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Exploring the bridge between digital transformation and sustainable supply chain performance: An empirical study based on Yunnan fresh cut flower supply chain

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Rapid global economic expansion and ongoing technological advancements have made digital transformation an essential tactic for businesses looking to boost their competitiveness and accomplish sustainable development. The study aims to explore how digital transformation (DT) indirectly affects the sustainable supply chain performance (SSCP) of fresh-cut flower supply chains in Yunnan Province through organizational readiness (OR) and innovation capability (IC) and to examine the moderating role of technology readiness (TR) in this process. This study adopted the survey method of the questionnaire, and the final valid sample was 354. Based on the RBV and the philosophy of sustainable development, the PLS-SEM approach is used in this study to assess the fresh-cut flower supply chain in Yunnan Province. It was found that OR and IC played a significant mediating role in DT and SSCP. Furthermore, the link between DT and OR, IC and SSCP, was significantly moderated by TR. The empirical results suggest that high technological readiness and innovativeness help firms assimilate and apply new technologies faster and thus achieve better results in digital transformation. This paper provides valuable guidance for firms and policymakers, suggesting active investment in digital technologies and infrastructure development, and focusing on the combination of innovation capability and sustainability to promote the sustainable development of agricultural supply chains.

1. Introduction

As a high-value-added agricultural product, fresh-cut flowers occupy an important position in the global flower trade. With the increase in consumer demand for a high quality of life and the advancement of e-commerce platforms and logistics technology, the fresh-cut flower market has shown rapid development in recent years. As China's largest fresh-cut flower production and export base, Yunnan Province is blessed with natural conditions, such as a suitable climate, abundant water resources and fertile land, which make it an important flower supply center in China and even in Asia (Zhang, 2017). Yunnan has led China in cut flower producing area, output, and export value for 29 years running as of 2023. Among them, Yunnan Province ranks 1st in the world in terms of production area and output of fresh-cut flowers (Wang, 2024). For industries worldwide, digital transformation has become a vital instrument for raising competitiveness, reducing costs, and increasing production. For agriculture and food supply chains, digitalization can not only optimize production processes and improve product quality but also achieve more accurate supply chain management and transparency through new technologies (Zhao & Chen, 2024). In recent years, the Chinese government has aggressively supported the modernization and intelligent growth of agriculture, and it has implemented a number of measures that facilitate the digital transformation of agricultural businesses. Accelerating the development of rural information infrastructure and encouraging the digital administration of the entire agricultural production process are two recommendations made in the Outline of the Strategy for the Development of the Digital Countryside (Kong, Ning, Mo, & Lan, 2024). Local governments in Yunnan Province have also launched many preferential policies and support programs, such as setting up special funds and providing technical training, to promote the digital upgrading of the local flower industry. Furthermore, the Kunming Dounan Flower Market, the biggest flower market

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in Asia and the second largest worldwide, has been a good example of digital change (Chen, You, & Zhu, 2021). The Kunming International Flower Auction Centre's founding has even opened the door for innovation and digital transformation in Yunnan Province's fresh-cut flower supply chain, while also offering other areas important lessons. In light of this, investigating the application of digital transformation to Yunnan Province's fresh-cut flower supply chain has emerged as a pressing research issue. At the same time, one of the main concerns of the twenty-first century is sustainability. For the cut flower supply chain, ensuring sustainability is not just about responding to the international community's call for environmental protection, it is also about responding to increasingly stringent environmental regulations and consumer demand for greener products. Sustainable supply chain performance encompasses economic, social and environmental dimensions, aiming to maximize economic benefits while reducing environmental impact and safeguarding employee welfare and social responsibility (Narimissa, Kangarani-Farahani, & Molla-Alizadeh-Zavardehi, 2020). Enhancing the sustainability of the supply chain is particularly important in the current policy environment that emphasizes the building of an ecological civilization. However, successful implementation of digital transformation does not happen overnight, and its effectiveness is often affected by some factors. First and foremost, an organization's ability to successfully execute digital transformation is largely determined by its organizational readiness. Organizational readiness encompasses some aspects such as an organization's technological infrastructure, employee skills, management support, etc. Only when organizational readiness is high can digital transformation move forward smoothly and achieve the desired results (Aboelmaged, 2014). Second, the process of digital transformation also heavily relies on innovation capability (IC). Through constant innovation, organizations must adjust to the rapidly shifting market environment and transform digital technology into genuine competitive advantages. Research shows that good organizational readiness and strong innovation capabilities are key factors for successful digital transformation and good performance (Machado et al., 2021). In addition, technology readiness (TR), as an external environmental factor, may have a moderating effect on the effectiveness of digital transformation. The effects of digital transformation can be further amplified in a sector that heavily relies on information technology, particularly when it comes to fostering organizational preparedness and innovative capabilities. Firms with high technology readiness can assimilate and apply new technologies faster and thus achieve better results in digital transformation (Parasuraman & Colby, 2015). Understanding how technology readiness affects the relationship between digital transformation and other variables is therefore critical to developing an effective strategy. Despite extensive research on the potential impact of digital transformation on various businesses, little is known about the fresh-cut flower industry specifically, particularly in regions like Yunnan Province that have a distinct geographic advantage and room for growth. Therefore, to fill this gap, the research objectives of this paper are 1) to understand how digital transformation indirectly affects the sustainable performance of supply chains through organizational readiness and innovation capability; 2) to examine the moderating role of technological readiness in this process; and 3) to provide a valuable reference for relevant firms and policymakers.

In conclusion, this study fully examines the complex connection among organizational readiness, innovation capability, technological readiness, digital transformation, and sustainable supply chain performance using the Yunnan Province fresh-cut flower supply chain as a backdrop and the PLS-SEM approach. It aims to determine the primary influencing routes and the underlying mechanisms by combining the RBV with the theory of sustainability. By developing theoretical models and empirical assessments, this work contributes to the theoretical research on the relationship between supply chain performance and digital transformation. But for Yunnan Province's fresh-cut flower businesses, it offers strategic advice on supply chain optimization and digital transformation that will help them preserve their competitive advantages in the global market and promote the industry's sustainable growth. The study is noteworthy because of this.

2. Literature Review

2.1. Theoretical Background

2.1.1. Digital transformation （DT）

Digital transformation is a way of applying digital technologies to change business practices, products, and services in order to boost output, enhance customer happiness, and obtain a competitive advantage (Ismail, Khater, & Zaki, 2017). For the agricultural sector, digital transformation involves not only technological innovation in the production chain but also the optimization of the entire supply chain management. The digitization of the agricultural supply chain refers to information sharing, process optimization, efficiency enhancement, quality and safety control and marketing innovation along the entire chain through the application of data and information technology to agricultural production, procurement, processing and sales (Yin et al., 2024). According to Hongtao (2021), the digital supply chain manifests itself as the digitization of agricultural products, digitization of agricultural transactions, digitization of the agricultural supply chain, digitization of various scenarios of agricultural products, digitization of spatial management of agricultural products, digitization of agricultural consumption, and digitization of various aspects of agricultural market governance. In the agriculture and floriculture industries, the application scenarios of digital transformation include intelligent planting management, real-time monitoring of logistics precision marketing, etc. Implementing these technologies enhances product quality and resource utilization efficiency in addition to lowering manufacturing costs (Kamilaris et al., 2017).

2.1.2. Sustainable Supply Chain Performance (SSCP)

Sustainable supply chain performance is an important component of modern business in its quest for long-term success and competitive advantage. Achieving sustainable supply chain performance is particularly important for the cut flower industry, which is sensitive to environmental conditions and involves complex supply chain management. An essential measure of a supply chain's overall economic, environmental, and social performance is its sustainable performance (Narimissa et al., 2020). In the economic dimension, sustainable supply chain performance focuses on cost efficiency, profit growth, and market competitiveness; in the environmental dimension, resource consumption, carbon emissions, and waste management; and the social dimension, employee welfare, community impact, and consumer satisfaction (Qorri, Mujkić, & Kraslawski, 2018). In the cut flower industry, improved sustainable supply chain performance not only helps companies reduce carbon emissions and resource consumption but also enhances brand image and market competitiveness.

2.1.3. Organizational Readiness (OR)

Organizational readiness is the extent to which a business is prepared to implement change in terms of technology, people and culture. (Weiner, 2020). In an environment of digital transformation, organizational readiness includes the sophistication of the technological infrastructure, the mastery of employees' digital skills, the level of management support for digital transformation, and the openness and innovation of the corporate culture (AlNuaimi, Singh, Ren, Budhwar, & Vorobyev, 2022). Research indicates that businesses with high levels of organizational preparedness are better able to manage the challenges presented by digital transformation and benefit from it (Westerman, Bonnet, & McAfee, 2014). In the cut flower industry, companies with a high level of organizational readiness can adopt smart growing technologies and digital logistics systems more quickly, resulting in higher production efficiency and product quality.

2.1.4. Innovation Capabilities (IC)

An organizational capacity to adjust to shifting market conditions and generate competitive advantages through managerial and technological innovation is known as its innovation capability (Ferreira, Coelho, & Moutinho, 2020). Innovation capability includes not only technology research and development but also organizational management, market insight and resource integration (Eng & Okten, 2011). In supply chain management, the ability to innovate is recognized as a key factor in improving the efficiency, flexibility and sustainability of the supply chain (Tseng, Chang, & Chen, 2019). In the cut flower industry, technological innovation can be seen in the research and development of new varieties, the development and application of intelligent planting technology and precision irrigation systems (Kamilaris et al., 2017). By introducing agile management methods and cross-functional collaboration mechanisms, companies can respond more quickly to changes in market demand, thereby improving management processes and organizational structures to increase efficiency and flexibility (Teece, Pisano, & Shuen, 1997). The ability to enhance competitiveness through insight into market demand and the development of new markets, the rise of e-commerce has not only changed the shopping habits of consumers but the flower companies are also faced with a huge challenge to the innovation of marketing channels.

2.1.5. Technology Readiness (TR)

Technology readiness refers to the readiness of an enterprise in terms of its technological infrastructure, its technological absorptive capacity and its ability to apply technology (Parasuraman, 2000). Technology readiness includes not only an enterprise's existing technological resources and capabilities but also its ability to learn and apply new technologies (Aydın & Tasci, 2005). Technology preparedness is regarded as one of the most important elements for an organization's effective digital transformation deployment. Enterprises with high technology readiness typically have well-developed technology infrastructures, such as high-speed networks, cloud computing platforms and IoT devices (Jafari-Sadeghi, Garcia-Perez, Candelo, & Couturier, 2021). The sophistication of these infrastructures has a direct impact on an organization's ability to implement digital transformation.

2.2. Resource-Based View (RBV) and sustainable development theory

The RBV, which was proposed by Barney, is one of the fundamental theories in the subject of strategic management. According to the thesis, a company's competitive advantage stems from having special resources and capabilities that are priceless, limited, non-replaceable, and distinctive (Barney, 1991). Businesses can obtain a long-term competitive edge in the market by efficiently allocating and utilizing these resources. Regarding the digital transformation, the resource-based view can help explain how enterprises can build and enhance their resources and capabilities through digital technologies (e.g. big data, IoT, AI, etc.). By investing in advanced technological infrastructures, organizations can enhance their operational efficiency and agility, thereby gaining a competitive advantage (Roberts & Grover, 2012). By training employees in digital skills, their capacity for technological and managerial innovation can be enhanced (Rexhepi Mahmutaj & Jusufi, 2023). By fostering an open and innovative organizational culture, firms can better meet the challenges posed by digital transformation and reap greater benefits from it (Asif, Yang, & Hashim, 2024). According to the principle of sustainable development, present needs should be met without compromising the ability of future generations to meet their own (Tian, 1996). The three main facets of the idea are social, environmental, and economic. When it comes to supply chain management, sustainability theory emphasizes the sustainability of the supply chain by optimizing resource allocation, reducing negative environmental impacts and enhancing social well-being (Carter & Rogers, 2008). In the cut flower industry, sustainability theory can help to explain how companies can achieve supply chain sustainability through digital transformation and innovation capability enhancement. For example, through digital transformation and innovation capacity enhancement, companies can reduce operational costs and increase productivity, thus enhancing market competitiveness (Fatorachian & Kazemi, 2021). By introducing green logistics solutions and sustainable cultivation techniques, firms can reduce resource consumption and carbon emissions, thereby reducing negative impacts on the environment (Trivellas, Malindretos, & Reklitis, 2020). By improving working conditions and product quality, firms can enhance employee and consumer satisfaction, thereby increasing social well-being (Carter & Rogers, 2008). The combination of the resource-based view and the sustainable development theory can provide solid theoretical support for the research in this paper. Specifically, the resource-based view emphasizes that firms gain a competitive advantage through their unique resources and capabilities, while the sustainable development theory emphasizes sustainable development through optimizing resource allocation and reducing negative environmental impacts. The combination of the two can help explain how firms can build and enhance their resources and capabilities through digital transformation and innovation capability enhancement to achieve sustainable supply chain development.

2.3. Hypothesis Development

2.3.1. DT and OR

Digital transformation and organizational readiness go hand in hand. Based to research, using digital tools greatly improves an organization's capacity for information analysis and decision-making (Ali et al., 2024). Digital transformation requires new skills for employees, the study noted that through training and education programs, employees can adapt to new technologies more quickly, thus increasing overall organizational readiness (Lehman, Greener, & Simpson, 2002). Digital transformation is often accompanied by a redesign of management processes, Bolcer & Taylor suggested that the introduction of new management software could optimize workflows, reduce redundant steps and improve efficiency (Bolcer & Taylor, 1998). Ahlquist's research points out that digital transformation requires organizations to be fully prepared in terms of technology, people and culture to implement it successfully and achieve the desired results. Digital transformation significantly enhances organizational readiness by improving technology infrastructure and upgrading employees' digital skills. Research points out that digital transformation requires organizations to be fully prepared in terms of technology, people and culture to implement it successfully and achieve the desired results. Digital transformation significantly enhances organizational readiness by improving technology infrastructure and upgrading employees' digital skills (Ahlquist & Birgisdóttir, 2020). Digital transformation significantly enhances organizational readiness by upgrading technology infrastructure and employee digital skills. Organizations with high organizational readiness are better able to meet the challenges posed by digital transformation and reap greater benefits from it (Halpern et al., 2021). In the fresh cut flower sector, the effect of digital transformation on organizational preparedness is very significant. By implementing digital transformation, fresh cut flower companies can enhance their organizational readiness by upgrading their technological infrastructure and employees' digital skills. This not only helps companies to successfully implement digital transformation, but also improves productivity and product quality and enhances market competitiveness. As a result, this work puts forth the following research hypotheses:

H_1: *Digital transformation (DT) significantly influences organizational readiness (OR).*

2.3.2. OR and SSCP

Through the intricate preparation of people, technology, and culture, organizational readiness—a crucial capability for putting sustainable supply chain management techniques into practice—directly impacts the supply chain's performance in the economic, environmental, and social dimensions. Technological infrastructure upgrades can increase efficiency, lower operating costs, and optimize supply chain operations (Huo, 2024). In the cut flower industry, smart greenhouse technology can monitor the production environment in real time, reducing wastage and increasing yields. Businesses with high organizational readiness reduce water, energy and fertilizer wastage and lower carbon emissions (Kamilaris et al., 2017). Organizationally prepared businesses are more likely to spend in safety facilities and staff training to raise workplace standards (Moric Milovanovic, Bubas, & Cvjetkovic, 2022). Organizationally prepared businesses react more quickly to shifts in consumer demands and, through resource allocation optimization, greatly enhance the supply chains' economic and environmental performance (Javaid, Haleem, Singh, Suman, & Gonzalez, 2022). Hebaz and Oulfarsi found that organizational readiness (e.g. technological infrastructure and employee skills) is a key driver for the implementation of green supply chain management, directly affecting the level of carbon emissions and resource consumption. They also emphasize that management support and a culture of openness in organizational readiness can drive businesses to adopt sustainable practices (e.g. circular economy models) and thus improve social performance (Hebaz & Oulfarsi, 2021). Therefore, the research hypothesis was formulated:

H_2: *Organizational readiness (OR) significantly influences sustainable supply chain performance (SSCP).*

2.3.3. DT and IC

The relationship between DT and IC is an important topic in current innovation management and supply chain research. Digital transformation, through the introduction of new technologies, provides organizations with new technological tools and data resources that can facilitate technological and managerial innovation (Dubey, Gunasekaran, Childe, Papadopoulos, et al., 2019). In the fresh-cut flower industry, enterprises can develop more accurate market forecasting models through big data analysis technology, thus enhancing market innovation capability. By introducing agile management methods and cross-departmental collaboration mechanisms, enterprises can respond faster to changes in market demand, thus enhancing management innovation capability. By integrating internal and external resources, digital transformation can enhance the enterprise's resource integration capability, thus improving innovation capability (Zhang & Li, 2023). Research indicates that an organization's technological and managerial innovation skills can be significantly enhanced by implementing big data and artificial intelligence technologies through digital transformation. DT can improve innovation culture and resource integration skills in addition to streamlining the innovation process. (Yang, Chen, & Li, 2022). Fatorachian & Kazemi found that digital transformation can improve the efficiency and effectiveness of innovation by optimizing business processes and organizational structures. Digital transformation can also enhance the innovation culture of enterprises by promoting changes in corporate culture (Fatorachian & Kazemi, 2021). According to research, by supplying new technical tools and data resources, digital transformation can foster managerial and technological innovation. DT can also increase an organization's ability to integrate resources by merging internal and external resources. (Saunila, Ukko, & Rantala, 2018). In the fresh-cut flower sector, the effect of DT on IC is very significant. By implementing digital transformation, fresh-cut flower enterprises can improve their technological innovation and management innovation capabilities, thereby enhancing their market competitiveness. For example, by introducing big data analytics, companies can develop more accurate market forecasting models, thereby enhancing market innovation capabilities. In addition, digital transformation can improve the efficiency and effectiveness of innovation by optimizing business processes and organizational structures, thereby enhancing management innovation capabilities. This not only helps enterprises to enhance market competitiveness, but also meets consumer demand for innovative products. Therefore, this paper proposes the hypothesis:

H$_3$: *Digital transformation (DT) significantly influences innovation capabilities (IC).*

2.3.4. IC and SSCP

Innovation capability, a crucial element of an organization's core competitiveness, can significantly enhance the economic, environmental, and social performance of supply chains through technological and management innovation. This, in turn, has a major effect on the performance of sustainable supply chains. By reducing resource consumption and carbon emissions through the research and development of novel technologies and processes, businesses may enhance the environmental performance of supply chains (Saunila et al., 2018). The capacity for technological innovation can be seen in the development and application of smart planting technologies and precision irrigation systems that reduce the use of water and fertilisers. By improving management processes and organizational structures, companies can increase the efficiency and flexibility of their supply chains, thereby enhancing their economic performance (Martínez Sánchez & Pérez Pérez, 2005). By introducing agile management methods and cross-functional collaboration mechanisms, enterprises can respond faster to changes in market demand, thereby reducing inventory and logistics costs. By gaining insight into market demand and developing new markets, enterprises can enhance their brand image and market competitiveness, thereby improving the social performance of the supply chain (Mani, Gunasekaran, & Delgado, 2018). Through big data analytics and market research, companies can more accurately predict market demand and develop new products that meet consumer preferences, thereby enhancing consumer satisfaction and brand loyalty. Through the creation of new technologies and procedures, technical innovation capability can dramatically lower resource consumption and carbon emissions, improving supply chains' environmental performance, the study finds. By streamlining production procedures, technological innovation capabilities can also enhance supply chains' financial performance (Cao & Li, 2024). Carvalho and others research found that management innovation capabilities can significantly improve the efficiency and flexibility of supply chains by improving management processes and organizational structures, thereby enhancing the economic performance of supply chains. Management innovation capabilities can also reduce inventory costs and logistics costs by introducing agile management methods (Carvalho, Azevedo, & Cruz-Machado, 2012). Research by Dubey shows that market innovation capabilities can significantly enhance brand image and market competitiveness through insights into market needs and the development of new markets, thereby enhancing the social performance of supply chains. Market innovation capabilities can also enhance consumer satisfaction and brand loyalty through big data analysis and market research (Dubey, Gunasekaran, Childe, Papadopoulos, et al., 2019). Teece shown that by combining internal and external resources, resource integration capacity may greatly enhance a supply chain's overall performance (Teece, 2010). The ability to integrate resources can also enhance supply chain sustainability by building partnerships with research organizations, suppliers and customers to obtain additional innovation resources and support. This study puts up the following hypothesis in light of the aforementioned theories and research:

H$_4$: *Innovation capabilities (IC) significantly influence sustainable supply chain performance (SSCP).*

2.3.5. OR and IC

Organizational readiness can have a profound impact on an enterprise's innovation capability and competitiveness by providing the necessary technological infrastructure, employee skills and management support to significantly enhance its technological and managerial innovation capabilities. Firms with high organizational readiness usually have a well-developed technological infrastructure. The degree of sophistication of these infrastructures has a direct impact on the technological innovation capacity of firms (Westerman et al., 2014). In the cut flower industry, companies can improve their technological innovation capabilities by improving production efficiency and product quality through smart greenhouse technology and digital logistics systems. At the same time, companies with high organizational readiness often have strong digital skills, and by training their employees to use big data analytics tools, they can improve their ability to anticipate market demand and thus increase their market innovation capabilities. Organizations with high organizational readiness often have strong management support and open corporate culture. A company's capacity to innovate is directly impacted by the degree of management's focus on and encouragement of innovation (Weiner, 2020). According to their research, organizations that are highly prepared are better equipped to adopt and use new technologies, which greatly boosts technological innovation.

Organizational readiness enhances a firm's ability to innovate by improving its technological infrastructure and upgrading the digital skills of its employees. Firms with high organizational readiness typically have strong management support and an open corporate culture, factors that can significantly enhance a firm's managerial innovation capability. Organizational readiness enhances a firm's ability to innovate by providing the necessary management support and innovation culture (Zhen, Yousaf, Radulescu, & Yasir, 2021). Saunila et al. (2018) showed that firms with high organizational readiness usually have strong resource integration capabilities and can integrate internal and external resources to enhance innovation. Organizational readiness enhances the firm's innovation capability by increasing resource integration capability. In light of the aforementioned theories and research, this study puts forth hypothesis H5:

H_5: *Organizational readiness (OR) significantly influences innovation capabilities (IC).*

2.3.6. DT and SSCP

DT can have a profound impact on SSCP by introducing advanced information technologies that can significantly improve supply chain transparency, efficiency and flexibility. Digital transformation enables real-time monitoring and data analytics of supply chains through the introduction of big data and IoT technologies, thus improving supply chain transparency (Fatorachian & Kazemi, 2021). In the cut flower industry, companies can monitor the temperature and humidity of cold chain logistics in real time through IoT devices to ensure product quality and reduce resource wastage. Through big data analysis, companies can more accurately predict market demand, thereby optimizing inventory management and logistics routes. By implementing sustainable farming practices and green logistics solutions, digital transformation may lower carbon emissions and resource consumption in the supply chain (Agbelusi, Arowosegbe, Alomaja, Odunfa, & Ballali, 2024). According to Oubrahim and others, digital transformation can significantly improve sustainable supply chain performance by increasing supply chain transparency and efficiency (Oubrahim, Sefiani, & Happonen, 2023). Digital transformation not only reduces operational costs but also reduces negative environmental impacts and improves social well-being. By using Big Data and AI technology, digital transformation can optimize the supply chain's resource allocation, enhancing its performance over the long term. Digital transformation can also reduce environmental risks and increase consumer trust by improving supply chain transparency and traceability (Rashid, Baloch, Rasheed, & Ngah, 2025). By introducing green logistics solutions and sustainable agricultural practices, digital transformation can lower carbon emissions and resource consumption in the supply chain, improving the performance of the sustainable supply chain(Rehman Khan, Ahmad, Sheikh, & Yu, 2022). This study puts up the following hypothesis in light of the aforementioned theories and research:

H_6: *Digital transformation (DT) significantly influences sustainable supply chain performance (SSCP).*

2.3.7. OR's Mediating Role

Digital transformation often requires new skills from employees, and through ongoing training programs, employees can adapt more quickly to new technologies, thereby increasing overall organizational readiness. This high level of readiness enables companies to make more effective use of digital tools, optimize supply chain management, and improve innovation and supply chain sustainability (Rehman Khan et al., 2022). Digital transformation is often accompanied by a redesign of management processes. Companies with high organizational readiness can quickly adapt their management processes, adopting lean manufacturing methods and project management software to reduce redundant steps and increase efficiency. This optimized management process helps companies to achieve higher economic, environmental and social objectives in supply chain management and helps them to be more flexible and efficient in their innovation activities (Vaittinen & Martinsuo, 2019). Digital transformation requires sound technical support and infrastructure. A corporation with a high level of organizational preparedness has the IT tools in place to better monitor and control every part of the supply chain, guaranteeing resource efficiency and reducing environmental impact (Lafioune, Desmarest, Poirier, & St-Jacques, 2023). These systems can help organizations to better support innovative activities such as new product development, new technology applications, etc. AlNuaimi and colleagues demonstrated how organizational preparedness partially mediates the relationship between DT and SSCP and how, through improving employee skills and technological infrastructure, digital transformation indirectly improves the supply chain's economic and environmental performance (AlNuaimi et al., 2022). Alsmairat discovered that one important factor in implementing green supply chain management is organizational readiness, which includes things like staff competencies and technology infrastructure. This can greatly increase the influence of digital transformation on environmental performance (Alsmairat, 2022). Westerman and others emphasize that management support and an open culture in organizational readiness can drive companies to transform the technological advantages of digital transformation into sustainable practices that improve social performance (Westerman et al., 2014). Considering the theoretical and practical backing mentioned above, it is possible to formulate the following research hypotheses:

H_7: *Organizational readiness (OR) mediates the relationship between digital transformation (DT) and sustainable supply chain performance (SSCP).*
H_9: *Organizational readiness (OR) mediates the relationship between digital transformation (DT) and innovation capabilities (IC).*

2.3.8. Mediating Role of IC

Innovation skills are essential for businesses to turn new technology into real competitiveness during the digital transformation process. By introducing big data analytics and artificial intelligence technologies, companies can develop more accurate market forecasting models and more efficient supply chain management solutions (Dubey, Gunasekaran, Childe, Blome, & Papadopoulos, 2019). In the cut flower industry, companies with strong innovation abilities can respond faster to changes in market demand and introduce new varieties and services, thus enhancing market competitiveness. Nayal's research shows that digital transformation indirectly drives the economic and environmental performance of supply chains by enhancing technological innovation (Nayal, Raut, Yadav, Priyadarshinee, & Narkhede, 2022). When implementing green supply chain management, Saunila discovered that innovativeness is a crucial mediating factor that greatly amplifies the effect of digital transformation on environmental performance (Saunila et al., 2018). Zhu and his college emphasize that the ability to integrate resources into innovation capabilities can drive firms to transform the technological advantages of digital transformation into sustainable practices that improve social performance (Zhu, Song, Hazen, Lee, & Cegielski, 2018). By strengthening innovative skills, organizational readiness—a company's basic resource—can indirectly promote sustainable supply chain performance by fusing the RBV and sustainability theory. The following theories are put out in this paper in light of the aforementioned research:

H$_8$: *The relationship between digital transformation (DT) and sustainable supply chain performance (SSCP) is mediated by organizational readiness (OR).*

H$_{10}$: *The relationship between organizational readiness (OR) and sustainable supply chain performance (SSCP) is mediated by innovation capabilities (IC).*

2.3.9. The moderating effect of technology readiness

Higher levels of technical readiness enable organizations to adapt and apply new technologies more quickly, improving the results of digital transformation (Demirci & Ersoy, 2008). Technological readiness encompasses how ready an organization is to use modern technologies effectively. In Yunnan's fresh-cut flower industry, technological readiness has to do with the availability and accessibility of modern technologies, the ability of the workforce to use these technologies and the infrastructure required to support their adoption. When a firm's technological readiness is high then it has sophisticated systems like automated sorting machines, IoT devices for environmental monitoring purposes and complex logistics software used in supply chain management (Rusli, Samah, & Kamaruddin, 2023). This preparedness allows the company to embrace new technology easily to improve its operations and innovativeness in production processes. Therefore, businesses which possess high levels of technological readiness can better enhance their supply chain performance, achieve more sustainability, and rapidly respond to market requirements as well as problems (Rusli et al., 2023). Therefore, the article proposes the following research hypothesis:

H$_{11}$: *Technology readiness (TR) plays a moderating role in the relationship between Digital transformation (DT) and Organizational readiness (OR) (the higher TR, the stronger the relationship between DT and OR).*

H$_{12}$: *Technology readiness (TR) plays a moderating role in the relationship between Digital transformation (DT) and supply chain performance (SSCP) (the higher TR, the stronger the relationship between DT and SSCP).*

H$_{13}$: *Technology readiness (TR) plays a moderating role in the relationship between Digital transformation (DT) and innovation capabilities (IC) (the higher TR, the stronger the relationship between DT and IC).*

This study proposes the following conceptual framework based on the above assumptions (Fig. 1).

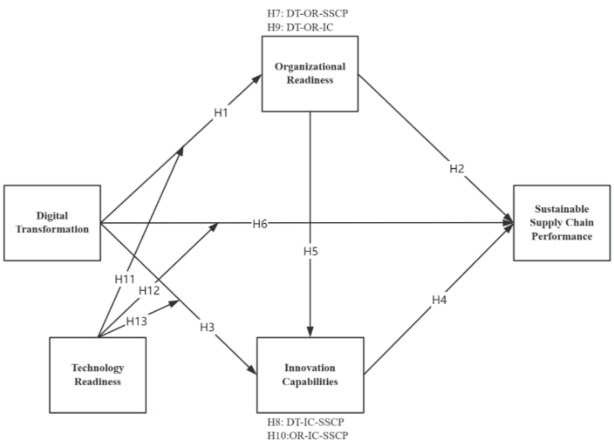

Fig. 1. Conceptual framework.

3. Research Methodology

3.1. Instrument development

The primary purpose of this quantitative investigation is to evaluate the research theories and hypotheses. This study's target sample is restricted to Yunnan Province's fresh-cut flower sector, which includes all kinds of businesses involved in its supply chain. To guarantee that all scales remain voluntary, unambiguous, and clear when translated into Chinese, experts were asked to translate, back-translate, and re-test the scales before they were used. All scales were taken from already-existing authoritative scales. DT references Nasiri et al. (2020) and Zhang's (Zhang, Wan, & Liu, 2022) five measurement items for a digital transformation research scale. IC is measured from the scales of Hong et al. (Hong, Zhang, & Ding, 2018) and (Barreto, Freitas, & de Paula, 2024) with five measurement items. OR draws from Kandi Liu's (Liu, 2022) 4-measurement questions that measure the organizational readiness of a firm. The SSCP measure was partially modified from the scales of (Green, Whitten, & Inman, 2008) and (Kamble et al., 2023), with 6 measurement questions. The TR measure referenced the scales of ((Parasuraman & Colby, 2015) and (Blut & Wang, 2020) and consisted of 4 items. Each item was scored on a 7-point Likert scale, where 1 represented “strongly disagree” and 7 represented “strongly agree”. To further enhance the measuring method, five individuals with over 15 years of experience in the cut flower industry and five academic supply chain management specialists were asked to examine the questionnaire prior to data collection. The aforementioned scales were further analyzed and modified through the questionnaire's pre-survey, and the questionnaire was refined and optimized to create a formal measurement index system, as indicated in Table 1.

Table 1
Variables and measurement items.

Variables	Measurement items	Code
DT	Our firm is increasing its investment in digital technology.	DT1
	Our firm introduces digital management processes.	DT2
	Our firm is committed to collecting and storing as much data as possible from all links of the supply chain.	DT3
	Our business is committed to creating a digital supply chain management system that is more effective.	DT4
	In order to accomplish real-time information tracking and monitoring in all supply chain connections, our organization is committed to utilizing sensors, the Internet of Things, big data analysis, and other tools.	DT5
OR	Our company thinks that a certain change (like digital technology) could make things better.	OR1
	Corporate management offers precise implementation plans when adjustments are required.	OR2
	Employers encourage their staff to independently learn and discuss applied technology.	OR3
	The majority of workers are open to trying new things and changing their priorities when needed to accommodate new developments.	OR4
IC	In order to meet the needs of local or regional markets, our organization can quickly adapt its technology, processes, and products.	IC1
	Our firm can adopt new management methods according to changes in the environment.	IC2
	Our firm has adopted new marketing channels to promote our products.	IC3
	Our company is able to introduce new goods to the market.	IC4
	New technology can be swiftly adopted by our company.	IC5
SSCP	Our firm's sales and market share have increased significantly.	SSCP1
	Our firm has a good profit margin.	SSCP2
	Employee welfare, health, and safety are very important to our company.	SSCP3
	Our firm’s relationships with community stakeholders, such as NGOs, have significantly improved.	SSCP4
	Our firm takes measures to control supply chain pollution, such as water pollution, air pollution, soil pollution, etc.	SSCP5
	Our firm focuses on the recovery and recycling of products and materials.	SSCP6
TR	I feel a lack of control over technology and a sense of being overwhelmed by it.	TR1
	I like to think of myself as a technological pioneer and a thinking leader.	TR2
	My doubts about how technology works and my concerns about its possible drawbacks are the main causes of my skepticism of it.	TR3
	I support technology because I believe it can make people's lives better by granting them greater autonomy, efficiency, and control.	TR4

3.2 Sampling Technique

To obtain a representative and comprehensive sample, a stratified sampling technique was employed. Taking into account the responsibilities and duties of participants, the population was stratified according to various supply chain segments of fresh-cut flower enterprises. The companies include flower growers, distributors, wholesalers, and retailers. To guarantee representation from various departments and organizational levels, stratified random sampling was used. According to Krejcie and colleagues' general rule, "Researchers can apply a conventional rule of thumb to estimate the appropriate sample size when the population size is unknown or infinite." Generally speaking, the total amount of independent variables in the research project must be no less than 30 times the sample size. This notion is supported by the Central Limit Theorem, which asserts that as sample size increases, the distribution of sample means approaches a normal distribution regardless of the form of the population distribution. The 30-times rule is also commonly applied (Krejcie & Morgan, 1970). The sample size should be no less than five times thirty, according to this general recommendation, or 150 responders because there are five variables in total. The questionnaires were mainly distributed through both field distribution and online research, and the collected questionnaires were reviewed for information before data entry. In the end, 422 questionnaires were returned, 68 invalid questionnaires were excluded, leaving 354 valid questionnaires, and the validity rate of the questionnaires was 83.89%.

3.3. Data analysis

To evaluate the hypotheses, this study used SPSS 26.0 for descriptive statistical analysis and Smart PLS 4.0 for SEM. This study used SEM based on partial least squares to examine how digital transformation affects sustainable supply networks' performance. This approach is used for some reasons: First off, compared to CB-SEM, PLS-SEM requires fewer samples. When the model has numerous structures and a high number of items, it also provides a solution with a smaller sample size that can be used. In these situations, approaches such as CB-SEM either fail to converge or yield unacceptable results. Second, unlike standard linear regression models, PLS-SEM does not require that the data have a normal distribution and does not make as severe distributional assumptions about the data. This is so because, instead of making rigid assumptions about the variables, the PLS-SEM technique concentrates more on the relationships and interactions between the variables while building the model. PLS-SEM uses SEM to describe the relationships between the latent variables after partial least squares (PLS) are used to extract the latent variables. Since the extraction of latent variables is dependent on every observation in the data set instead of the assumption of a normal distribution, this method may apply to data that is not regularly distributed. Third, multivariate covariance is less likely to affect strongly linked variables. When using alternative structural equation modelling software at this stage, the model is more impacted by multi-variate covariance because some of the variables in this study are intrinsically connected. However, PLS-SEM can reduce this effect. Lastly, PLS-SEM is capable of handling increasingly intricate research models; in this instance, the model included several mediating and moderating factors. Because this study satisfies PLS-SEM standards, two phases of analysis were conducted: the measurement model and the structural model.

4. Results

4.1. Sample Characteristics

Based on the industry's criteria, the sample enterprises are categorized according to the number of employees, annual turnover, years of operation, and type of business. Among them, the number of employees is classified into four categorical groups: 0–20, 21–50, 51–100, and beyond 100 workers. Annual income is divided into four categories: CNY 490,000 and below, CNY 500,000-4.99 million, CNY 5 million-19.99 million, and more than CNY 19.99 million. Years in business are categorized as 5 years and under, six to ten years, eleven to fifteen, sixteen to twenty, and over twenty years. The above classification indicators and groupings can categorize different enterprises in this industry better, and the characteristic classification indicators are more comprehensive. Out of these 354 valid responses, the sample characterization was calculated by SPSS 26.0, as shown in Table 2. It can be found that the number of employees in the respondents' enterprises in the range of 21-50 employees occupies 40.1%, and the number of employees in the range of 100 or more employees is less, only 13%. Most of the respondents' enterprises have annual operating revenues in the range of 500-49.9 million CNY(38.1%) and 5-199.9 million CNY (26%). Enterprises with an operating period of between 6-10 years account for 46.3% of the total, followed by 23.7% in the range of 11-15 years, and very few enterprises with an operating period of more than 21 years account for only 5.4% of the total. The primary business of the companies in this study includes all of the participants in the Yunnan Province fresh-cut flower supply chain: flower growers (22%), distributors (38.4%), wholesalers (26.3%), and retailers (13.3%). According to China's 'Standard Provisions for the Classification of Small and Medium-sized Enterprises', from the above basic information, it can be seen that the enterprises in the fresh cut flower supply chain are small and micro-enterprises.

Table 2
Variables and measurement items.

Variable	Categories	Frequency	Percentage (%)
Number of employees	0-20	66	18.6
	21-50	142	40.1
	51-100	100	28.2
	>100	46	13.0
Annual operating income (Unit: 10,000 CNY)	0-49	54	15.3
	50-499	135	38.1
	500-1999	92	26.0
	>1999	73	20.6
Years of Enterprise (Years)	0-5	61	17.2
	6-10	164	46.3
	11-15	84	23.7
	16-20	26	7.3
	>20	19	5.4
Main business of the enterprise	Flower grower	78	22
	Distributor	136	38.4
	Wholesaler	93	26.3
	Retailer	47	13.3

4.2. Measurement model evaluation

The extrinsic or measuring model must be tested before the intrinsic or structural model can be hypothesized. This is necessary to ensure that the study's constructs make sense and offer sufficient theoretical insight. The validity (discrimination and convergence) and reliability of the scales were assessed through several criteria as suggested by Hair et al. Firstly, for reliability, Cronbach's alpha (α) and composite reliability (CR) were used. Table 3 shows that all values in these two metrics exceeded the critical value of 0.7, which indicates that the reliability reached an appropriate level. Secondly, all factor loading values were above the critical value of 0.708, further demonstrating the convergent validity of the scale. Convergent validity was further demonstrated by the average variance extracted (AVE) values, which ranged from 0.628 to 0.731 and were higher than the suggested threshold of 0.50. Sarstedt et al. (2017) concluded that covariance is present when the VIF value is greater than 5. Table 3 demonstrates that the items' VIF values were less than 3, suggesting that multicollinearity was not an issue in the study's data.

Table 3
Assessment of the Outer Model Validity.

Construct	Items	Loadings	VIF	Cronbach's alpha	CR (rho_a)	AVE
DT	DT1	0.796	1.805	0.856	0.861	0.634
	DT2	0.803	1.913			
	DT3	0.753	1.699			
	DT4	0.802	1.834			
	DT5	0.826	1.934			
OR	OR1	0.863	2.263	0.878	0.878	0.731
	OR2	0.844	2.077			
	OR3	0.847	2.112			
	OR4	0.866	2.323			
IC	IC1	0.778	1.773	0.852	0.855	0.628
	IC2	0.797	1.878			
	IC3	0.785	1.769			
	IC4	0.819	1.932			
	IC5	0.783	1.709			
SSCP	SSCP1	0.832	2.277	0.906	0.907	0.679
	SSCP2	0.822	2.160			
	SSCP3	0.832	2.283			
	SSCP4	0.823	2.261			
	SSCP5	0.809	2.124			
	SSCP6	0.827	2.264			
TR	TR1	0.817	1.773	0.816	0.824	0.644
	TR2	0.798	1.748			
	TR3	0.768	1.583			
	TR4	0.824	1.684			

Lastly, measurement models were evaluated using the "Heterotrait-Monotrait ratio (HTMT)" and the Fornell-Larcker criterion, as recommended by Henseler to test discriminant validity. (Henseler, Ringle, & Sarstedt, 2015). Testing for statistical discriminant validity can be based on HTMT (Franke & Sarstedt, 2019). A lack of discriminant validity is indicated by HTMT values greater than 0.90, according to Henseler, Ringle, and Sarstedt (2015). Whereas in this study, a lower and more conservative threshold of 0.85 was used as an assessment. In Table 4, it is shown that all values in all HTMT matrices are less than 0.85, which implies that the measurement model provides satisfactory construct validity.

Table 4
HTMT

	DT	IC	OR	SSCP	TR
DT					
IC	0.451				
OR	0.495	0.491			
SSCP	0.506	0.497	0.61		
TR	0.379	0.407	0.538	0.432	

Discriminant validity was evaluated using the Fornell-Larcker criterion (Fornell & Larcker, 1981). This criterion contrasts the latent variable correlations with the square root of the AVE value. In particular, each construct's square root of the AVE should be higher than its highest correlation with the others. The Fornell-Larcker condition is met since the diagonal of the square root of the AVE is larger than the non-diagonal component of the same column (Table 5).

Table 5
Fornell-Larcker

	DT	IC	OR	SSCP	TR
DT	0.796				
IC	0.391	0.792			
OR	0.432	0.425	0.855		
SSCP	0.448	0.44	0.546	0.824	
TR	0.319	0.343	0.461	0.376	0.802

It is evident from the preceding study's structure that the model structure has strong discriminant validity and reliability and does not include the multicollinearity issue. Therefore, the outputs of the externally measured model are considered sufficient to advance the assessment of the structural model.

4.3. Structural model evaluation

Following an evaluation of the external (measurement) model's validity and reliability, the model should also possess adequate explanatory and predictive capacity. The explanatory power of the sample is examined using the endogenous variables' coefficient of determination (R^2). According to Table 6, the R^2 values of OR and SSCP are 0.366 and 0.424 respectively, which are both above 0.33, which indicates that the explanatory power of these two OR and SSCP is good. Although the R^2 value of IC is 0.283, it also exceeds 0.19, so the explanatory power of innovativeness is also acceptable. Similarly, Stone-Geisser (Q^2) for IC, OR and SSCP, which are 0.241, 0.364 and 0.327 respectively, have values greater than zero. This indicates that the models have sufficient explanatory power and predictive validity and the relevant research data can be used for subsequent hypothesis testing analyses.

Table 6
R^2 and Q^2

Endogenous Variables	R^2	Q^2
IC	0.283	0.241
OR	0.366	0.346
SSCP	0.424	0.327

In the next step, the structural model was estimated by bootstrapping 5000 samples through Smart PLS 4.0 and the proposed research hypotheses were analyzed and the results are shown in Figure 2. The first six hypotheses are related to the test of direct path, H7-H10 are related to the assessment of mediation effects, and H11-H13 are about the test of moderating variables. The original sample, p-value, and t-value (p-value should be less than 0.05; t-value should be more than 1.96) were used to assess the relevance of the study hypotheses.

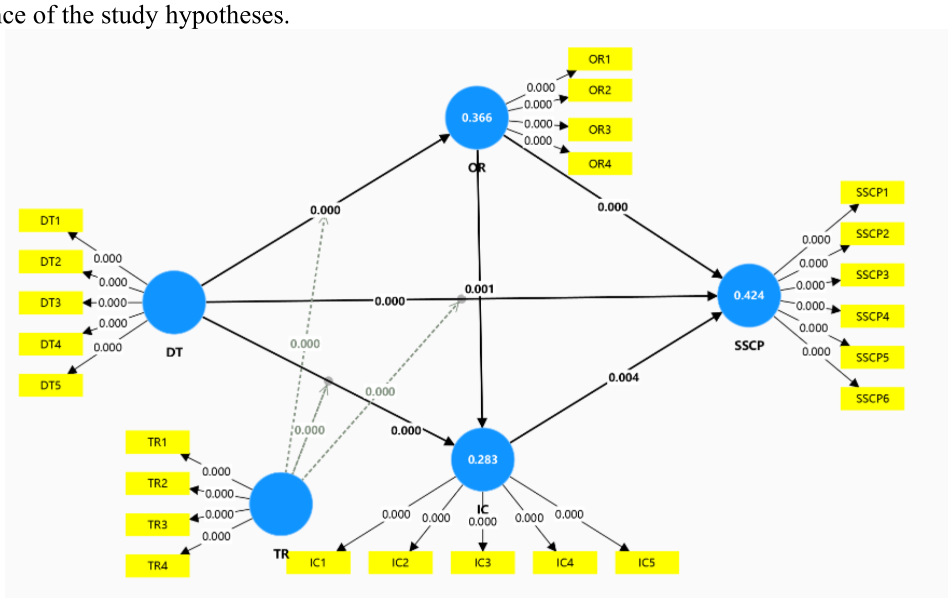

Fig. 2. Structural equation model

Table 7 shows the path coefficients used to test the direct effects between the factors.

Table 7
Direct effects analysis (H1-H6)

Path	Original sample	T statistics	P values	Results
H1: DT→OR	0.311	6.821	0.000	Supported
H2: OR→SSCP	0.278	4.968	0.000	Supported
H3: DT→IC	0.249	5.247	0.000	Supported
H4: IC→SSCP	0.142	2.864	0.004	Supported
H5: OR→IC	0.187	3.315	0.001	Supported
H6: DT→SSCP	0.228	4.514	0.000	Supported

For H1, the P value is 0.000<0.05, the T value is 6.821>1.96, and the original sample is 0.311. This demonstrates that DT significantly and favorably affects OR. From the perspective of the entire sample, the higher the degree of DT, the higher the OR. Therefore, H1 is established. Regarding the path between OR and SSCP, Table 7 shows that the original sample is 0.278, the T value is 4.968, and the P value is 0.000. This shows that when the organizational readiness is higher, the sustainable supply chain performance will also improve. Therefore, OR has a significant positive impact on SSCP, and H2 is supported. In the path between the variables DT and IC, each indicator shows that H3 is established (original sample=0.249, T value=5.247, P value=0.000). The higher the degree of DT of the supply chain, the stronger the IC. Similarly, the path between IC and SSCP (original sample=0.142, T value=2.864, P value=0.004), data analysis shows that there is a positive and significant impact between the two. The stronger the IC, the higher the SSCP. H4 is established. Similarly, H5 and H6 are also supported. The data of OR for IC is original sample=0.187, T value=3.35, P value=0.001. The better the organizational readiness, the stronger the innovation capability. DT for SSCP (original sample=0.228, T value=4.514, P value=0.001). The higher the degree of DT of the supply chain, the higher the SSCP. Therefore, all direct effects of H1-H6 are established. In this study, there are 4 mediation paths. The following Table 8 lists the analysis of these paths.

Table 8
Mediation effect analysis

Path	Original sample	T statistics	P values	Results
H7: DT→OR→SSCP	0.086	3.864	0.000	Supported
H8: DT→IC→SSCP	0.035	2.391	0.017	Supported
H9: DT→OR→IC	0.058	2.839	0.005	Supported
H10: OR→IC→SSCP	0.027	2.049	0.041	Supported

The results show that the research hypotheses H7-H10 are all established. In H7, original sample=0.086, T value=3.864, P value=0.000. This shows that OR has a significant mediating effect between DT and SSCP. The same data analysis of H8 (original sample=0.035, T value=2.391, P value=0.017) also shows that IC has a significant mediating effect between DT and SSCP. In H9, OR participates as a mediating factor connecting DT and IC, and OR has a significant mediating effect (original sample=0.058, T value=2.839, P value=0.005). Regarding the last hypothesis of the mediating effect H10, the original sample=0.027 (positive), T value=2.049 (greater than 1.96), and P value=0.041 (less than 0.05). Therefore, IC has a significant mediating effect between OR and SSCP. After the main model of this study was verified, the article also discussed the modulating ability of TR, namely H11-H13 (Table 9).

Table 9
Moderating effect analysis

Path	Original sample	T statistics	P values	Results
H11: TR × DT →OR	0.247	6.078	0.000	Supported
H12: TR × DT →SSCP	0.190	4.172	0.000	Supported
H13: TR × DT → IC	0.184	4.395	0.000	Supported

By establishing the relationship between DT and OR, SSCP and IC respectively, and generating interaction terms with TR, H11-13 are obtained. H11 (original sample=0.247, T value=6.078, P value=0.000); H12 (original sample=0.190, T value=4.172, P value=0.000); H13 (original sample=0.184, T value=4.395, P value=0.000). Therefore, TR has an obvious moderating effect on the relationship between DT and OR, DT and SSCP, and DT and IC, and research hypotheses H11-H13 are supported. Through the analysis of direct effects, mediating effects and moderating effects, all 13 research hypotheses of this article are established.

5. Discussion

This study aims to explore how digital transformation (DT) indirectly affects sustainable supply chain performance (SSCP) through organizational readiness (OR) and innovation capability (IC) and to examine the moderating role of technological readiness (TR) in this process. DT not only has a direct impact on SSCP, but it also further optimizes the process by boosting OR preparedness and IC, according to an empirical analysis of fresh-cut flower supply chain companies in Yunnan Province.

5.1. Theoretical contributions

The RBV and sustainability theory serve as the foundation for this study's integrated framework, which explains the connection between digital transformation and SSCP. Using organizational readiness and innovation capacity as mediating factors, this study contributes to the body of knowledge on how digital transformation affects supply chain management. Specifically, the relationship between DT and OR: the findings support research that shows that digital transformation significantly improves the organizational readiness of firms. This is consistent with earlier studies that emphasize the significance of managerial support, staff competencies, and technology infrastructure in executing digital transformation. High organizational readiness enables firms to use digital tools more effectively to optimize supply chain management processes. Relationship between OR and SSCP: The study found that organizational readiness significantly affects sustainable supply chain performance, further validating the notion that companies with high organizational readiness are better able to respond to changes in market demand, reduce resource wastage, and improve economic and social benefits. Relationship between DT and IC: the results show that digital transformation promotes the innovation capability of firms. Digital transformation can significantly improve technological innovation and management innovation capabilities through the application of big data and artificial intelligence technologies, thus enhancing market competitiveness. Relationship between IC and SSCP The research results show that innovation capability has a significant positive impact on sustainable supply chain performance. Technological innovation capability can enhance environmental performance by reducing resource consumption and carbon emissions, while management innovation capability can improve supply chain efficiency by improving management processes. In addition, this study reveals the important moderating role that technology readiness plays in the digital transformation process. Firms with high technology readiness can assimilate and apply new technologies faster, leading to better results in digital transformation. This finding provides a new perspective for understanding the successful implementation of digital transformation.

5.2. Practical implications

Practically speaking, this report offers useful recommendations for companies and legislators. Enterprise management level: Enterprises should actively invest in digital technology and infrastructure development, and improve employee digital skills and management support to enhance organizational readiness. At the same time, enterprises need to focus on the combination of innovation capability and sustainable development to improve the overall performance of the supply chain through technological innovation and management innovation. Level of policy development: To promote and assist the digital transformation of agribusinesses, local governments should keep introducing pertinent policies. For instance, actions like creating specific funds and offering technical training can assist floriculture businesses in becoming more technologically savvy and support the long-term growth of the sector.

5.3. Research limitations and future directions

Despite its remarkable results, this study has certain drawbacks. First off, while the study sample is representative, it might not accurately represent the situation in other areas or businesses because it is restricted to the fresh-cut flower sector in Yunnan Province. The sample size could be increased in future studies to improve universality and variety. Second, this study is a cross-sectional study that fails to capture the trend of digital transformation and sustainable supply chain performance over time. Future research could adopt a longitudinal design to track firms at different stages to gain deeper insights. Finally, this study focuses on the impact of internal factors (e.g., organizational readiness and technological readiness) on digital transformation, but in practice, external environmental factors (e.g., market competition, policy changes, etc.) may also have a significant impact on the results. Future research could consider introducing more external variables to comprehensively assess the effects of digital transformation.

In summary, this study offers useful recommendations for relevant businesses and governments in addition to enhancing the theoretical understanding of supply chain management and digital transformation. Future studies can further explore the existing foundation to make a greater contribution to promoting the sustainable development of global agricultural supply chains.

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