CMIN/DF) as it is less than 3. The comparative fit index (CFI) is above the suggested threshold of 0.90 and the standardized root mean square residual (SRMR) is below or equal to the suggested threshold of 0.08 (Bentler and Bonett 1980). The measurement model fit statistics indicate a good fit for the data, as shown in the following:

Chi-square = 751.96 (df = 335, $p < 0.001$), Chi-square/df = 2.24
CFI = 0.94, SRMR = 0.037, RMSEA = 0.048. *$p < 0.001$.

TABLE 2 | Factor pattern coefficients of the items ($n = 271$).

Variable	Digital	Innov.	Agility
Our company applies digital technologies in our organizations	0.70		
Our company uses enterprise systems (ERP) in our organizations	0.72		
Our company applies advanced technologies to improve the process	0.74		
Our company standardizes the operating process	0.65		
Our company applies digital technologies to integrate SCs	0.73		
Our company applies digital technologies to facilitate payment	0.66		
Our company applies digital technologies to facilitate goods delivery	0.67		
Our company applies digital technologies to support customer service	0.68		
Our company applies creative techniques in business operations		0.64	
Our company embraces inventive technologies and creative solutions to address challenges		0.70	
Our company promotes a culture of innovation		0.78	
Our company is willing to take risks to get better results		0.76	
Our company encourage staff members to develop new ideas and methods in business operations		0.75	
Our company attracts skilled and qualified staff		0.64	
Our company can swiftly respond to both supplier and customer requests			0.76
Our company has the capability to adapt its production or service capacity and capability as needed			0.76
In the event of an unforeseen situation, our company and the supplier collaborate to effectively resolve issues			0.82
In the face of unexpected situations, our company possesses the ability to reconfigure its operational processes to accommodate the changes			0.77
In the event of a disagreement arising, both the supplier and our company can reassess the situation to find a mutually satisfactory solution			0.77

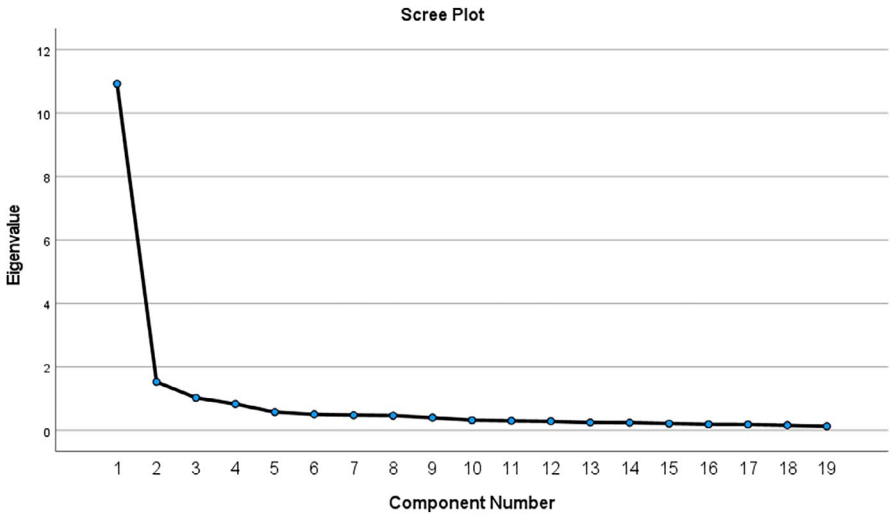

FIGURE 2 | The scree-plot in EFA.

In addition, a variance inflation factor was employed to check the multicollinearity of all the variables, and the multicollinearity assumption remained unviolated. The next section presents a structural model analysis and hypotheses test.

5.3 | Structural Model

Following the validation of the measurement models, we proceeded to validate the structural model, which included

TABLE 3 | Measurement model results ($n = 271$).

Latent variable	Item	Mean	SD	St. loading	*t*-value
SC Digitalization	D1. Our company applies digital technologies to improve the process	5.73	1.42	0.75	(Fixed)
	D2. Our company applies digital technologies to integrate SCs	5.29	1.57	0.89	21.81*
	D3. Our company applies digital technologies to facilitate payment	5.56	1.50	0.82	16.33*
	D4. Our company applies digital technologies to facilitate goods delivery	5.27	1.49	0.83	20.07*
	D5. Our company applies digital technologies to support customer service	5.48	1.56	0.81	19.56*
Innovation	I1. Our company applies creative techniques in business operations	5.39	1.39	0.81	(Fixed)
	I2. Our company embraces inventive technologies and creative solutions to address challenges	5.35	1.37	0.87	24.23*
	I3. Our company promotes a culture of innovation	5.42	1.47	0.88	24.37*
	I4. Our company is willing to take risks to get better results	5.30	1.53	0.77	20.09
	I5. Our company encourage staff members to develop new ideas and methods in business operations	5.46	1.57	0.83	22.49
SC Agility	A1. Our company can swiftly respond to both supplier and customer requests	5.52	1.39	0.87	(Fixed)
	A2. Our company has the capability to adapt its production or service capacity and capability as needed	5.48	1.32	0.85	26.09*
	A3. In the event of an unforeseen situation, our company and the supplier collaborate to effectively resolve issues	5.55	1.29	0.85	26.54*
	A4. In the face of unexpected situations, our company possesses the ability to reconfigure its operational processes to accommodate the changes	5.58	1.27	0.86	24.86*
	A5. In the event of a disagreement arising, both the supplier and our company can reassess the situation to find a mutually satisfactory solution	5.59	1.20	0.82	21.19*

*$p < 0.001$ measurement model fit statistics: chi-square = 751.96 (df = 335, $p < 0.001$), chi-square/df = 2.24 CFI = 0.94, SRMR = 0.037, RMSEA = 0.048.

hypothesis testing as a key component of the analysis (see Table 5 for the outcomes of the hypothesis testing). We used both T-statistics and the bootstrapping technique (with $n = 2000$ bootstrap resamples) to assess the significance of the paths within the structural model. Table 5 provides a list of standardized path coefficients within the model. The results indicated a favorable model fit, as evidenced by the following model fit indices: chi-square = 757.35, df = 345, chi-square/df = 2.19, CFI = 0.941, RMSEA = 0.047, and SRMR = 0.036.

SC Digitalization exerted a positively significant influence on *SC Agility* ($\beta = 0.26$, $p < 0.001$), hence supporting H1. This suggests the importance of SC digitalization in driving SC agility in firms. Looking at the effects of *SC Digitalization* on *Innovation* ($\beta = 0.79$, $p < 0.001$), the results suggest that *SC Digitalization* also exhibited a significant impact on *Innovation*. This supports H2. *Innovation* had a significant impact on *SC Agility* ($\beta = 0.59$, $p < 0.001$) and so, H3 is also supported (as there is a positive impact of innovation on SC Agility).

5.4 | Mediation Test

One of the primary aims of this study is to examine the mediating role of innovation. To achieve this, we employed SEM, which is a technique that can mitigate issues of mediation, unreliability, and method effects commonly encountered in models of moderation and mediation (Hopwood 2007). For this study, we proposed two SEM models. To ensure the interpretability of path coefficients, model fit statistics should be assessed before examining the mediation effects. The first model shows the direct relationships between SC digitalization and SC agility (see Figure 3). The data demonstrated a good fit to the model, as evidenced by the following fit indices (Model 1): chi-square = 131.37, df = 68, chi-square/df = 1.93, CFI = 0.97, RMSEA = 0.059, and SRMR = 0.031. The second model involves the integration of the mediating factor, innovation (see Figure 4). The outcomes indicated a favorable model fit, as supported by the following model fit indices (Model 2): chi-square = 757.35, df = 345, chi-square/df = 2.19, CFI = 0.941, SRMR = 0.036, and RMSEA = 0.047.

TABLE 4 | Matrix of correlations and measures of validity.

	SC Agility	*SC Digitalization*	Innovation	CR	AVE	α
SC Agility	**0.88**			0.94	0.78	0.92
SC Digitalization	0.67*	**0.86**		0.93	0.74	0.91
Innovation	0.74*	0.74*	**0.87**	0.94	0.76	0.92

Note: The square root of the AVE is denoted in bold.
*$p < 0.001$.

TABLE 5 | Results of the hypotheses test.

Hypothesis	Path	Estimate	*T*-value	Note
H1	SC Digitalization → SC Agility	0.26	4.43*	Supported
H2	SC Digitalization → Innovation	0.79	16.03*	Supported
H3	Innovation → SC Agility	0.59	9.70*	Supported

*$p < 0.001$.

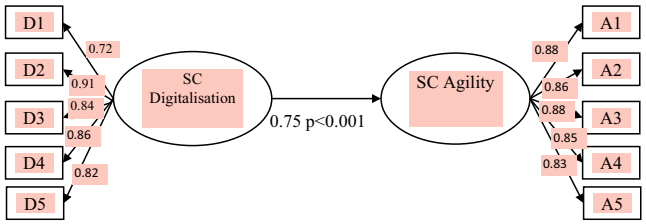

FIGURE 3 | Model 1 Structural equation model (SC Digitalization and SC Agility).

To evaluate the mediation model, the study followed the mediation test procedure (Baron and Kenny 1986; Zhao, Lynch, and Chen 2010). We first checked all the direct relationships between SC digitalization, firm innovation, and SC agility are significant at $p < 0.001$ (see Figure 4). Then, we added the mediator firm innovation into the second model, and we identified that the direct relationship between the independent variable (SC Digitalization) and the mediator (Innovation) and the direct relationship between the mediator (Innovation) and the dependent variable (SC Agility) are significant at $p < 0.001$ in Model 2 (Figure 4). The mediator was strongly related to both the independent and dependent variables, and the direct relationship between the independent and dependent variables became weak and retained significantly. These results indicate strong evidence of complementary mediation of the relationship between *SC Digitalization* and SC *Agility*, by the mediator *Innovation* (Baron and Kenny 1986; Zhao, Lynch, and Chen 2010). We also performed Sobel's test to confirm the mediation effect in the research model. The results indicated that the mediation effect of *Innovation* was statistically significant (*T*-statistic: 8.33, SE: 0.057, $p < 0.001$). Thus, H4 is strongly supported.

5.5 | Multigroup Analysis

Having confirmed the mediating effect of firm innovation in the structural model, we further investigated the moderating effect of firm size and industries by using multigroup and structural path analyses. The first MGA I was related to firm size. According to the UAE Ministry of Economy's company size classification, we stratified the sample into two groups based on their annual revenue. The first group contained small and medium enterprises (SMEs) ($n = 192$) with annual revenues of less than US $68 million, while the second group contained large companies ($n = 79$) with annual revenues above US $68 million. The sample was reasonable, as of mid-2020, over 94% of all firms in the UAE were SMEs (Visa Economic Empowerment Institute 2022). The second MGA (MGA II) compared industries. The split of MGA II was related to dynamic and static industries (as mentioned previously), and we used industry clockspeed classification (Fine 1998) to divide our sample into dynamic and static industries: those situated in dynamic industries ($n = 147$) and those situated in static industries ($n = 124$).

Table 6 indicates the results of the MGA. The overall fits of the structural models are good (see Table 7). In MGA I, we did not find any significant differences between the path coefficients across the groups. Then, we took a closer look at the relationships in MGA I. The results showed that both the *SC Digitalization* → *Innovation* relationship and *Innovation* → *SC Agility* relationship are significant but invariant in SMEs and large enterprises. The results further indicated that the *SC Digitalization* → *SC Agility* relationship is significant in SMEs ($\beta = 0.26$, $p < 0.001$), but insignificant in large enterprises ($\beta = 0.31$, $p = 0.127$). Therefore, the results do not support H5a–c.

In MGA II, the results showed that the relationship between *SC Digitalization* and *Innovation* is significantly different between the two groups ($p < 0.05$), and the path coefficient in dynamic industries is higher than in static industries; hence, the results support H6b. We can argue that the positive effect of *SC Digitalization* on *Innovation* (b) is more pronounced among firms located in dynamic industries compared to those in static industries. Our results indicated that both the correlation between *SC Digitalization* and *Innovation*, and the correlation between *Innovation* and *SC Agility* are significant in firms situated in dynamic and static industries. However, the *SC Digitalization–SC Agility* relationship is significant in the dynamic industries ($\beta = 0.32$, $p < 0.001$), but insignificant in the

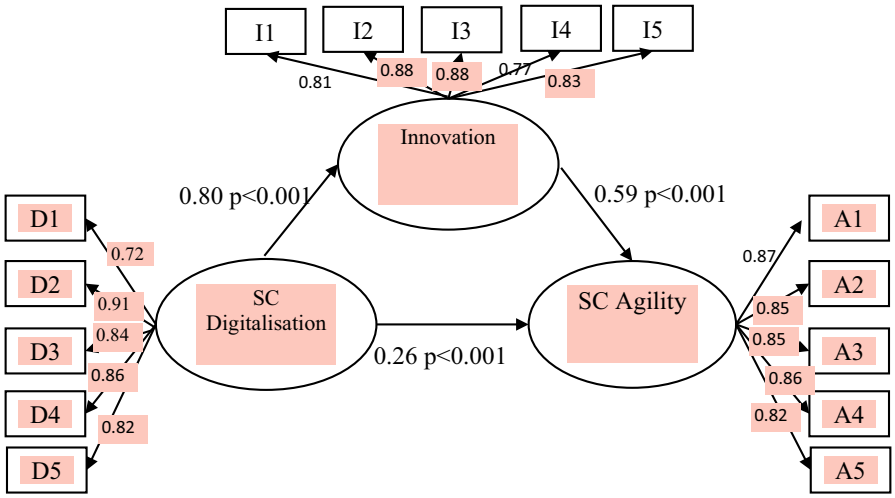

FIGURE 4 | Model 2 Structural equation model including the mediator.

static industries ($\beta = 0.135$, $p = 0.126$). Thus, the results do not support H6a–c.

Due to the insignificant relationship between *SC Digitalization* and *SC Agility* in MGA, we decided to conduct additional mediation tests on MGA I and MGA II to further investigate the mediation effect of firm innovation in the groups. We tested the relationships in two models. MGA I—Model 1 does not contain the mediator, the direct relationship between *SC Digitalization* and *SC Agility* is significant in SMEs ($\beta = 0.748$, $p < 0.001$) and large-sized enterprises ($\beta = 0.812$, $p < 0.001$). Although we found that the *SC Digitalization–SC Agility* relationship was invariant in the two groups, the path coefficient value in large enterprises is higher than that in SMEs. In Model 2, we added the mediator innovation and the direct relationship between *SC Digitalization* and *Innovation*, and the direct relationship between *Innovation* and *SC Agility*, were significant in these groups (see Table 6). However, the relationship between *SC Digitalization* and *SC Agility* became insignificant in large-sized enterprises ($\beta = 0.308$, $p = 0.127$).

In MGA I, we used Sobel's test to confirm the mediation effects. The results showed that complementary mediation in SMEs, the mediating role of firm innovation was found to be statistically significant in the indirect relationship between *SC Digitalization* and *SC Agility* (*T*-statistic: 7.90, SE: 0.06, $p < 0.001$); full mediation (or indirect-only mediation) was found in large enterprises (Baron and Kenny 1986; Zhao, Lynch, and Chen 2010)—the mediator firm innovation dropped the relationship between the independent variable (SC Digitalization) and the dependent variable (SC Agility) in large-sized enterprises (*T*-statistic: 2.62, SE: 0.19, $p < 0.01$).

We conducted the same analysis to examine the mediation effect in MGA II. Our results showed that complementary mediation was found in dynamic industries and the indirect effect of *SC Digitalization* on *SC Agility*, through the mediator firm innovation, was statistically significant (*T*-statistic: 6.87, SE: 0.07, $p < 0.001$). Full mediation (or indirect-only mediation) was found in firms situated in static industries (Zhao, Lynch, and Chen 2010), and the relationship between *SC Digitalization* and *SC Agility* became insignificant in static industries (*T*-statistic: 4.83, SE: 0.09, $p < 0.001$).

6 | Discussion and Conclusion

In this article, we present empirical research (from our research questionnaire) that examines the relationships between SC digitalization, firm innovation, and SC agility in firms based in the UAE. The chronic challenge of instability in SCs has been exacerbated by events such as COVID-19, the Russia–Ukraine war, and the China–United States trade conflict, leading to increased uncertainty and disruptions in the SCs of global businesses (Shih 2020; Velayutham et al. 2021; Wang, Kim, and Chan 2022). Innovative firms are early adopters of emerging technologies and trends that can enhance SC agility. These technologies, such as blockchain, artificial intelligence (AI), and Internet of Things (IoT), enable firms to improve visibility, traceability, and responsiveness across the SC (Wang et al. 2021). Digital technologies have the potential to revolutionize how firms innovate within their SCs. By leveraging these technologies to innovate and optimize SC processes, firms enhance their agility by reducing lead times, improving forecasting accuracy, and increasing flexibility in response to changing market conditions.

Building an agile SC is a critical success factor for surviving and creating a competitive advantage in unpredictable markets (Agarwal, Shankar, and Tiwari 2007; Braunscheidel and Suresh 2018; Do et al. 2021; Kim and Chai 2017). SC agility, as a crucial organizational capability, enables swift responses and adaptations to change, facilitating the establishment of an agile SC (Braunscheidel and Suresh 2009; Müller, Hoberg, and Fransoo 2022; Swafford, Ghosh, and Murthy 2006; Teece, Peteraf, and Leih 2016). The ability to rapidly innovate in response to customer preferences or disruptions in the SC can significantly enhance overall agility. Digitalization facilitates faster communication and decision-making across SC partners, which is crucial in today's dynamic business environment. Furthermore, Holmström et al. (2019) stress that digitalization should be geared toward enhancing firm performance. Digital technologies enable firms to optimize their processes, streamline operations, and even create new business models. These innovations not only improve efficiency but also strengthen the firm's ability to respond swiftly to market changes. For example, through data-driven insights and analytics, firms can identify opportunities for product and service innovation, improve

TABLE 6 | Multigroup analysis.

MGA I Firm size as a moderating variable ($n = 271$)											
	Small- and medium-sized enterprises				Large-sized enterprises				MGA		
Hypothesis	**Estimate**	**SE**	***t*-value**	***p***	**Estimate**	**SE**	***t*-value**	***p***	**Difference**	***p***	**Note**
H5a D→A	0.264	0.061	4.356	0.000	0.308	0.202	1.524	0.127	0.044	0.838	Insignificant
H5b D→I	0.788	0.053	14.805	0.000	0.882	0.153	5.751	0.000	0.094	0.560	Insignificant
H5c I→A	0.597	0.064	9.280	0.000	0.576	0.196	2.937	0.003	0.021	0.922	Insignificant
MGA II industries as a moderating variable ($n = 271$)											
	Dynamic industries				Static industries				MGA		
Hypothesis	**Estimate**	**SE**	***t*-value**	***p***	**Estimate**	**SE**	***t*-value**	***p***	**Difference**	***p***	**Note**
H6a D→A	0.319	0.072	4.404	0.000	0.135	0.088	1.530	0.126	0.184	0.113	Insignificant
H6b D→I	0.856	0.063	13.646	0.000	0.632	0.077	8.206	0.000	0.224*	0.031	Significant
H6c I→A	0.566	0.071	7.934	0.000	0.680	0.114	5.971	0.000	0.114	0.392	Insignificant

*$p < 0.05$.

customer responsiveness, and mitigate risks associated with SC disruptions. Overall, firm innovation plays a crucial role in enhancing SC agility by adopting emerging technologies, improving internal processes, fostering collaborative partnerships, and promoting a culture of continuous improvement.

The UAE government promotes the adoption of new technologies and digitalization in businesses (Cabral 2023). According to our survey results, not surprisingly, UAE companies show a relatively high level of SC digitalization (mean range from 5.27 to 5.73), a relatively high level of innovation capability (mean range from 5.30 to 5.65), and a relatively high level of SC agility (mean range from 5.38 to 5.59). These results are in line with the current situation in the UAE. Firms should explore different value-added activities in SCs by leveraging new technologies and digitalization. The research findings support our Hypotheses H1–H4 in the model. The empirical results reveal that SC digitalization positively affects SC agility (H1) and firm innovation (H2). In addition, the results affirm that firm innovation positively affects SC agility (H3). Our results are consistent with those of previous studies (Russell and Swanson 2019; Sambamurthy, Bharadwaj, and Grover 2003; Seyedghorban et al. 2020; Vial 2019). Furthermore, we identified firm innovation as a mediator, which was shown to partially mediate the effect of SC digitalization on SC agility (H4).

Firm size is an important control variable, and prior studies indicate that size may play a vital role in digitalization (Hess et al. 2016; Reuschl, Deist, and Maalaoui 2022). We conducted an MGA to examine the moderating effect of the control variables to better understand the relationships in the research models. We did not find a significant moderator (H5a–H5c) in this research. However, upon closer examination, we investigated the mediation effect of firm innovation in various groups. Interestingly, our findings revealed that firm innovation acted as a full mediator in the relationship between SC digitalization and SC agility within large-sized enterprises, as well as those firms operating in static industries. Firm innovation partially mediated the effect of SC digitalization on SC agility in SMEs and those firms situated in dynamic industries. This provides empirical evidence to support the view that successful and sustainable digitalization should build on an integrated approach when changing a firm's structures, processes, technologies, and culture (Reuschl, Deist, and Maalaoui 2022; Vial 2019). Large-sized enterprises, with their greater resources and capabilities, have a more conducive environment for fostering innovation. As a result, the innovative initiatives driven by SC digitalization play a crucial role in enhancing SC agility within these organizations. Similarly, in static industries where environmental factors are relatively stable, firms may focus more on internal innovation processes to improve agility in response to SC digitalization. Our results align with those of previous studies (Wang, Kim, and Chan 2022). Furthermore, H6b is also supported—the relationship between SC digitalization and innovation is stronger for firms situated in dynamic industries than those situated in static industries (the evidence revealed that SC digitalization is more likely to foster innovation in dynamic industries).

This study offers valuable insights into the influence of SC digitalization on firm innovation, ultimately contributing to the

TABLE 7 | Goodness-of-fit indices of the models in multigroup analysis ($n = 271$).

Model	CMIN	df	*p*	CMIN/df	CFI	RMSEA	SRMR
MGA I							
Model 1	131.36	68	0.000	1.93	0.970	0.059	0.041
Model 2	699.75	294	0.000	2.38	0.942	0.051	0.040
MGA II							
Model 1	174.97	68	0.000	2.57	0.951	0.076	0.039
Model 2	754.02	294	0.000	2.56	0.935	0.054	0.040

Note: Recommended model fit indices: $\chi^2/df < 3$, CFI > 0.90, RMSEA < 0.08, and SRMR < 0.08 (Bentler and Bonett 1980; Hair 2010).

attainment of SC agility. Firms can use digital technologies to revolutionize traditional SC operations and innovate across various facets of their SCs (Perano et al. 2023). For instance, digital platforms facilitate seamless communication and collaboration among SC partners, fostering co-innovation and rapid adaptation to market changes. Moreover, digitalization enables firms to optimize inventory management, enhance logistics efficiency, and create agile manufacturing processes tailored to customer demands. Although the extant literature identified SC digitalization as a game-changing opportunity for companies, the existing research mainly focuses on the antecedents of digitalization (Vial 2019). This study offers innovative guidance for firms to gain a deeper understanding of the mechanism between SC digitalization, firm innovation, and SC agility.

6.1 | Theoretical Implications

Our study makes theoretical contributions to the SC digitalization literature. The measuring instruments and research models employed in this study were validated. Specifically, the measurement models of SC digitalization and firm innovation were introduced and validated for the first time within this research. SC digitalization can be viewed as a strategic resource that firms can leverage to drive innovation. According to the RBV, firms achieve competitive advantage by accumulating and deploying valuable, rare, and non-substitutable resources. SC digitalization, as a valuable and unique resource, enables firms to innovate by leveraging digital technologies, data analytics, and process automation to develop new products, services, or processes. According to the dynamic capabilities approach, SC digitalization can be conceptualized as a dynamic capability that enables firms to sense, seize, and reconfigure resources in response to changing market conditions. SC digitalization enhances a firm's ability to innovate by providing it with the tools, technologies, and capabilities to respond rapidly to emerging opportunities or threats. This innovation-driven agility enables firms to reconfigure their SCs in real-time, optimize processes, and adapt to evolving customer demands, thereby enhancing overall SC agility. Our study expands upon the RBV and dynamic capabilities theories by integrating SC digitalization into operations and SC management. We demonstrate that SC digitalization serves as a valuable resource for firms, while dynamic capability fosters firm innovation. This innovation, in turn, enhances SC agility and highlights the interconnectedness of digitalization, innovation, and agility within the organizational context.

The results underline the importance of digitalization in operations and SC management, and how this can help firms achieve SC agility through firm innovation. For example, digital technologies (such as blockchain and AI) require new ways or changes in how business is conducted, and this brings opportunities to SC digitalization (Seyedghorban et al. 2020). Furthermore, in accordance with the dynamic capabilities approach, SC agility is considered a dynamic capability that empowers organizations to swiftly adapt and respond to these changes (Braunscheidel and Suresh 2009; Christopher and Towill 2001; Teece, Peteraf, and Leih 2016) and compete effectively in a fast-changing and unpredictable business environment (Müller, Hoberg, and Fransoo 2022; Patel and Sambasivan 2022). Firm innovation is viewed as a firm's ability to manage innovation activities. In this study, our findings indicate that firm innovation mediates the effect of digitalization on SC agility. This also implies that dynamic capabilities require certain resources and a firm's ability to achieve. Wang and Prajogo (2024) and Vial (2019) stress that technologies alone offer little value to a firm. Our study recommends that, in the post-pandemic era, digitalization efforts should integrate firm innovation to enhance the development of dynamic capabilities.

6.2 | Managerial Implications

Our study holds significant managerial implications and advocates fostering a proactive approach to innovation within organizations, emphasizing that it plays a pivotal role in enhancing SC agility. SC digitalization can improve SC capabilities by leveraging technologies, such as IoT, blockchain, data analytics, and cloud computing. These advancements have the potential to enhance innovation, foster collaboration, and increase responsiveness across the SC. Managers should strategically invest in digitalization, for example, by allocating resources to digitalization initiatives that will improve operational efficiency and cultivate innovation capabilities. By embracing digitalization, firms can create a foundation for innovation and agility in their SC operations.

The results of our study specifically show that full mediation or an indirect-only mediation effect was found in large enterprises and static industries. Managers in these organizations and industries may need to prioritize innovation practices during digitalization. For instance, in large organizations situated in static industries, it is essential to align technology with appropriate innovation practices to achieve an agile SC. Firm innovation

acted as a partial mediator in the relationship between SC digitalization and SC agility in SMEs located in dynamic industries. Managers of SMEs in dynamic industries should focus on developing a dynamic and adaptive SC strategy. This involves adapting SC strategies to leverage innovations effectively. It is crucial to integrate digitalization efforts with innovation practices to establish agile SC capabilities that cater specifically to the needs of SMEs and dynamic industries.

Our findings also highlight the importance of promoting a culture of innovation within organizations, encouraging both managers and staff members to generate new ideas and solutions to address business challenges. It is imperative for managers to continuously assess and improve SC digitalization efforts and innovation initiatives, ensuring their alignment with strategic objectives and adapting to evolving market dynamics. Conventionally, SC management involves managing three types of flows: physical goods, information, and cash (Christopher 2005). Digitalization may involve all types of flows in SCs (Wang, Childerhouse, and Abareshi 2024), as discussed. In this study, digitalization focuses on the adoption of digital technologies in firms to enhance SC operations. Based on our findings, managers should prioritize enhancing business process improvement and leveraging digital technologies to innovate in their SCs. This includes improving the payment process (cash), physical delivery of goods (goods), and customer service (information). This proactive approach may lead to improved SC agility.

Looking at SC agility, our findings suggest that managers should work closely with suppliers and rapidly respond to both internal and external changes. Most importantly, firms should be flexible in resolving problems (Shih 2020; Wang, Jie, and Frederico 2024). Managers should pay close attention to the adoption of new digital technologies (especially those firms situated in dynamic industries) and, when implementing them in their SCs, should embrace innovation to rethink how these technologies can facilitate the simultaneous flow of physical goods, information, and cash. This proactive approach is crucial for achieving SC agility through innovative practices.

6.3 | Limitations of the Study and Future Research

The study has its limitations. First, it did not concentrate on a particular industry or sector; therefore, the generalizability of the findings may be limited. Conducting focused studies within specific industries or sectors can enhance the applicability and generalizability of the findings. Future research could explore how SC digitalization, innovation, and agility interact differently across other industries (e.g., manufacturing, healthcare, or retail). Second, the measurement items of SC digitalization and firm innovation were tested for the first time in our research. Further research could refine and validate the measurement items for SC digitalization and firm innovation. This would involve rigorous testing and validation of these constructs across different contexts and industries to ensure robustness and reliability. Third, previous studies indicate that firm size significantly influences digital transformation. However, in our analysis, we did not find a statistically significant moderating effect of firm size. It might be useful to investigate other potential moderating factors that could influence the relationship between SC digitalization and outcomes such as agility and innovation (aside from firm size). For instance, factors such as environmental dynamics, geographic location, and organizational culture could be explored to understand their moderating effects. In addition, we found that firm innovation partially mediated the relationship between SC digitalization and SC agility in our model. We suggest investigating other mediating variables or mechanisms through which SC digitalization influences SC agility, beyond innovation, could provide deeper insights into the underlying processes and dynamics.

In addition to the future research directions mentioned above, further testing of the research models can involve incorporating different firm capabilities and additional constructs. This approach could lead to a deeper understanding of the organizational phenomenon. We also suggest conducting longitudinal studies to track changes over time in SC digitalization efforts and assessing their impacts on agility and innovation. Additionally, cross-national studies could compare practices and outcomes across different countries or regions to identify variations and best practices. Also, partial mediation and unproven hypotheses may imply future research opportunities in SC digitalization. We recommend complementing the quantitative findings with qualitative approaches, such as interviews or case studies, to gain a richer understanding of how organizations perceive and implement SC digitalization, innovation, and agility strategies. Moreover, future research could delve into diverse stakeholder perspectives—encompassing customers, suppliers, and communities—to glean insights into the ramifications of digitalization. There is also scope to investigate how external factors, such as regulatory changes, economic conditions, and technological advancements, influence the relationship between SC digitalization, innovation, and agility. Dyadic data collection could also be undertaken to holistically understand the impact of SC digitalization from multiple perspectives concurrently.

Our study provides empirical evidence that demonstrates the connections between SC digitalization, innovation, and SC agility. The findings also highlight the importance of SC digitalization in building agile SCs through innovation. This research offers a valuable perspective on enhancing SC agility and resilience post COVID-19, significantly advancing the literature on SC digitalization.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

Agarwal, A., R. Shankar, and M. K. Tiwari. 2007. "Modeling Agility of Supply Chain." *Industrial Marketing Management* 36, no. 4: 443–457. https://doi.org/10.1016/j.indmarman.2005.12.004.

Ahsan, M., S. Adomako, F. Donbesuur, and K. F. Mole. 2022. "Entrepreneurial Passion and Product Innovation Intensity in New Ventures: Mediating Effects of Exploration and Exploitation Activities." *British Journal of Management* 34: 1–23. https://doi.org/10.1111/1467-8551.12627.

Aslam, H., C. Blome, S. Roscoe, and T. M. Azhar. 2020. "Determining the Antecedents of Dynamic Supply Chain Capabilities." *Supply Chain Management* 25, no. 4: 427–442. https://doi.org/10.1108/SCM-02-2019-0074.

Azadegan, A., and K. J. Dooley. 2010. "Supplier Innovativeness, Organizational Learning Styles and Manufacturer Performance: An Empirical Assessment." *Journal of Operations Management* 28, no. 6: 488–505. https://doi.org/10.1016/j.jom.2010.02.001.

Baron, R. M., and D. A. Kenny. 1986. "The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations." *Journal of Personality and Social Psychology* 51, no. 6: 1173–1182.

Bentler, P. M., and D. G. Bonett. 1980. "Significance Tests and Goodness of Fit in the Analysis of Covariance Structures." *Psychological Bulletin* 88, no. 3: 588–606. https://doi.org/10.1037/0033-2909.88.3.588.

Bertoni, F., S. Bonini, V. Capizzi, M. G. Colombo, and S. Manigart. 2022. "Digitization in the Market for Entrepreneurial Finance: Innovative Business Models and New Financing Channels." *Entrepreneurship Theory and Practice* 46, no. 5: 1120–1135. https://doi.org/10.1177/10422587211038480.

Braunscheidel, M. J., and N. C. Suresh. 2009. "The Organizational Antecedents of a Firm's Supply Chain Agility for Risk Mitigation and Response." *Journal of Operations Management* 27, no. 2: 119–140. https://doi.org/10.1016/j.jom.2008.09.006.

Braunscheidel, M. J., and N. C. Suresh. 2018. "Cultivating Supply Chain Agility: Managerial Actions Derived From Established Antecedents." In *Supply Chain Risk Management: Advanced Tools, Models and Developments*, edited by Y. Khojasteh, 289–309. Singapore: Springer Singapore. https://doi.org/10.1007/978-981-10-4106-8_17.

Brennen, J. S., and D. Kreiss. 2016. "Digitalization." In *The International Encyclopedia of Communication Theory and Philosophy*, 1–11. Hoboken, NJ. https://doi.org/10.1002/9781118766804.wbiect111.

Cabral, A. R. 2023. *How Companies in the UAE, Saudi Arabia and Egypt Can Take Advantage of Digitalisation*. Abu Dhabi, UAE: National.

Calantone, R. J., S. T. Cavusgil, and Y. Zhao. 2002. "Learning Orientation, Firm Innovation Capability, and Firm Performance." *Industrial Marketing Management* 31, no. 6: 515–524. https://doi.org/10.1016/S0019-8501(01)00203-6.

Childerhouse, P., and D. R. Towill. 2003. "Simplified Material Flow Holds the Key to Supply Chain Integration." *Omega* 31, no. 1: 17–27. https://doi.org/10.1016/S0305-0483(02)00062-2.

Christopher, M. 2000. "The Agile Supply Chain: Competing in Volatile Markets." *Industrial Marketing Management* 29, no. 1: 37–44. https://doi.org/10.1016/S0019-8501(99)00110-8.

Christopher, M. 2005. *Logistics and Supply Chain Management: Strategies for Reducing Costs, Improving Services and Managing the Chain of Demand*. 3rd ed. New York: Financial Times Prentice Hall.

Christopher, M., and D. Towill. 2001. "An Integrated Model for the Design of Agile Supply Chains." *International Journal of Physical Distribution and Logistics Management* 31, no. 4: 235–246. https://doi.org/10.1108/09600030110394914.

Cichosz, M., W. Carl Marcus, and A. M. Knemeyer. 2020. "Digital Transformation at Logistics Service Providers: Barriers, Success Factors and Leading Practices." *International Journal of Logistics Management* 31, no. 2: 209–238. https://doi.org/10.1108/IJLM-08-2019-0229.

Clottey, T. A., and S. J. Grawe. 2014. "Non-Response Bias Assessment in Logistics Survey Research: Use Fewer Tests?" *International Journal of Physical Distribution and Logistics Management* 44, no. 5: 412–426. https://doi.org/10.1108/IJPDLM-10-2012-0314.

Cole, R., M. Stevenson, and J. Aitken. 2019. "Blockchain Technology: Implications for Operations and Supply Chain Management." *Supply Chain Management* 24, no. 4: 469–483. https://doi.org/10.1108/SCM-09-2018-0309.

Coreynen, W., P. Matthyssens, and W. Van Bockhaven. 2017. "Boosting Servitization Through Digitization: Pathways and Dynamic Resource Configurations for Manufacturers." *Industrial Marketing Management* 60: 42–53. https://doi.org/10.1016/j.indmarman.2016.04.012.

Dawkes, J. 2008. "Do Data Characteristics Change According to the Number of Scale Points Used? An Experiment Using 5-Point, 7-Point and 10-Point Scales." *International Journal of Market Research* 50, no. 1: 61–104. https://doi.org/10.1177/147078530805000106.

Dillman, D. A. 1991. "The Design and Administration of Mail Surveys." *Annual Review of Sociology* 17, no. 1: 225–249. https://doi.org/10.1146/annurev.so.17.080191.001301.

Do, Q. N., N. Mishra, N. B. I. Wulandhari, A. Ramudhin, U. Sivarajah, and G. Milligan. 2021. "Supply Chain Agility Responding to Unprecedented Changes: Empirical Evidence From the UK Food Supply Chain During COVID-19 Crisis." *Supply Chain Management* 26, no. 6: 737–752. https://doi.org/10.1108/SCM-09-2020-0470.

Fabrigar, L. R. 2012. *Exploratory Factor Analysis*. New York: Oxford University Press.

Fine, C. 1998. *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*. New York: Perseus Books.

Fitzgerald, M., N. Kruschwitz, D. Bonnet, and M. Welch. 2014. "Embracing Digital Technology: A New Strategic Imperative." *MIT Sloan Management Review* 55, no. 2: 1.

Fornell, C., and D. F. Larcker. 1981. "Evaluating Structural Equation Models With Unobservable Variables and Measurement Error." *Journal of Marketing Research* 18, no. 1: 39–50. https://doi.org/10.2307/3151312.

Gligor, D., N. Gligor, M. Holcomb, and S. Bozkurt. 2019. "Distinguishing Between the Concepts of Supply Chain Agility and Resilience: A Multidisciplinary Literature Review." *International Journal of Logistics Management* 30, no. 2: 467–487. https://doi.org/10.1108/IJLM-10-2017-0259.

Gligor, D. M., and M. C. Holcomb. 2012. "Antecedents and Consequences of Supply Chain Agility: Establishing the Link to Firm Performance." *Journal of Business Logistics* 33, no. 4: 295–308. https://doi.org/10.1111/jbl.12003.

Hair, J. F. 2010. *Multivariate Data Analysis*. 7th ed. Upper Saddle River, NJ: Prentice Hall.

Henderson, J. C., and N. Venkatraman. 1993. "Strategic Alignment: Leveraging Information Technology for Transforming Organizations." *IBM Systems Journal* 32, no. 1: 4–16. https://doi.org/10.1147/sj.382.0472.

Hess, T., C. Matt, A. Benlian, and F. Wiesböck. 2016. "Options for Formulating a Digital Transformation Strategy." *MIS Quarterly Executive* 15, no. 2: 123–139.

Hill, T. 2000. *Manufacturing Strategy: Text and Cases*. 2nd ed. Basingstoke, UK: Palgrave.

Holmström, J., M. Holweg, B. Lawson, F. K. Pil, and S. M. Wagner. 2019. "The Digitalization of Operations and Supply Chain Management: Theoretical and Methodological Implications." *Journal of Operations Management* 65, no. 8: 728–734. https://doi.org/10.1002/joom.1073.

Hopwood, C. J. 2007. "Moderation and Mediation in Structural Equation Modeling: Applications for Early Intervention Research."

Journal of Early Intervention 29, no. 3: 262–272. https://doi.org/10.1177/105381510702900305.

Huang, J., O. Henfridsson, M. J. Liu, and S. Newell. 2017. "Growing on Steroids: Rapidly Scaling the User Base of Digital Ventures Through Digital Innovation." *MIS Quarterly* 41, no. 1: 301–314. https://doi.org/10.25300/MISQ/2017/41.1.16.

Iddris, F., G. B. Awuah, and D. A. Gebrekidans. 2016. "Achieving Supply Chain Agility Through Innovation Capability Building." *International Journal of Supply Chain and Operations Resilience* 2, no. 2: 114–143. https://doi.org/10.1504/IJSCOR.2016.078181.

Ivanov, D. 2022. "Viable Supply Chain Model: Integrating Agility, Resilience and Sustainability Perspectives – Lessons From and Thinking Beyond the COVID-19 Pandemic." *Annals of Operations Research* 319: 1411–1431. https://doi.org/10.1007/s10479-020-03640-6.

Jeong, S., A. Oke, and T. Y. Choi. 2022. "Opportunistic Innovation in the Age of Digital Services." *Journal of Operations Management* 68, no. 4: 328–352. https://doi.org/10.1002/joom.1181.

Kaiser, H. F. 1958. "The Varimax Criterion for Analytic Rotation in Factor Analysis." *Psychometrika* 23, no. 3: 187–200. https://doi.org/10.1007/BF02289233.

Khazanchi, S., M. W. Lewis, and K. K. Boyer. 2007. "Innovation-Supportive Culture: The Impact of Organizational Values on Process Innovation." *Journal of Operations Management* 25, no. 4: 871–884. https://doi.org/10.1016/j.jom.2006.08.003.

Kim, M., and S. Chai. 2017. "The Impact of Supplier Innovativeness, Information Sharing and Strategic Sourcing on Improving Supply Chain Agility: Global Supply Chain Perspective." *International Journal of Production Economics* 187: 42–52. https://doi.org/10.1016/j.ijpe.2017.02.007.

Koufteros, X., M. Vonderembse, and J. Jayaram. 2005. "Internal and External Integration for Product Development: The Contingency Effects of Uncertainty, Equivocality, and Platform Strategy." *Decision Sciences* 36, no. 1: 97–133. https://doi.org/10.1111/j.1540-5915.2005.00067.x.

Kraus, S., F. Schiavone, A. Pluzhnikova, and A. C. Invernizzi. 2021. "Digital Transformation in Healthcare: Analyzing the Current State-Of-Research." *Journal of Business Research* 123: 557–567. https://doi.org/10.1016/j.jbusres.2020.10.030.

Lim, M. K., Y. Li, C. Wang, and M.-L. Tseng. 2021. "A Literature Review of Blockchain Technology Applications in Supply Chains: A Comprehensive Analysis of Themes, Methodologies and Industries." *Computers & Industrial Engineering* 154: 107133. https://doi.org/10.1016/j.cie.2021.107133.

Lindell, M. K., and D. J. Whitney. 2001. "Accounting for Common Method Variance in Cross-Sectional Research Designs." *Journal of Applied Psychology* 86, no. 1: 114–121. https://doi.org/10.1037/0021-9010.86.1.114.

Lorenz, R., C. Benninghaus, T. Friedli, and T. H. Netland. 2020. "Digitization of Manufacturing: The Role of External Search." *International Journal of Operations & Production Management* 40, no. 7/8: 1129–1152. https://doi.org/10.1108/IJOPM-06-2019-0498.

Müller, J., K. Hoberg, and J. C. Fransoo. 2022. "Realizing Supply Chain Agility Under Time Pressure: Ad Hoc Supply Chains During the COVID-19 Pandemic." *Journal of Operations Management* 69, no. 3: 426–449. https://doi.org/10.1002/joom.1210.

Nambisan, S., M. Wright, and M. Feldman. 2019. "The Digital Transformation of Innovation and Entrepreneurship: Progress, Challenges and Key Themes." *Research Policy* 48, no. 8: 103773. https://doi.org/10.1016/j.respol.2019.03.018.

Patel, B. S., and M. Sambasivan. 2022. "A Systematic Review of the Literature on Supply Chain Agility." *Management Research Review* 45, no. 2: 236–260. https://doi.org/10.1108/MRR-09-2020-0574.

Perano, M., A. Cammarano, V. Varriale, C. Del Regno, F. Michelino, and M. Caputo. 2023. "Embracing Supply Chain Digitalization and Unphysicalization to Enhance Supply Chain Performance: A Conceptual Framework." *International Journal of Physical Distribution and Logistics Management* 53, no. 5/6: 628–659. https://doi.org/10.1108/IJPDLM-06-2022-0201.

Podsakoff, P. M., S. B. MacKenzie, J.-Y. Lee, and N. P. Podsakoff. 2003. "Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies." *Journal of Applied Psychology* 88, no. 5: 879–903. https://doi.org/10.1037/0021-9010.88.5.879.

Prajogo, D. I., and P. K. Ahmed. 2006. "Relationships Between Innovation Stimulus, Innovation Capacity, and Innovation Performance." *R&D Management* 36, no. 5: 499–515. https://doi.org/10.1111/j.1467-9310.2006.00450.x.

Reuschl, A. J., M. K. Deist, and A. Maalaoui. 2022. "Digital Transformation During a Pandemic: Stretching the Organizational Elasticity." *Journal of Business Research* 144: 1320–1332. https://doi.org/10.1016/j.jbusres.2022.01.088.

Richey, R. G., A. S. Roath, F. G. Adams, and A. Wieland. 2022. "A Responsiveness View of Logistics and Supply Chain Management." *Journal of Business Logistics* 43, no. 1: 62–91. https://doi.org/10.1111/jbl.12290.

Ritter, T., and C. L. Pedersen. 2020. "Digitization Capability and the Digitalization of Business Models in Business-To-Business Firms: Past, Present, and Future." *Industrial Marketing Management* 86: 180–190. https://doi.org/10.1016/j.indmarman.2019.11.019.

Ross, J. 2017. *Don't Confuse Digital With Digitization*. Cambridge, MA: Massachusetts Institute of Technology.

Russell, D. M., and D. Swanson. 2019. "Transforming Information Into Supply Chain Agility: An Agility Adaptation Typology." *International Journal of Logistics Management* 30, no. 1: 329–355. https://doi.org/10.1108/IJLM-09-2017-0237.

Sambamurthy, V., A. Bharadwaj, and V. Grover. 2003. "Shaping Agility Through Digital Options: Reconceptualizing the Role of Information Technology in Contemporary Firms." *MIS Quarterly: Management Information Systems* 27, no. 2: 237–264. https://doi.org/10.2307/30036530.

Seyedghorban, Z., H. Tahernejad, R. Meriton, and G. Graham. 2020. "Supply Chain Digitalization: Past, Present and Future." *Production Planning and Control* 31, no. 2–3: 96–114. https://doi.org/10.1080/09537287.2019.1631461.

Shashi, K., P. Centobelli, R. Cerchione, and M. Ertz. 2020. "Agile Supply Chain Management: Where Did It Come From and Where Will It Go in the Era of Digital Transformation?" *Industrial Marketing Management* 90: 324–345. https://doi.org/10.1016/j.indmarman.2020.07.011.

Shih, W. C. 2020. "Global Supply Chains in a Post-Pandemic World: Companies Need to Make Their Networks More Resilient. Here's How." *Harvard Business Review* 98, no. 5: 82.

Subramani, M. 2004. "How Do Suppliers Benefit From Information Technology Use in Supply Chain Relationships?" *MIS Quarterly: Management Information Systems* 28, no. 1: 45–73. https://doi.org/10.2307/25148624.

Swafford, P. M., S. Ghosh, and N. Murthy. 2006. "The Antecedents of Supply Chain Agility of a Firm: Scale Development and Model Testing." *Journal of Operations Management* 24, no. 2: 170–188. https://doi.org/10.1016/j.jom.2005.05.002.

Swafford, P. M., S. Ghosh, and N. Murthy. 2008. "Achieving Supply Chain Agility Through IT Integration and Flexibility." *International Journal of Production Economics* 116, no. 2: 288–297. https://doi.org/10.1016/j.ijpe.2008.09.002.

Teece, D., M. Peteraf, and S. Leih. 2016. "Dynamic Capabilities and Organizational Agility: Risk, Uncertainty, and Strategy in the

Innovation Economy." *California Management Review* 58, no. 4: 13–35. https://doi.org/10.1525/cmr.2016.58.4.13.

Teece, D. J., G. Pisano, and A. Shuen. 1997. "Dynamic Capabilities and Strategic Management." *Strategic Management Journal* 18, no. 7: 509–533.

Tidd, J., and J. R. Bessant. 2013. *Managing Innovation: Integrating Technological, Market and Organizational Change*. 5th ed. Chichester, West Sussex, UK: John Wiley & Sons.

van Hoek, R. I., A. Harrison, and M. Christopher. 2001. "Measuring Agile Capabilities in the Supply Chain." *International Journal of Operations & Production Management* 21, no. 1/2: 126–148. https://doi.org/10.1108/01443570110358495.

Velayutham, A., A. R. Rahman, A. Narayan, and M. Wang. 2021. "Pandemic Turned Into Pandemonium: The Effect on Supply Chains and the Role of Accounting Information." *Accounting, Auditing & Accountability Journal* 34, no. 6: 1404–1415. https://doi.org/10.1108/AAAJ-08-2020-4800.

Venkatesh, V., M. G. Morris, G. B. Davis, and F. D. Davis. 2003. "User Acceptance of Information Technology: Toward a Unified View." *MIS Quarterly: Management Information Systems* 27, no. 3: 425–478. https://doi.org/10.2307/30036540.

Verbeke, A. 2020. "Will the COVID-19 Pandemic Really Change the Governance of Global Value Chains?" *British Journal of Management* 31, no. 3: 444–446. https://doi.org/10.1111/1467-8551.12422.

Vial, G. 2019. "Understanding Digital Transformation: A Review and a Research Agenda." *Journal of Strategic Information Systems* 28, no. 2: 118–144. https://doi.org/10.1016/j.jsis.2019.01.003.

Visa Economic Empowerment Institute. 2022. *Small Business in the Digital Age. Dubai MSMEs: Digital and Resilient*. Dubai, UAE: Visa.

Wagner, S. M., and R. Kemmerling. 2010. "Handling Nonresponse in Logistics Research." *Journal of Business Logistics* 31, no. 2: 357–381. https://doi.org/10.1002/j.2158-1592.2010.tb00156.x.

Wamba, S. F., R. Dubey, A. Gunasekaran, and S. Akter. 2020. "The Performance Effects of Big Data Analytics and Supply Chain Ambidexterity: The Moderating Effect of Environmental Dynamism." *International Journal of Production Economics* 222: 107498. https://doi.org/10.1016/j.ijpe.2019.09.019.

Wang, E., and H.-L. Wei. 2007. "Interorganizational Governance Value Creation: Coordinating for Information Visibility and Flexibility in Supply Chains." *Decision Sciences* 38, no. 4: 647–674. https://doi.org/10.1111/j.1540-5915.2007.00173.x.

Wang, M. 2016. "The Role of Innovation Capability in the Australian Courier Industry." *International Journal of Innovation Management* 20, no. 7: 1–18. https://doi.org/10.1142/S1363919616500705.

Wang, M. 2018. "Impacts of Supply Chain Uncertainty and Risk on the Logistics Performance." *Asia Pacific Journal of Marketing and Logistics* 30, no. 3: 689–704. https://doi.org/10.1108/APJML-04-2017-0065.

Wang, M. 2020. "Assessing Logistics Capability for the Australian Courier Firms." *International Journal of Logistics Systems and Management* 37, no. 4: 576–589. https://doi.org/10.1504/ijlsm.2020.111827.

Wang, M., S. Asian, L. C. Wood, and B. Wang. 2020. "Logistics Innovation Capability and Its Impacts on the Supply Chain Risks in the Industry 4.0 Era." *Modern Supply Chain Research and Applications* 2, no. 1: 1–16. https://doi.org/10.1108/mscra-07-2019-0015.

Wang, M., R. Y. K. Chan, M. Kumar, and N. Tsolakis. 2024. "Does Increasing Supply Chain Flexibility Contribute to the Enhancement of a Firm's Sustainability Performance?" *IEEE Transactions on Engineering Management* 71: 8606–8622. https://doi.org/10.1109/TEM.2024.3394034.

Wang, M., P. Childerhouse, and A. Abareshi. 2024. "Global Logistics and Supply Chain Integration in the Digital Era: A Focus on China's Belt and Road Initiative." *Journal of International Logistics and Trade* 22, no. 2: 58–79. https://doi.org/10.1108/JILT-03-2023-0018.

Wang, M., A. Hill, and K.-S. Hwang. 2022. "Measuring Firm's Digitalisation in the Supply Chains." Paper Presented at the AMLRN Annual Symposium: Contemporary Developments in Sustainable Maritime Logistics, Perth, Australia.

Wang, M., F. Jie, and F. G. Frederico. 2024. "Measuring Supply Chain Agility During the COVID-19 Pandemic: Empirical Evidence From the Firms in the United Arabs Emirates." *International Journal of Agile Systems and Management* 17, no. 1: 1–15.

Wang, M., N. Kim, and R. Y. K. Chan. 2022. "Impacts of Environmental Uncertainty on Firms' Innovation Capability and Stakeholder Value: Evidence From the Australian Courier Industry." *International Journal of Innovation Management* 26, no. 1: 22500086. https://doi.org/10.1142/s1363919622500086.

Wang, M., and D. Prajogo. 2024. "The Effect of Supply Chain Digitalisation on a Firm's Performance." *Industrial Management & Data Systems* 124, no. 5: 1725–1745. https://doi.org/10.1108/IMDS-09-2023-0629.

Wang, M., and B. Wang. 2023. "Supply Chain Agility as the Antecedent to Firm Sustainability in the Post COVID-19." *International Journal of Logistics Management* 35, no. 1: 281–303. https://doi.org/10.1108/IJLM-02-2022-0059.

Wang, M., Y. Wu, B. Chen, and M. Evans. 2021. "Blockchain and Supply Chain Management: A New Paradigm for Supply Chain Integration and Collaboration." *Operations and Supply Chain Management: An International Journal* 14, no. 1: 111–122.

Wang, Y., Y. Chen, N. Wang, S. Nevo, G. Kou, and F. E. Alsaadi. 2020. "Impact of the Strategic Role of IT on Explorative and Exploitative Innovation Activities: The Role of Environmental Uncertainty." *Decision Sciences* 51, no. 3: 542–574. https://doi.org/10.1111/deci.12377.

White, A., E. M. Daniel, and M. Mohdzain. 2005. "The Role of Emergent Information Technologies and Systems in Enabling Supply Chain Agility." *International Journal of Information Management* 25, no. 5: 396–410.

Wiengarten, F., M. Pagell, and B. Fynes. 2012. "Supply Chain Environmental Investments in Dynamic Industries: Comparing Investment and Performance Differences With Static Industries." *International Journal of Production Economics* 135, no. 2: 541–551. https://doi.org/10.1016/j.ijpe.2011.03.011.

Wolf, E. J., K. M. Harrington, S. L. Clark, and M. W. Miller. 2013. "Sample Size Requirements for Structural Equation Models: An Evaluation of Power, Bias, and Solution Propriety." *Educational and Psychological Measurement* 76, no. 6: 913–934. https://doi.org/10.1177/0013164413495237.

Wulandhari, N. B. I., P. Budhwar, N. Mishra, S. Akbar, Q. Do, and G. Milligan. 2023. "Organizational Resilience to Supply Chain Risks During the COVID-19 Pandemic." *British Journal of Management* 34: 1282–1315. https://doi.org/10.1111/1467-8551.12648.

Zhang, M. F., J. F. Dawson, and R. B. Kline. 2021. "Evaluating the Use of Covariance-Based Structural Equation Modelling With Reflective Measurement in Organizational and Management Research: A Review and Recommendations for Best Practice." *British Journal of Management* 32, no. 2: 257–272. https://doi.org/10.1111/1467-8551.12415.

Zhao, X., J. G. Lynch, and Q. Chen. 2010. "Reconsidering Baron and Kenny: Myths and Truths About Mediation Analysis." *Journal of Consumer Research* 37, no. 2: 197–206. https://doi.org/10.1086/651257.

Appendix A

Innovation

To what extent do you agree with the following statements as they related to your firm's innovation? (1 = strongly disagree, 7 = strongly agree).

Statement	Mean
1. Our company applies creative techniques in business operations	5.39
2. Our company regularly improves company's operational systems	5.42
3. Our company adopts creative technologies and innovative solutions for problem solving	5.35
4. Our company promotes culture of innovation	5.42
5. Our company is willing to take risk to get better results	5.30
6. Our company encourage staff members to develop new ideas and methods in business operations	5.46
7. Our company attracts skilled and qualified staff	5.65

Note: $n = 271$.

Digitalization

To what extent do you agree with the following statements as they related to your firm's digital technologies? (1 = strongly disagree, 7 = strongly agree).

Statement	Mean
1. Our company applies digital technologies in our organizations	5.73
2. Our company uses enterprise systems (ERP) in our organizations	5.56
3. Our company applies advanced technologies to improve the process	5.54
4. Our company standardizes the operating process	5.62
5. Our company simplifies the operating process	5.40
6. Our company has a good technical and IT support	5.59
7. Our management supports the use of digital technologies	5.82
8. Our company applies digital technologies to integrate supply chains	5.29
9. Our company applies digital technologies to facilitate the payment	5.56
10. Our company applies digital technologies to facilitate goods delivery	5.27
11. Our company applies digital technologies to support customer service	5.48

Note: $n = 271$.

Supply chain agility

To what extent do you agree with the following statements as they related to your firm's supply chain agility? (1 = strongly disagree, 7 = strongly agree).

Statement	Mean
1. Our company is capable of responding to changing market demands	5.52
2. Our company is capable of joint planning with suppliers in purchasing, production and logistics	5.38
3. Our company is capable of responding to suppliers and customers' requests at a fast speed	5.55
4. Our company is capable of adjusting production/service capacity/capability	5.48
5. When an unexpected situation arises, our company and the supplier would solve problems adequately	5.55
6. When an unexpected situation arises, our company is capable of reconfiguring operations processes to adapt to the changes	5.58
7. When a disagreement arises in a transaction process, our company and the supplier would reevaluate the ongoing situation to achieve a mutually satisfactory solution	5.59

Note: $n = 271$.