On Relationships Between Supply Chain Resilience and Sustainability

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Abstract

The relationship between supply chain (SC) resilience and sustainable supply chain management (SSCM) remains complex and understudied. This study aims to fill this gap by using the perspectives of complex adaptive systems (CAS) and social network theory (SNT) to examine the interplay between these two concepts. Specifically, the study seeks to 1) identify common themes in the co-occurrence of resilience and sustainability in the supply chain management (SCM) field, 2) develop a framework for understanding their interplay, and 3) explore the relationship between SC resilience and SSCM on financial and innovation outcomes.

The study uses quantitative research methods, including network analysis and panel data analysis, and a sample of 1336 firm-year observations from Chinese public companies in the automobile, food, and heavy-polluting industries from 2010 to 2018. The study examines the direct effects of SC resilience (focal-, dyads-, and network-level) and SSCM practices (environmental, social, and governance) on financial and innovation outcomes, focusing on the moderation effect of SC resilience and SSCM.

The results suggest that SSCM practices and SC resilience have curvilinear impacts on financial performance, with SC resilience playing a more important role in innovation performance. The study highlights the complementary nature of CAS and SNT in studying the relationship between SC resilience and SSCM. The study provides empirical evidence of synergies between pairs of SC resilience and SSCM practices on financial and innovation performance, as well as the fit between SC resilience and SSCM dimensions.

Overall, this study contributes to a better understanding of the relationship between SC resilience and SSCM. It highlights the importance of considering the complex interplay between these two concepts to achieve better performance outcomes. The study's contributions include providing a framework for understanding their interplay, identifying common themes, and offering empirical evidence of synergies and fit between them.

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for a degree or other qualification at this University or elsewhere. All sources are acknowledged as references.

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Chapter 1 Introduction

1.1 Overview

Supply chains (SCs) are complex networks of organisations, people, activities, information, and resources that collaborate to produce and deliver goods and services to customers (Zhao, Zuo and Blackhurst, 2019). In today's dynamic and turbulent business environment, SCs face various internal and external challenges, such as natural disasters (Gunessee, Subramanian and Ning, 2018), geopolitical risks (Gozgor et al., 2022; Cimprich et al., 2017), economic uncertainties (Apaydin et al., 2021), social and environmental pressures (Rentizelas et al., 2020), and technological disruptions (Sahi et al., 2019), that threaten their sustainability and resilience(Ivanov, 2020; Negri, Cagno and Colicchia, 2022). Sustainability and resilience are two critical objectives that SCs need to achieve to ensure their long-term viability (Ivanov, 2023) and success (Ortiz-de-Mandojana and Bansal, 2016).

Sustainable SC management (SSCM) aims to reduce the negative social, environmental, and economic impacts of SC activities while enhancing their positive effects. SSCM practices include green procurement (Zhu, Sarkis and Lai, 2013; Alikhani, Torabi and Altay, 2019), eco-design (Cherrafi et al., 2018), carbon footprint reduction (Sumrin et al., 2021), waste management (Thapa Karki, Bennett and Mishra, 2021), ethical sourcing (Kim, Colicchia and Menachof, 2018), and stakeholder engagement (Andersson et al., 2022; Rebs et al., 2019). Sustainability has become a crucial issue for SCs due to the growing awareness of environmental and social issues among consumers, regulators, and investors, as well as the potential for cost savings, and risk mitigation (Giannakis and Papadopoulos, 2016; Gouda and Saranga, 2018a; Hallikas, Lintukangas and Kähkönen, 2020), and reputation enhancement (K. Roehrich, Grosvold and U. Hoejmose, 2014; Liao, 2018; Pham and Tran, 2020). The actions of SCs are increasingly reliant on the social and environmental performance of SSCM, which is crucial for economic sustainability (Carter and Rogers, 2008; Ortiz-de-Mandojana and Bansal, 2016).

Resilience, on the other hand, refers to the ability of SCs to anticipate, respond, and recover from disruptions and disturbances while maintaining their critical functions and objectives (Ali, Mahfouz and Arisha, 2017). SC resilience is a multidimensional concept that encompasses the capacity of SCs to absorb, adapt, and transform in the face of uncertainty (Novak, Wu and Dooley, 2021), complexity (Birkie, Trucco and Fernandez Campos, 2017), and ambiguity (Tarim, Finke and Liu, 2021). SC resilience capabilities include risk management, redundancy, flexibility, agility, collaboration, and learning (Christopher and Peck, 2004; Kamalahmadi and Parast, 2016; Medel, Kousar and Masood, 2020; Delbufalo, 2022). Resilience has become a critical issue for SCs due to the increasing frequency and severity and the interconnectedness and interdependence of SC actors and processes (Bode et al., 2011; Chu et al., 2019; Delbufalo, 2022).

The interplay between sustainability and resilience in SCs has gained significant attention in recent years (Ortiz-de-Mandojana and Bansal, 2016; Ivanov, 2018; Fahimnia and Jabbarzadeh, 2016; Negri et al., 2021), as managing environmental, social, and economic risks and opportunities becomes increasingly evident (Wieland et al., 2023; Gouda and Saranga, 2018b). Sustainability and resilience are often treated as separate strategies in SC literature (Fahimnia and Jabbarzadeh, 2016; Rajesh, 2021; Ivanov, 2018), there is growing recognition of their interdependence and synergy (Eggert and Hartmann, 2022; Negri, Cagno and Colicchia, 2022; Ivanov, 2020). The evidence on the synergies suggests that SC resilience can enhance sustainability by reducing the negative impacts of disruptions on the environment and society, and vice versa (Paul, Moktadir and Ahsan, 2021; Negri, Cagno and Colicchia, 2022). By prioritising both resilience and sustainability, firms can create more robust and sustainable SCs to address emerging challenges and opportunities in the ecological and sociological environment (Wieland et al., 2023). However, the relationship between sustainability and resilience in SC is complex and multidimensional, as there may be trade-offs and conflicts between the two objectives (Jabbarzadeh, Fahimnia and Rastegar, 2019; Eltantawy, 2016). The trade-off analysis implies it is important to balance investing in SC resilience and SSCM to achieve desirable outcomes (Jabbarzadeh, Fahimnia and Rastegar, 2019; Azevedo et al., 2013).

While there has been growing interest in the emergence of SC resilience and SSCM, there remains a lack of clarity on the relationship between SC sustainability and resilience. The inconclusive literature highlights a significant knowledge gap in understanding the interplays between SC resilience and SSCM practices and their impacts on SC performance. It calls for a holistic approach to exploring this relationship (Negri et al., 2021; Ivanov, 2020). Empirical evidence is also needed to provide practical insights for managers and policymakers (Negri, Cagno, & Colicchia, 2022), as mathematical and analytical methods tend to dominate due to their applicability to uncertainty (Hohenstein et al., 2015). Therefore, it is critical to investigate the co-occurrence and interaction mechanism between SC resilience and SSCM theoretically and empirically to better understand their relationship and inform managerial decision-making. This study aims to contribute to the existing SCM literature by investigating the interaction mechanism between SC resilience and SSCM.

1.2 Research context

Internal and external SC interruptions, ranging from an unforeseen IT or telecommunications outage to poor weather, cyber-attack and data breach, loss of talent/skills, transport network disruption, political changes to new laws or regulations, have adverse impacts on the flow of goods, materials and services, information, and cash (Boone et al., 2013) and restricted organisations' ability to satisfy the end customers (Ramanathan, Subramanian and Parrott, 2017). Companies suffered from a loss of productivity, customer complaints, increased work cost, revenue loss, and service outcome impairment due to SC disruptions/incidents. Significantly, natural and man-made disasters can severely disrupt SC operations, resulting in significant economic, social, and environmental damages (Gunessee, Subramanian and Ning, 2018; Hofmann et al., 2014). Therefore, it is crucial to develop solution techniques to effectively control and mitigate the uncertainty and risks associated with SC disruptions. This is where the concepts of SC resilience and SSCM become important as they offer a holistic approach to managing SC uncertainty, risks, and vulnerabilities. (Alora and Barua, 2021; Ambulkar, Blackhurst and Grawe, 2015; Azadegan et al., 2020; Cabral, Grilo and Cruz-Machado, 2012; Azevedo et al., 2013).

The recent outbreak of the COVID-19 pandemic, political conflicts, and natural disasters have highlighted the need for SC resilience and sustainability (Ivanov, 2020; Ali et al., 2022). Some companies demonstrated the ability to adapt to changing circumstances and meet social requirements quickly (Do et al., 2021). For example, 58 Gin, a London-based liquor brand, quickly adjusted its manufacturing line to produce large-batch sanitiser instead of small-batch gin. This adaptation was possible due to the company's sensing capability, which allowed them to identify the similarity of key ingredients between sanitiser and gin and quickly build flexible manufacturing lines. Similarly, the UK government ordered 10,000 ventilators from vacuum manufacturer Dyson. In addition, Shanghai General Motor Wuling (SGMW) began making face masks in and in China using medical-level textiles from a source that previously supplied interior materials for vehicles (BBC News, 2020). These examples illustrate the potential for SC resilience to enhance sustainability by enabling companies to respond to unforeseen events and meet societal needs (Goodarzian et al., 2021).

The dynamic business environment drives leading companies to adopt SSCM initiatives (Jabbarzadeh, Fahimnia and Sabouhi, 2018; Mari, Lee and Memon, 2014; Sharma, Singh and Rai, 2021), not only for business continuity but also with the consideration of the whole society (Wiengarten and Longoni, 2018; Chaudhuri et al., 2021). As a result, all stakeholders, including manufacturers, producers, retailers, governments, and policymakers, are inextricably tied to crucial global difficulties in defining and implementing sustainable solutions. (Rebs et al., 2019; Andersson et al., 2022). With the ongoing sustainable development, sustainability-related risks come from social, environmental, and financial issues (Barbosa-Póvoa, da Silva and Carvalho, 2018; Hofmann et al., 2014; Gouda and Saranga, 2018). Resilience thinking should be combined with sustainability objectives to regulate and reduce the negative effects of unplanned disruptions and disasters. (He et al., 2021; Silva, Pereira and Hendry, 2022).

Recent SSCM research embraces the importance of resilience thinking in the SSCM field with consideration of the sustainability-related uncertainties and long-term orientation (Ahi and Searcy, 2013; Xu, Marinova and Guo, 2015). Sustainability issues are recognised as the new sources of risks, as defined as sustainability risks. Identifying, controlling, and mitigating sustainability risks via resilience capabilities enables superior sustainable performance (da Silva et al., 2020; Giannakis and Papadopoulos, 2016; Rostamzadeh et al., 2018; Xu et al., 2019), which can be referred to as viable SCs (Ahi and Searcy, 2013; Xu, Marinova and Guo, 2015).

The nexus between risk management and both SSCM and SC resilience highlights their intertwined nature, as they are all critical for ensuring business continuity and sustainability, particularly in the context of SCs that operate in sociological and ecological environment (Wieland et al., 2023; Wieland, 2021; Wieland and Durach, 2021). SC resilience and sustainability share a common objective of mitigating risks, albeit with different approaches (Redman, 2014), with the former being process-oriented (Adobor, 2020; Ali, Mahfouz and Arisha, 2017) and the latter consequence-driven (Ahi and Searcy, 2013). The literature reveals that both SC resilience and SSCM are essential for ensuring business viability in a volatile world (Silva, Pereira and Hendry, 2022; Eggert and Hartmann, 2022), but further investigation is needed to explore how these concepts are integrated to achieve sustainable and resilient SCs. This literature gap provides a valuable opportunity for this study to delve deeper into this area and provide insights into how SC resilience and SSCM have interacted under a holistic framework and whether synergies exist between SC resilience and SSCM in pursuit of performance excellence.

1.3 Research problem

SC resilience can be referred to as a systematic approach to sustainability from the SC risk management perspective (Giannakis and Papadopoulos, 2016). Alternatively, SSCM could contribute to organisational and SC resilience (Eggert and Hartmann, 2022; Ortiz-de-Mandojana and Bansal, 2016; Sajko, Boone and Buyl, 2021). The SC design should consider resilience and sustainability (Fahimnia and Jabbarzadeh, 2016; Negri, Cagno and Colicchia, 2022; Negri et al., 2021). There are three perspectives for examining sustainability and resilience as separate disciplines: viewing resilience as a component of sustainability, considering sustainability as a component of resilience, or treating resilience and sustainability as distinct objectives (Marchese et al., 2018). These three perspectives underscore the challenges of integrating resilience and sustainability approaches. Achieving this integration has remained unclear within the context of SCs (Negri et al., 2021); it has been relatively underexplored (Fahimnia and Jabbarzadeh, 2016; Jabbarzadeh, Fahimnia and Sabouhi, 2018; Zahiri, Zhuang and Mohammadi, 2017).

Resilience, as the capability to resume operations and regain competitive advantages timely and effectively (Rajesh, 2019), could be considered as a contradictory principle to sustainability in SCM (Rajesh, 2021). However, in recent studies, synergies and trade-offs have been found between SC resilience and SSCM (Negri et al., 2022, 2021). Fahimnia et al. (2018) and Jabbarzadeh, Fahimnia, and Rastegar (2019) investigated the greenness-robustness trade-offs in the strategic design of SC networks, which echoes the trade-offs of sustainability and resilience performance in dynamic sustainability analysis of Fahimnia and Jabbarzadeh (2016). Rajesh (2018) offered an evolutionary answer to the trade-offs between sustainability and resilience, suggesting that sustainability strategies should be implemented in the upstream supply network, whereas those focusing on resilience best suit the downstream network. Even though these efforts have been made to explore the co-occurrence of SC resilience and sustainability, scant studies provide direct and holistic views of the interaction mechanism of the two constructs.

Unlike the distinct pursuit perspective, some studies consider SSCM as the enabler of SC resilience, where the implementation of SSCM for risk mitigation can build resilient SCs (Soni, Jain and Kumar, 2014; Nishat Faisal, 2010). This approach suggests that SCs with SSCM, which aim to increase economic, social, and environmental well-being, are less vulnerable to business disruptions (Ahi and Searcy, 2013). One explanation could be given that SCs with high social sustainability (e.g., advanced health care package) have built stronger connections with stakeholders (e.g., employees) and are less likely to production disruption (e.g., lose workforce capacity) in response to the unexcepted shock (e.g., the pandemic) (Aslam et al., 2022; Sajko, Boone and Buyl, 2021). Sustainability principles can provide significant strategies for mitigating SC vulnerability and enhancing SC resilience with observation in the circular economy context (Gaustad et al., 2018; Ortiz-de-Mandojana and Bansal, 2016). Improved understanding of sustainability and implementing sustainable practices in SCs helps decision-makers to decrease the risks of ethical and environmental issues (Hallikas, Lintukangas and Kähkönen, 2020).

Alternatively, another stream of studies shows that a resilient SC is a prerequisite for achieving SC sustainability (Fahimnia, Jabbarzadeh and Sarkis, 2018; Ivanov, 2018; Mari, Lee and Memon, 2016; Pavlov et al., 2019). Or in other words, resilience can be regarded as an indicator of sustainability (Walker and Salt, 2012; Magis, 2010). Resilience, jointly with security, reliability, and renewal, formulates the spectrum of four sustainability perspectives (Seager, 2008), which implies SC resilience can be used as a tool to achieve a broader goal, sustainability (Fiksel, 2006; Anderies et al., 2013). Jabbarzadeh et al. (2018) posited that though resilience strategies could be less cost-efficiency, they could yield optimal outcomes when the sustainability goal matters. Ivanov (2018) suggests that SC resilient structure could be designed to increase sustainability.

The intrinsic relationships between resilience and sustainability have yet to be explored in-depth and remain complicated and confusing. SC resilience and SSCM are important for SC viability and closely linked with turbulent changes. SC resilience and SSCM are not simply a matter of strength but the balance between the triggering risks and stakeholders' pressure and capabilities. These two concepts can complement or compete (Marchese et al., 2018) and share similarities (Al Naimi et al., 2020; Giannakis and Papadopoulos, 2016). Some studies view resilience as a contradictory principle to sustainability in SCM (Rajesh, 2021; Fahimnia, Jabbarzadeh and Sarkis, 2018), while others see sustainability as a prerequisite for achieving SC resilience (Eggert and Hartmann, 2022). The integration of resilience and sustainability into SC operations for superior performance has remained unclear and inadequate in the literature. Hence, it is essential to investigate the co-occurrence of SC resilience and SSCM and explore their interaction mechanisms.

1.4 Research aims, questions, and objectives

The relationship between sustainability and resilience is crucial in SCM. The interplay between sustainability and resilience is "the management of coordinated supply chains integrating economic, environmental and social considerations in the business system, while dynamically preparing, adapting and reacting to unexpected disruptions, to meet the stakeholder requirements and improve firm profitability and competitiveness in the short and long term" (Negri et al., 2021, pp. 2868). This is the only definition in the literature on the subject.. Despite its importance, there is limited research on the relationships between sustainability and resilience in SCM (Ivanov, 2020; Silva, Pereira and Hendry, 2022; Wieland, 2021). This lack of research motivates this study to explore the extant findings of the interaction mechanisms between SC resilience and SSCM in the extant literature and identify the common themes of the joint research of these two concepts.

Recognising the dynamism of embedded social-ecological systems, it is clear that both SSCM and SC resilience must be viewed as evolving processes rather than static approaches. SCs absorb, adapt, and transform in response to external disturbances or stresses while considering the ecological and social environment. A complex adaptive system (CAS) approach to SCs, which considers the interdependence and adaptability of social-ecological systems, provides a framework for aligning the ever-changing environment with SC resilience and SSCM (Choi, Dooley and Rungtusanatham, 2001; Nair et al., 2016). The complexity of relationships within SCs is captured through the lens of social network theory (SNT), which has proven to be a valuable tool for understanding the interconnectedness among SC members, as well as the structure and dynamism of SC networks (Borgatti and Li, 2009). SNT enables the exploration of the complex relationships and interdependencies among SC actors and understanding how these relationships evolve over time (Galaskiewicz, 2011; Han, Caldwell and Ghadge, 2020). Therefore, by applying the theoretical lenses of CAS and SNT to SCs, this study aims to interpret the interaction mechanism of SC resilience and SSCM in network-structured adaptive SC systems, where complex and evolving relationships exist within SC systems, as well as their interactions with the embedded environment.

There is also limited empirical knowledge of the complex relationships between SC resilience and SSCM (Negri et al., 2021; Negri, Cagno and Colicchia, 2022). One reason could be the difficulty of measuring SC resilience (Ambulkar, Blackhurst and Grawe, 2015; Cohen et al., 2022), arising from its multidimensionality (Christopher and Peck, 2004), multiscale (Creazza et al., 2022), dynamic nature (Adobor and McMullen, 2018), lack of consensus on its definition and operationalisation (Castillo, 2022), and the complex interplay of various factors that influence it (Yang et al., 2021; Cotta and Salvador, 2020; Iftikhar, Purvis and Giannoccaro, 2021).

In addition to exploring the interaction mechanisms between SC resilience and SSCM, this study also aims to address the difficulty of measuring SC resilience. Deploying SNT, this study explores the measurement of SC resilience from multilevel network structures, including nodes (individual firms), dyads (supplier-customer relationships), and the entire network. Previous studies have used similar approaches to measure SC resilience and have shown the usefulness of SNT in this concept (Kim et al., 2011; Alinaghian, Qiu and Razmdoost, 2021; Zhu, Yeung and Zhou, 2021; Essuman et al., 2022). Through this approach, this study aims to provide a more comprehensive and nuanced understanding of SC resilience. With the measurement of SC resilience, this study aims to empirically examine the relationships between SC resilience and SSCM on firm performance. The empirical study uses secondary data from two common databases of publicly traded companies in China, where the complexity of SC networks and increasing environmental pressure make it a suitable context for this study.

The general goal of this research is to explore the interplay between resilience and sustainability in the realm of SCM. To achieve this objective, this study examines the co-occurrence of resilience and sustainability in the SCM field and identifies the common themes between SC resilience and SSCM from literature. Drawn upon CAS and SNT, this study aims to provide a holistic theoretical view of the interaction mechanisms for further empirical studies. Furthermore, this study seeks to address the difficulty of SC resilience measurement from SNT and empirically examine the synergies between SC resilience and SSCM for performance outcomes.

Table 1 Research objectives and aims

Research objectives	**Research aims**
(1) Investigate the interplay between resilience and sustainability in the SCM field	(1) Examine the co-occurrence of resilience and sustainability in the SCM field to identify common themes
(2) Provide a holistic theoretical view of the interaction mechanisms for further empirical studies	(2) Draw on CAS and SNT to develop a framework for understanding the interplay between SC resilience and SSCM
(3) Address the difficulty of SC resilience measurement from SNT and examine synergies between SC resilience and SSCM	(3) Explore the measurement of SC resilience from multilevel network structures and conduct empirical examination of the relationships between SC resilience and SSCM on performance outcomes

Source: Author.

Given that there is an understanding of the interconnection between SC resilience and SSCM, it is still unclear how these concepts interact and to what extent the integration of SC resilience and SSCM implementation is beneficial for performance outcomes. It is worth exploring whether SC resilience and SSCM should be combined for better performance or pursued as distinct concepts. To achieve the research aims, this work will focus on examining the synergies between SC resilience and SSCM for performance outcomes, including financial and non-financial performance, on ensuring long-term business continuity. This study explicitly focuses on financial and innovation performance to evaluate whether it is possible to "do well by doing good and being resilient". The research questions (RQs) developed for this study aim to uncover the complex interplay between SC resilience and SSCM:

RQ 1. What common themes are developed in the joint research of SC resilience and SSCM in the extant literature?

RQ 2. How can SC resilience and SSCM be integrated under the framework of CAS and SNT?

RQ 3. What is the nature of the interplay between SC resilience and SSCM in terms of firm performance?

1.5 Research significance

1.5.1 Theoretical contribution

Several theoretical contributions are made by this work. To begin, this study comprehensively reviews the existing literature and evaluates the common themes in the joint research of SC resilience and SSCM. This review highlights the emergence of SC resilience and SSCM roots in risk management and the pursuit of long-term continuity. The attributes of sustainability are integrated into the enlarged scale of SC risks with sustainability concerns (i.e., sustainability risks). The attributes of resilience are embedded in comprehensive SSCM performance indexes containing risk mitigation and sustainable performance. This literature review offers a holistic view of the integration of resilience and sustainability in the SCM field.

Second, this study supports for the equal prominence of SC resilience and SSCM and presents an integrated theoretical framework for their interplay. Drawing on the theoretical lens of CAS and SNT, it provides a holistic perspective on how SCs, as network-structured adaptive systems, can adjust their internal mechanisms (i.e., SC resilience and SSCM paradigms) and network structures in response to turbulent environments while pursuing desired performance outcomes. From CAS and SNT perspectives, this framework provides an understanding of how SC resilience and SSCM are intertwined from both risk-driven and performance-oriented perspectives. By bridging the gap between SC resilience and SSCM research, this framework contributes to the SCM literature, highlighting the need for further empirical studies to explore the synergies and trade-offs between these two concepts (Negri et al., 2021; Negri, Cagno and Colicchia, 2022; Cohen et al., 2022; Wieland, 2021; Silva, Pereira and Hendry, 2022).

Third, in response to the call for empirical studies of SC resilience (Cohen et al., 2022), this study develops the operationalisation of SC resilience from multilevel network structures. Drawing upon SNT, the study proposes an approach for measuring SC resilience that considers resource resilience at the focal level (i.e., capacity, inventory, and SC slacks), relational resilience at the dyad level (i.e., supplier and customer base concentration), and structural resilience at the network level (i.e., composite network resilience). Notably, the proposed operationalisation measures SC resilience at the scale of the SC rather than at the organisational level, which echoes the call of Novak, Wu and Dooley (2021). The use of firm-level secondary data in measuring SC resilience from the multiple levels of SC networks contributes to the development of empirical knowledge in the SC resilience literature.

Furthermore, the complex relationships between SC resilience and SSCM remain conceptual (Wieland, 2021; Ivanov, 2020). Prior studies have examined the topics of SC resilience and sustainability; most have been analytical (Fahimnia and Jabbarzadeh, 2016; Ivanov, 2018) or case studies (Negri, Cagno and Colicchia, 2022; Choudhary et al., 2022), lacking empirical validation of the interplay between SC resilience and SSCM. Therefore, this study is among the first to empirically examine the synergies and trade-offs, focusing on the interaction between SC resilience and SSCM practices for financial and non-financial performance outcomes. More specifically, this study serves as the first to deploy the firm-level public data of Chinese companies to investigate the interaction of SC resilience and SSCM and their impacts on financial and innovation performance.

The final contribution of this study is the advocacy of using the CAS and SNT as theoretical lenses to explain the interaction of SC resilience and SSCM and develop the measurement of SC resilience, addressing the call of recent studies (Choi, Dooley and Rungtusanatham, 2001; Abbasi and Varga, 2022; Nair and Reed-Tsochas, 2019; Braz and Marotti de Mello, 2022; Han, Caldwell and Ghadge, 2020; Lu et al., 2018). CAS and SNT are complementary and emphasise the adaptive and evolving nature of SCs as network-structured systems. By incorporating these theoretical lenses, this study provides a more nuanced and comprehensive understanding of the interplay between SC resilience and SSCM, which can guide future research.

1.5.2 Practical contribution

This study makes several practical contributions. Firstly, it sheds light on the sustainability and resilience of China's automotive, food, and heavy-polluting SCs. These industries face unique challenges and disruptions, such as network design, natural disasters, and regulatory stress. The empirical results imply that these companies can achieve financial benefits and innovation by being both sustainable and resilient, advocating SSCM practices and SC resilience development at the network scale. Secondly, the empirical study investigates the interaction between SC resilience and SSCM dimensions on financial and innovation performance, providing empirical evidence of the synergies of different combinations of SC resilience and SSCM practices. Thus, the empirical results can provide valuable guidance to SC managers in designing and analysing integrated strategies for SC resilience and SSCM to achieve desired performance outcomes. Overall, this empirical model can be extended to help the development of SC resilience and SSCM in the context of Chinese public firms.

1.6 Thesis structure

This thesis is organised and presented in eight chapters in **Figure 1**. The thesis is composed of an overview of the thesis, an initial review of the literature and the proposed theoretical framework and conceptual framework with hypotheses development for empirical examination, research methodology that explains the research design, data collection process, and variable measurement, followed by empirical findings and discussion and a closing section, discussing the outcomes and the combined contribution.

Chapter 1- Introduction: This chapter provides a summary of the study, including an overview of the topic, the research setting, and an identification of research problems, and research objectives, aims, and questions. And finally, the research significance, followed by thesis structure.

Chapter 2- Literature Review: Chapter 2 begins by defining the fundamental concepts of SC resilience and SSCM and the dimensions of the two concepts, along with SC risks. This chapter presents a systematic literature review focusing on the co-occurrence of resilience and sustainability in SCM literature to identify the common themes in the two streams of studies, from SC risks, SC structure, SC resilience elements, SC sustainability elements, and performance outcomes.

Chapter 3- Theoretical Framework: Chapter 3 introduces CAS and SNT and examines their suitability and complementarities in SCM. Based on a review of the literature, a theoretical framework for the intersections of SC resilience and SSCM, which guide design of conceptual framework in the following chapter.

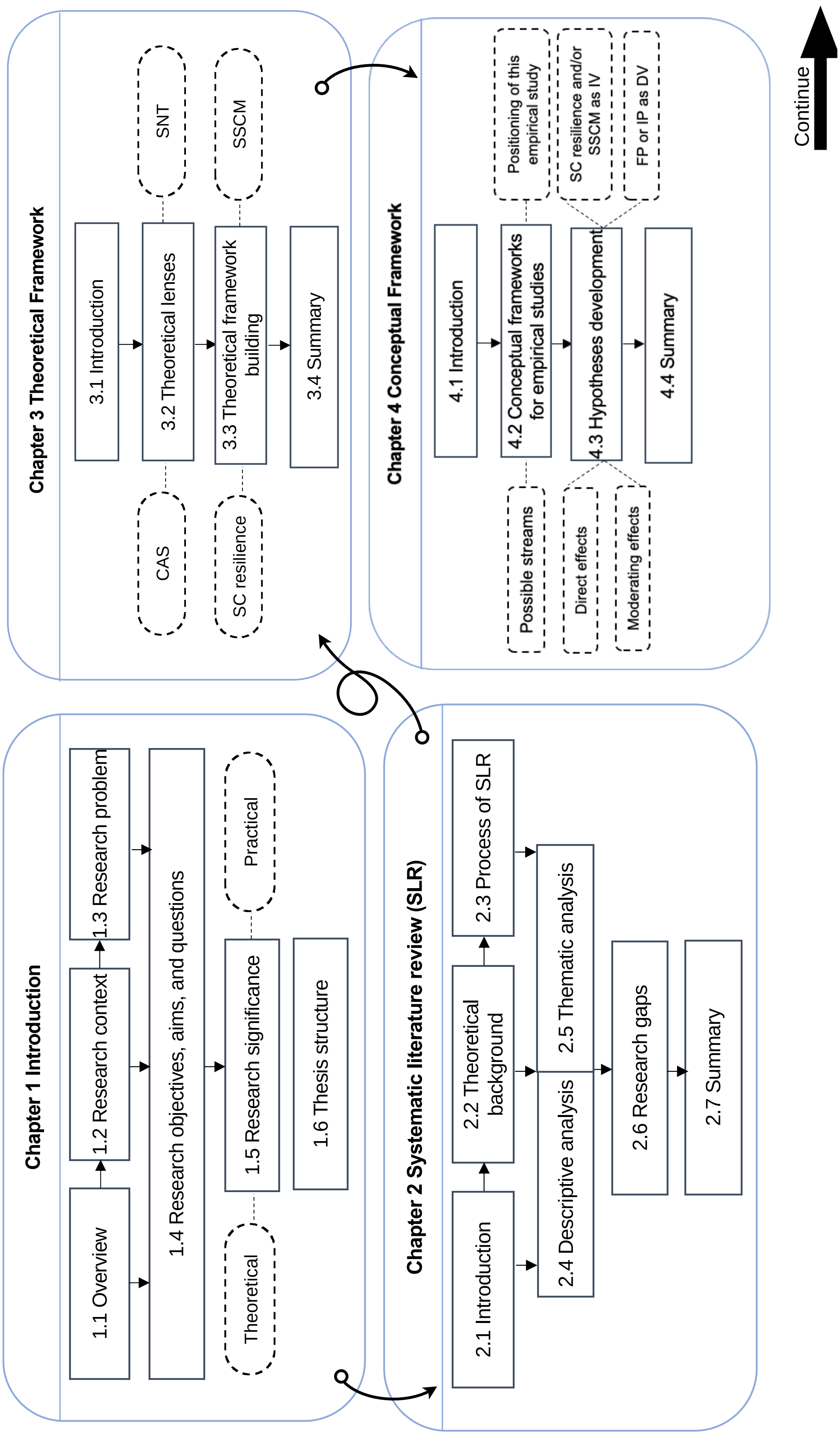
Chapter 4- Conceptual Framework: Chapter 4 presents a reflection on the formulation and design of conceptual frameworks for empirical studies. Chapter 4 develops hypotheses and proposes an empirical model with an emphasis on the positioning of the study.

Chapter 5- Research Methodology: The overall research methodology section begins by discussing positivism as the underlying philosophical approach of the dissertation. It will then present the justification for the chosen quantitative research design. Afterwards, it explains the sample selection (e.g., country and sectors), data collection, and variable measurement for the empirical testing in Chapter 6.

Chapter 6- Empirical Study: Fixed-effect model is justified for the sample data, followed by the interpretation of the empirical model equations. Afterwards, descriptive statistics and correlation matrix, and regression results are presented in the light of panel data analysis to assess the hypothesised relationships among the SSCM, SC resilience, and performance outcomes. The results confirm the moderating effects of SC resilience on SSCM-performance relationships, and SSCM on SC resilience-performance relationships, with a focus on financial and innovation performance.

Chapter 7- Discussions: This chapter summarises the empirical findings in response to the hypotheses in the empirical model. Firstly, the chapter explores how the results confirm or contradict the theoretical assumptions made in Chapter 4. The discussion highlights the importance of SC resilience and SSCM in achieving financial and innovation performance and confirms the synergies of SC resilience and SSCM for desirable performance outcomes.

Chapter 8- Conclusions: The last chapter summarises research findings responding to research questions and discuss the overarching insights of this research. This chapter discusses the overall theoretical and practical contributions. This chapter also analyses the study's limitations and finishes with a discussion of future research directions in the study's topic area.



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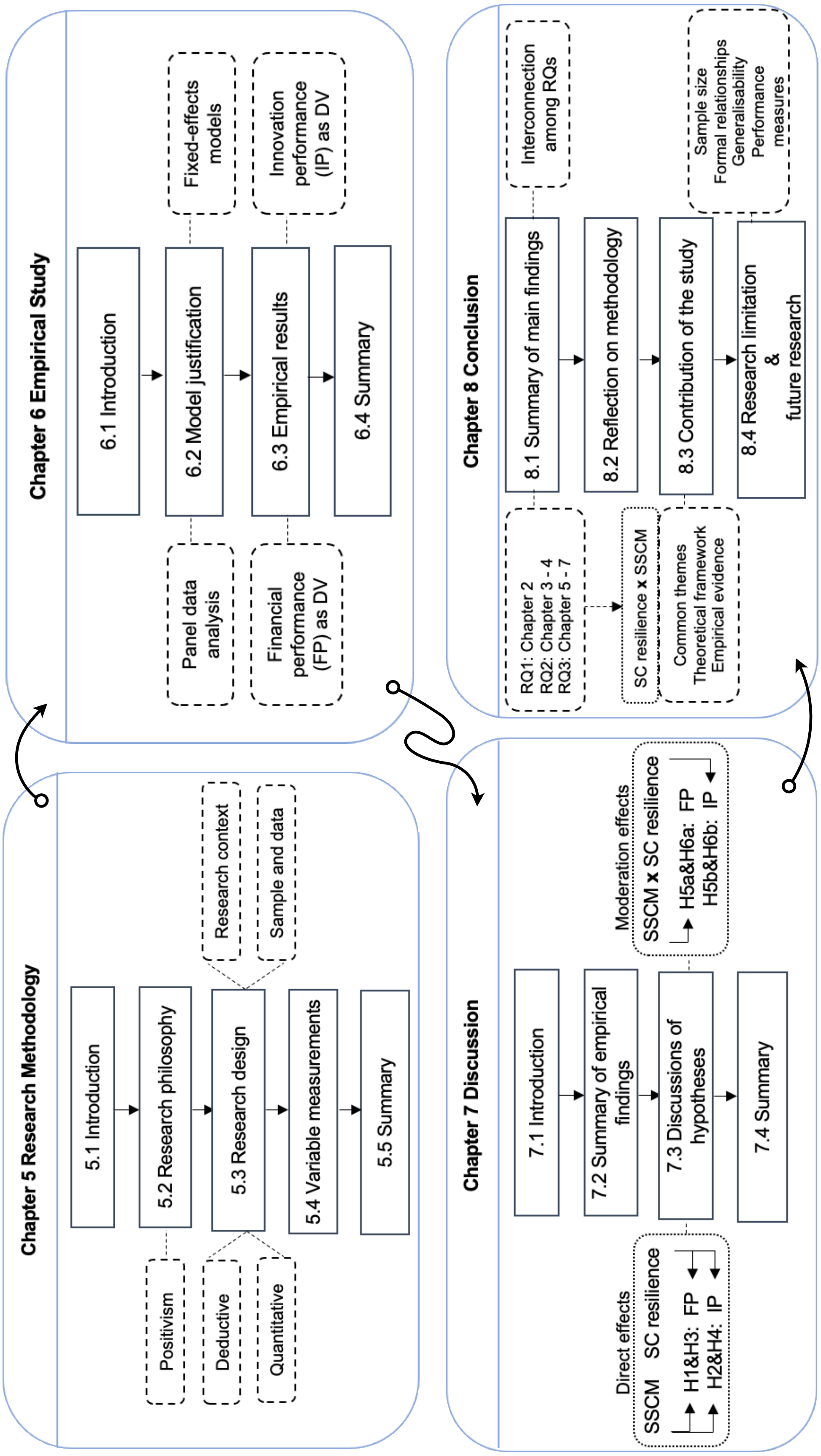

Figure 1 The structure of this thesis

Chapter 2 Literature Review

2.1 Introduction

The aim of this chapter is to review the study of the co-concurrence of SSCM and SC resilience in the current literature and systematically review how the two concepts are jointly investigated and what is the interaction mechanism between SC resilience and SSCM. This is intended to classify the common themes of the SSCM-resilience joint research and clarify the research gap and provide support for a theoretical framework in Chapter 3. Moreover, this chapter responds to ***RQ1*** by answering **what are common themes currently developed in the joint research of SC resilience and SSCM in the extant literature**.

Driven by the research questions above, it is essential to define the constructs first and briefly discuss the identified interrelationships between SC resilience and sustainability, which could help to guide the review process and clarify the research boundary. Therefore, the structure of this chapter is organized as follows: first, presenting the theoretical background of SC resilience and SSCM and the discussion between the two concepts; second, conducting a systematic literature review to investigate the current research status lastly, identify common themes of resilience-sustainability joint studies in SCM literature and clarify the research gaps.

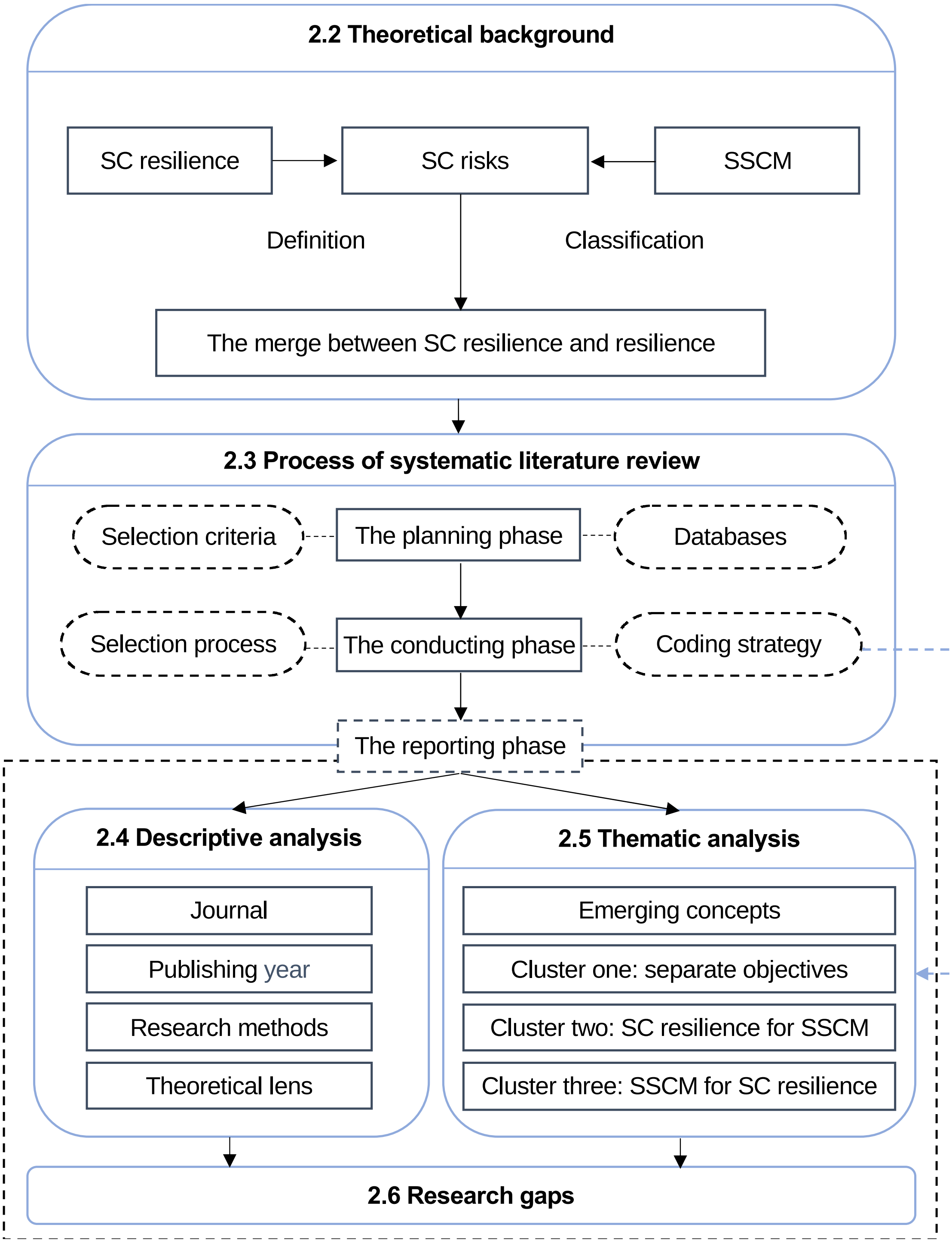

Figure 2 Outline of Chapter 2

2.2 Theoretical background

2.2.1 SC resilience

2.2.1.1 Definition of SC resilience

The concept of resilience has been widely advocated across various fields to address turbulence (Gao et al., 2016). A fundamental definition of resilience can be found in the engineering domain: "*the tendency of a material to return to its original shape after the removal of a stress that has produced elastic strain*" (Merriam-Webster 2007). Holling (1996), as an ecologist, provided one of the most prominent interpretations of resilience and distinguished resilience into two aspects- engineering resilience and ecological resilience-suggesting that the former pertains to the fail-safe design to safeguard an engineered system from systematic or component failures and the latter involves the safe-fail design of an organism's ability to persist and adapt to the environment. The literature also highlights the relevance of other fields in the development and definition of SC resilience, including ecology, psychology, organisation theory, and engineering (Shishodia et al., 2021). **Figure 3** highlights the interdisciplinary aspect of the resilience idea, which has allowed SCs to adapt it to their settings by drawing on resilience concepts from different domains.

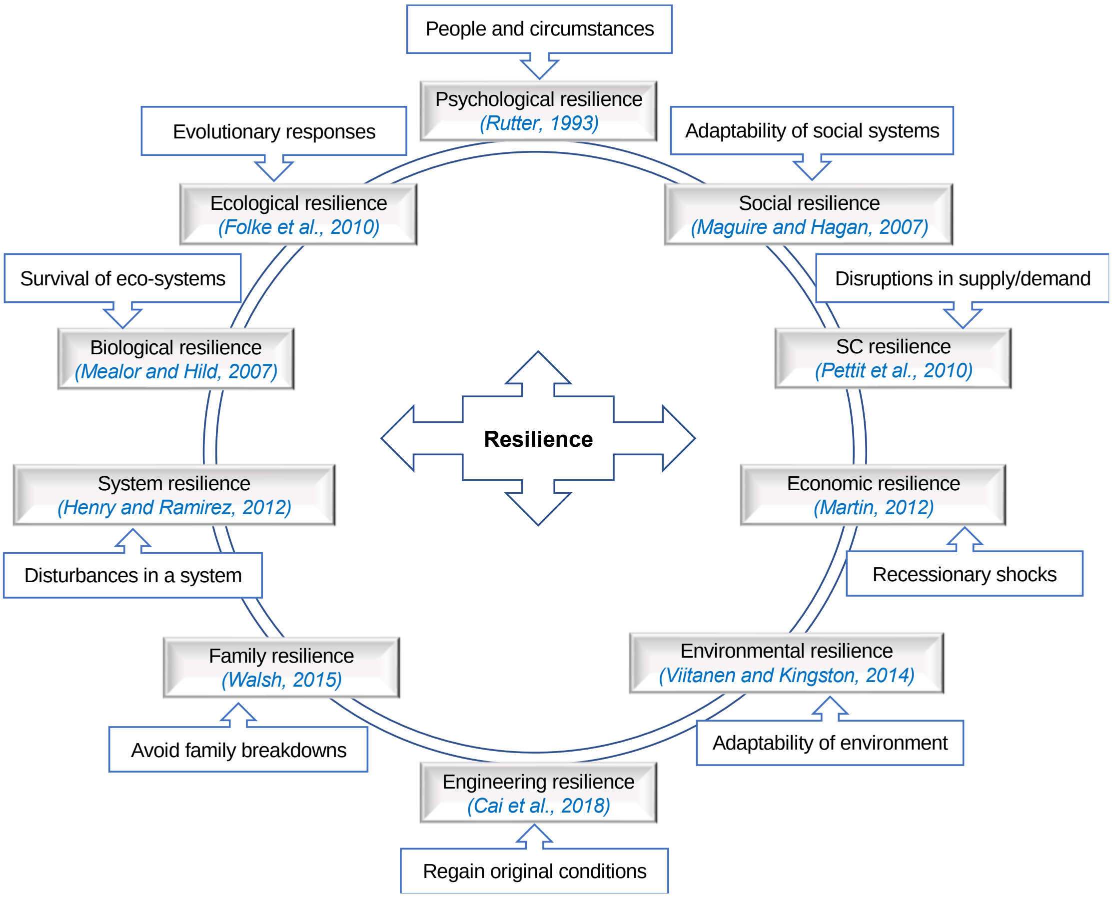

Figure 3 Resilience concepts in multiple disciplines

Source: Shishodia et al. (2021).

In SCM literature, a core concept commonly shared in the definition is that SC resilience is multidisciplinary and multidimensional and related to the system's ability to tackle uncertainties and return to normality and stabilisation at a desirable level (Yu Han, Woon Kian Chong and Dong Li. 2020; Castillo, 2022). In the context of SCM, the system is not a single firm or a simple chain but a more complex network, as SCs are prominently defined as a "network of connected and interdependent organisations mutually and co-operatively working together" (Christopher 2016, p. 3). Organisational or enterprise resilience and SC resilience are interchangeably used in management studies (Iftikhar, Purvis and Giannoccaro, 2021; Ambulkar, Blackhurst and Grawe, 2015). However, SC resilience is the resilience beyond the firm's scope with the extended SC members, which emphasises inter-firm resources and relations with an SC's external and internal stakeholders (Pettit et al., 2019; Madhavaram, 2022).

SC resilience literature has garnered broader attention in academics and practices for the past two decades. SC resilience was initially studied by researchers as part of SC vulnerability studies (Svensson 2000; 2002) or as a component of SC risk management (SCRM) (Juttner et al., 2003; Water, 2007). Pettit et al. (2010) described SC resilience as matching vulnerability factors and SC capabilities. Juttner and Maklan (2011) empirically explored this. More recently, SC resilience has been considered to enhance and upgrade to SCRM (Pettit, Croxton and Fiksel, 2019), where SC resilience focuses on systematic characteristics rather than identifying, assessing, controlling, and monitoring risk sources or factors (Norrman and Wieland, 2020; Wieland and Durach, 2021). Many conceptual and review papers provided the definitions of SC resilience (see **Table 2**), where SC resilience is defined as a remedy towards disruptions, turbulences, unavoidable events or risks (Christopher and Peck, 2004; Jüttner and Maklan, 2011; Ponis and Koronis, 2012; Tukamuhabwa et al., 2015; Kamalahmadi and Parast; 2016; Datta, 2017).

Table 2 Example definitions of SC resilience

Selected articles	Definition of SC Resilience
Rice and Caniato (2003)	"Ability to react to an unexpected disruption and restore normal operations."
Christopher and Peck (2004)	"Ability of a system to return to its original state or move to a new, more desirable state after being disturbed."
Fiksel (2006)	"Capacity for complex industrial systems to survive, adapt, and grow in the face of turbulent change."
Ponomarov and Holcomb (2009, p. 131)	"The adaptive capability of the SC to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function."
Jüttner and Maklan (2011, p. 247)	"SC resilience addresses the SC's ability to cope with the consequences of unavoidable risk events in order to return to its original operations or move to a new, more desirable state after being disturbed."
Carvalho et al. (2012, p. 331)	"SC resilience is concerned with the system's ability to return to its original state or to a new, more desirable one after experiencing a disturbance, and avoiding the occurrence of failure modes."

Ponis and Koronis (2012, p. 925)	"The ability to proactively plan and design the SC network for anticipating unexpected disruptive events, respond adaptively to disruptions while maintaining control over structure and function and transcending to a post-event robust state of operations, if possible, more favourable than the one prior to the event, thus gaining competitive advantage."
Golgeci and Ponomarov (2013, p. 604)	"SCs that have an adaptive capability to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations."
Pettit et al. (2013, p. 46)	"Resilience – the ability to survive, adapt, and grow in the face of turbulent change."
Sawik (2013, p. 260)	"Resiliency refers to a firm's capacity to survive, adapt, and grow in the face of change and uncertainty."
Tukamuhabwa et al. (2015, p. 8)	"The adaptive capability of a SC to prepare for and/or respond to disruptions, to make a timely and cost-effective recovery, and therefore progress to a post-disruption state of operations-ideally, a better state than prior to disruption."
Kamalahmadi and Parast (2016, p. 121)	"The adaptive capability of a SC to reduce the probability of facing sudden disturbances, resist the spread of disturbances by maintaining control over structure and functions, and recover and respond by immediate and effective reactive plains to transcend the disturbance and restore the SC to a robust state of operations."
Li et al. (2017, p. 256)	"SC resilience refers to a SC's capability to cope with changes, which is formed through being prepared to endure future changes, being alert to changes and being agile in response to changes."
Novak, Wu and Dooley (2021, p. 332)	"A supply chain is resilient to the extent that the system can maintain core functionality by continually adapting, evolving, and transforming in response to the dynamic multiscale feedbacks that occur between the multitude of interconnected organizations, institutions, and social and ecological systems that are all parts of the larger supply chain."

Source: Author.

Christopher and Peck (2004) established the first definition of SC resilience in the literature as the ability of a system to return to its original state or move to a new desirable state following a disturbance. This definition was expanded some years later to include the ability to adapt to the turbulences and bounce back to the initial and the requirement for acquiring a better new state (Ponomarov and Holcomb, 2009). Considering the stages of disruptions, some studies emphasise resilience as SC capabilities for recovery after disruptions (Rice and Caniato, 2003; Juttner and Maklan, 2011) and others considered resilience as SC preparedness for unforeseen events (Datta, 2017). With consideration of all the different phases of SC resilience (before, during and after disruption), Kamalahmadi and Parast (2016) emphasises the dynamic and adaptative nature of SC resilience in the face of turbulence (e.g., natural and human-made disasters). Therefore, following Kamalahmadi and Parast (2016), this study defines SC resilience as

> "*the adaptive capability of a SC to reduce the probability of facing sudden disturbances, resist the spread of disturbances by maintaining control over structures and functions, and recover and respond by immediate and effective reactive plains to transcend the disturbance and restore the SC to a robust state of operations*" (Kamalahmadi and Parast, 2016, p. 121).

This definition of SC resilience implies the standpoint of this research that developing and maintaining SC resilience involves the dynamic exchanges between SC systems and the environment, the adaptability of SC systems towards the changes of the environment, the internal structural evolution and control mechanism, which demonstrates the spatial and temporal scopes of SC resilience.

2.2.1.2 Classification of SC resilience

SC resilience can be treated as an empirical performance measure or the capability to respond towards disruptive events (Novak, Wu and Dooley, 2021). Though there is no universal definition of SC resilience, many studies define SC resilience as the ability to successfully recover from a disruptive event that causes the system to go away from normal operations. SC resilience, by definition, can be viewed as an adaptive capability from multiple perspectives. One stream in resilience literature is to classify SC resilience regarding disruption stages, which are consolidated into three: readiness, response, and recovery (Han et al., 2020; Hohenstein et al., 2015). It is also referred to proactive, concurrent, and reactive resilience capabilities (Ali et al., 2017; Li et al., 2017). The other stream focuses more on the formative capabilities of SCRE (Ambulkar et al., 2015; Castillo, 2022; Christopher and Peck, 2004;

Ponis and Koronis, 2012). The most common elements are flexibility, redundancy, agility, visibility, and risk management culture (Iftikhar et al., 2021; Li et al., 2017).

Among the studies, Christopher and Peck (2004) first explore the categories of SC resilience principles. This work is the frequently cited source for SC resilience principles and has been verified and examined by following research (Golgeci and Ponomarov, 2013; Scholten et al., 2014; Scholten and Schilder, 2015; Li et al., 2017; Liu et al., 2018; Iftikhar et al., 2021). The study of Christopher and Peck (2004) serves as the fundamental basis for operationalising SC resilience. However, only a few had clear-cut distinctions among these concepts, which were mainly semantic. Adapted to the model of Christopher and Peck (2004), Kamalahmadi and Parast (2016) recently incorporated the major enablers of SC resilience and further examined the relationships among the four components in previous literature, which revealed the popularity in these elements had been used interchangeably. Therefore, this study follows this existing framework (see **Figure 4**) and considers the four pillars as the primary capabilities of SC resilience: (1) SC reengineering, (2) collaboration, (3) agility, and (4) SC risk management culture.

(1) *SC re-engineering*, refers to the design of SC incorporating resilience, including SC understanding, supply base strategy, and strategic assessment and the trade-off between redundancy and efficiency (Christopher and Peck, 2004). Flexibility and redundancy are two essential practices. Flexibility refers to the ability to rapidly respond and adapt to significant changes in the SC (Kamalahmadi and Parast, 2016; Prater, Biehl and Smith, 2001). Flexibility through flexible sourcing/production/distribution systems, multi-skilled workforce or customised products (Jüttner and Maklan, 2011) (Sheffi and Rice, 2005; Tomlin, 2006; Pettit et al., 2013) enable SC resilience (Hohenstein et al., 2015). Redundancy responds to sudden SC changes through redundant resources, e.g., multiple supply bases, backup suppliers and overcapacity in production or transportation (Craighead et al., 2007; Zsidisin and Wagner, 2010; Bode et al., 2011).

(2) Collaboration is the capability to work effectively with other entities for mutual benefits, including sharing crucial information and valuable knowledge and establishing joint efforts (Jüttner and Maklan, 2011; Pettit et al., 2010; Pettit et al., 2013). Collaborative activities like joint-decision making, knowledge sharing, supplier certification, and supplier development can increase SC resilience through two prerequisites, viz. inter-firm trust and information sharing (Christopher et al., 2011a; Christopher and Holweg, 2011; Kamalahmadi and Parast, 2016).

(3) Agility is “the ability of a SC to rapidly respond to change by adapting its initial stable configuration” (Wieland and Wallenburg, 2012). Velocity and visibility were inherent to agility (Christopher and Peck, 2004; Jüttner and Maklan, 2011). Velocity emphasises speed and responsiveness (Christopher and Peck, 2004; Wieland and Wallenburg, 2013). Quick reactions to unexpected emergencies helps SCs reduce the negative consequence of disruptions and accelerate the facilitated recovery (Blackhurst et al., 2011). Visibility is defined as the timely knowledge of the status of the entire SC (Pettit et al., 2013). Early warning indicators, real-time monitoring, risk and knowledge sharing lead to SC connectivity and visibility (Christopher and Peck, 2004; Craighead et al., 2007; Blackhurst et al., 2011; Jüttner and Maklan, 2011).

(4) SC risk management culture refers to a smooth process to create a resilience organisation (Christopher and Peck,2004). Cultivating organisation culture by embracing SC risk management is essential, as it would influence the operations, strategies and orientations accordingly (Christopher et al., 2011b; Mandal, 2017; Soni, Jain and Kumar, 2014). Kamalahmadi and Parast (2016) identified two key components of SC risk management culture: leadership and innovation. Leadership support the changes in organisation culture and risk profile of SCs (Chen et al., 2018). Furthermore, innovation emphasises the culture of learning and the adaptation to rapid changes for long-term survival (Santos-Vijande and Álvarez-González, 2007).

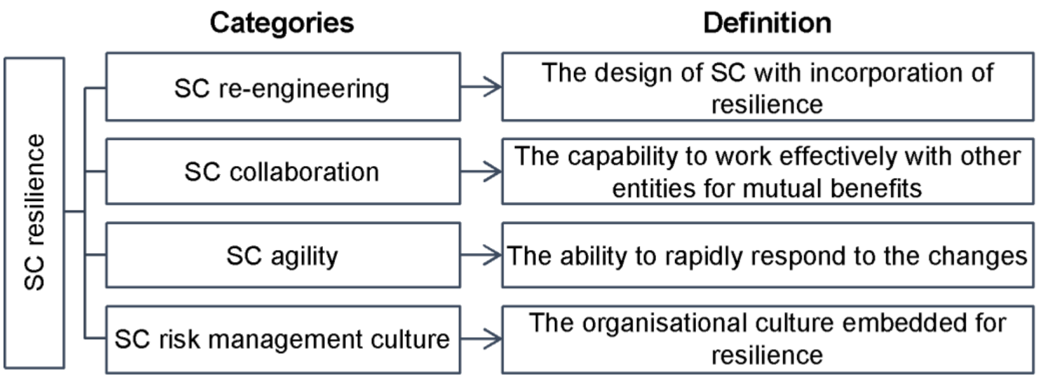

Figure 4 SC resilience categories

Source: updated from Christopher and Peck (2004)

SC resilience research investigate the possible outcomes of SC resilience (Liu et al., 2018; Belhadi et al., 2021) and its enablers (i.e., the variables that influence enterprises' engagement in SC resilience) (Iftikhar, Purvis and Giannoccaro, 2021; Pettit, Croxton and Fiksel, 2019). The former, which has been the main focus of SC resilience research (Adobor, 2020), presents questions as one can do well by being ready for uncertainties. Firms' engagement in SC resilience has been seen as an effective way to enhance performance outcomes such as firm/organisational performance (Liu et al., 2018; Gölgeci and Kuivalainen, 2020). The latter, which has been relatively less studied, concentrates on identifying factors that lead firms to develop SC resilience (Cotta and Salvador, 2020). Following Jüttner and Maklan (2011), this study views SC resilience as the capability built into the bones of SCs. This study is positioned in the research stream dealing with SC resilience antecedents for the construct measurement and emphasises the performance outcomes.

2.2.2 Sustainable SCM (SSCM)

2.2.2.1 Definition of SSCM

SSCM is a dynamic and interdisciplinary field that integrates knowledge and practices from various fields, including environmental science, social science, engineering, business, and management (Linton, Klassen and Jayaraman, 2007). SSCM involves considering multiple stakeholders in the SC, including suppliers, customers, employees, regulators, and communities

(Seuring et al., 2022). Stakeholder pressures are a crucial driver of SSCM, including demands for reduced environmental impacts, responsible labour practices, ethical sourcing, and transparency (Andersson et al., 2022). In response to these pressures, SSCM seeks to create a closed-loop system that emphasises reducing waste, emissions and using non-renewable resources (Bag and Rahman, 2021) while promoting responsible labour practices and ethical sourcing (Alghababsheh and Gallear, 2021). To do so, sustainability orientations (i.e., leadership for sustainability) should be integrated into SC practices, including sustainable planning (Fung, Choi and Liu, 2020), responsible sourcing (Mollenkopf, Peinkofer and Chu, 2022; Kim, Colicchia and Menachof, 2018), sustainable production, and sustainable distribution. The multifaceted nature of SSCM highlights the importance of collaboration and knowledge-sharing across SC partners to innovation and evolution (Carter and Washispack, 2018), and creating long-term value for stakeholders.

Sustainability issues are integrated into SCM from multiple aspects (Beske and Seuring, 2014). The incorporation of environmental sustainability concerns into SCM literature originated the term “Green SC management” (GSCM) which Srivastava (2007) defined as “integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life”. The literature on “green” or “environmental” SCs (Carter and Dresner, 2001, Zhu et al., 2008) argues that the impact of SCs on the natural environment must be taken into account when making management decisions. While the environmental implications of SCs are important, the concept of sustainability is more all-encompassing. It must include not only the economic and environmental dimensions but also the social impact of SC operations.

In the business context, sustainability was described as the ability to conduct business with the long-term objective of sustaining the well-being of the economy, environment, and society, which Elkington (1998) referred to as the "triple bottom lines” (TBL) to emphasise the integration of planet, people, and profit. The three intrinsically associated sustainability aspects (social, environmental, and economic) are frequently embedded in SSCM definitions (see **Table 3**) and have been embraced as critical performance criteria for sustainable SCs. (Ramezankhani, Torabi and Vahidi, 2018; Linton, Klassen and Jayaraman, 2007; Beske and Seuring, 2014a).

The two most frequently cited definitions were given by Seuring and Müller (2008, p. 1700) and Carter and Rogers (2008, p. 368), where TBL is highlighted as the integrated goal of SSCM. Following their definition of SSCM, this study defines SSCM as

> *"the strategic, transparent integration and achievement of an organisation's social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its SCs"*. Carter and Rogers (2008, p. 368)

By adopting this definition, this study emphasises that SSCM involves the integration of environmental, social, and economic practices into procurement, product design, finance, production, and distribution processes to create an evolving closed-loop system that emphasises risk management, collaboration, proactivity, and continuity in the strategic design of process, practices, structure, and network with the embeddedness of sustainability orientation.

Table 3 Example definitions of SSCM

Selected articles	**Definition of SC sustainability/SSCM**
Jorgensen and Knudsen (2006, p. 450)	"The means by which companies manage their social responsibilities across dislocated production processes spanning organizational and geographical boundaries."
Carter and Rogers (2008, p. 368)	"The strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its SCs."
Seuring and Müller (2008, p. 1700)	"The management of material, information and capital flows as well as cooperation among companies along the SC while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements."

Selected articles	Definition of SC sustainability/SSCM
Ciliberti et al. (2008, p. 1580)	“The management of SCs where all the three dimensions of sustainability, namely the economic, environmental, and social ones, are taken into account.”
Haake and Seuring (2009, p. 285)	“The set of SC management policies held, actions taken, and relationships formed in response to concerns related to the natural environment and social issues with regard to the design, acquisition, production, distribution, use, reuse, and disposal of the firm's goods and services.”
Hassini et al. (2012, p. 70)	“The management of SC operations, resources, information, and funds in order to maximize the SC profitability while at the same time minimizing the environmental impacts and maximizing the social well-being.”
Ahi and Searcy (2013, p. 339)	“The creation of coordinated SCs through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term.”
Ansari and Kant (2017, p. 2)	“Organisations willing to infuse sustainability practices in their SC need to satisfy various contradicting objectives such as profit maximisation while reducing environmental impacts and maximising social responsibility.”

Source: Author

Figure 5 illustrates the dynamic and multifaced nature of SSCM with a holistic view of core elements of SSCM. It involves the integration of sustainability orientation with environmental, social, and economic pillars into SC processes and practices (i.e., procurement, product design, finance, production, and distribution processes). SSCM requires a dedication to sustainability and must be incorporated into the company's strategic level and values. The embeddedness of sustainability orientation enables SC to reach the full potential of SSCM and create a dynamic and evolving closed-loop SC network-structured system, which allows the SC sustainable continuity with the benefits from risk management, performance management, stakeholder management, and partnership management (Beske and Seuring, 2014). Firms and SCs can benefit from engaging with stakeholders and aligning their sustainability goals with their stakeholders' expectations. This alignment can enhance the reputation of the entire SC, improve stakeholder relations, and create opportunities for innovation and collaboration, which empowers the SC proactively respond to sustainability pressures/incentives (Seuring et al., 2022).

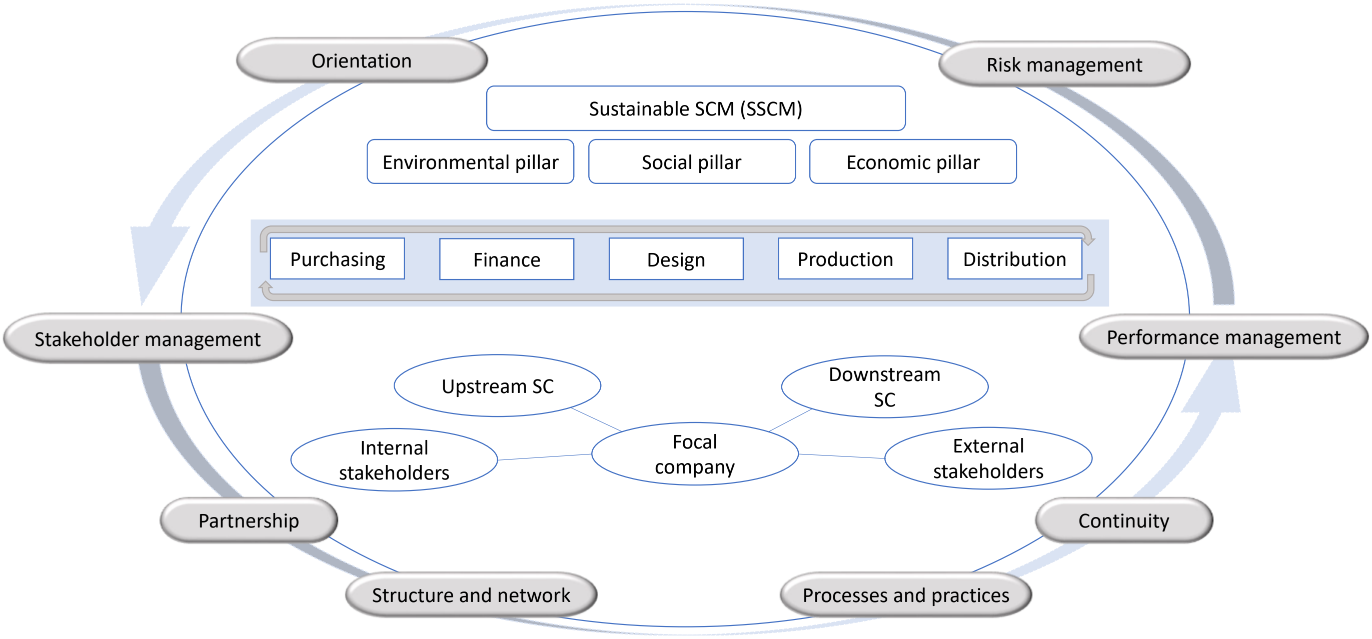

Figure 5 Core elements of SSCM

Source: updated from Beske and Seuring (2014) and Seuring et al. (2022).

2.2.2.2 Classification of SSCM

SSCM involves the integration of environmental, social, and economic practices into the procurement, manufacturing, and distribution of products and services to maximise positive benefits and minimise negative impacts on people, the earth, and profits (Pagell and Wu, 2009). SSCM seeks to create a closed-loop system that emphasises reducing waste, emissions, and the use of non-renewable resources while promoting responsible labour practices and ethical sourcing. One classical classification of SSCM is from the TBL perspective (Seuring and Müller, 2008), where SC sustainability with TBL principles can be categorised into (1) environmental/ecological sustainability, (2) social sustainability, and (3) economic sustainability (Pagell and Wu, 2009).

(1) Environmental sustainability, or ecological sustainability, refers to the efforts to promote sustainable practices and reduce the negative impact of SC activities on the natural environment, including air, water, and land. It focuses on the responsible use of natural resources to reduce greenhouse gas (GHG)

emissions, minimise waste generation, improve resource efficiency, and conserve natural resources (Hassan et al., 2018; Luzzini et al., 2015; Zhu and Sarkis, 2004; Zhu et al., 2008).

(2) Social sustainability refers to "concerns the impacts the organisation has on the social systems within which it operates" (GRI, 2013), where SC activities is ensured to contribute to the well-being of SC stakeholders – employees, customers, suppliers, and local communities. The typical issues involve implementing fair labour standards, human rights, ethical sourcing, and promoting diversity and inclusion. (Andersen and Skjoett-Larsen, 2009; Luzzini et al., 2015; Paulraj et al., 2014).

(3) Economic sustainability focuses on ensuring the long-term financial sustainability of the SC and is the most critical reason for SC management (Cao and Zhang, 2011; Kuei et al., 2015). It ensures that the SC is profitable and contributes to the overall sustainability of the business. Core practices include cost management for profitability, efficiency, and productivity. The measurement of economic sustainability includes growth in sales, profits, market shares, and return on investment (Flynn et al., 2010).

Table 4 summarises SSCM classification and core elements of each category's definition and focus area. In summary, SSCM considers the three pillars of sustainability - environmental, social, and economic - to promote responsible and sustainable SC practices that benefit the environment, society, and business. Environmental sustainability focuses on reducing the negative environmental impacts of SC activities, social sustainability focuses on contributing to the well-being of people impacted, and economic sustainability focuses on ensuring financial sustainability.

Table 4 SSCM categories and core elements

SSCM category	TBL principle	Definition	Key Focus Areas
Environmental Sustainability	Planet	- Refers to the responsible use of natural resources - Focuses on the impacts on the natural environment	- Reducing carbon emissions - Minimizing waste generation - Improving resource efficiency - Conserving natural resources

Social Sustainability	People	- Focuses on ensuring positive impacts of SC activities on stakeholders including employees, customers, suppliers, and local communities	- Fair labour standards - Human rights - Ethical sourcing - Diversity and inclusion
Economic Sustainability	Profit	- Focuses on ensuring the long-term financial sustainability	- Cost management - Revenue growth - Profitability

Source: author

Corporate social responsibility (CSR) and environmental, social, and governance (ESG) are terms used interchangeably with SSCM in SCM literature.. CSR focuses on a company's responsibility towards society and the environment, aiming to create shared value for all stakeholders. A modern understanding of CSR, not only focuses on socially responsible practices, integrates environmental protection, social responsibility, and corporate governance (Li, Lian and Xu, 2023). However, ESG, sometimes as a proxy of firms' CSR, stems from responsible investment and is the most widely accepted as the assessment of firms' sustainability impacts (Jo and Na, 2012). Other terms such as sustainable development, sustainability investment, and sustainability practices are also commonly used in the business and finance context (Andersson et al., 2022; Bassetti, Blasi and Sedita, 2021; Busch, Bauer and Orlitzky, 2016). This study uses the term SSCM, which is most suitable for reflecting sustainability issues in SCM context.

2.2.3 SC risks

SC risk is a common theme which is normally included in SC resilience literature, as it is hard to neglect the turbulent factors for balanced resilience. Risk management as one of the core elements of SSCM (see **Figure 5**), imposes the importance and necessity of understanding risks in SCM context. Vulnerabilities, uncertainties, and disruptions have been used interchangeably with risks in SCM literature (Peck, 2006; Gouda and Saranga, 2018) but with slight differences. SC vulnerability, as exposure to risks (Christopher and Peck, 2004a), can be defined as “fundamental factors that make an enterprise susceptible to disruptions” (Pettit, Fiksel and Croxton, 2010), “thus causing adverse supply chain consequences” (Jüttner, Peck and Christopher, 2003, p 200). As the exposure to SC risks increases, SCs are more vulnerable to unforeseen disruptions. Uncertainty is considered as the matching between risks and SC operations (e.g., demand, production and supply) (Tang and Nurmaya Musa, 2011), while disruption reflects one type of consequence of risks. To avoid the confusion of terminology, this study considers risks with resilience and SSCM elements (e.g., capabilities, practices, or performance) in SCM context.

There is no universal definition of SC risks, which causes a challenge to understanding the multidimensional nature of risks. From a quantitative perspective, SC risk is defined in terms of the probability of a risk event and the corresponding influence on the SC performance by Manuj and Mentzer (2008). Kumar et al. (2010) defined SC risks as the potential deviations from the initial overall objective that, consequently, trigger the decrease of value-added activities at different levels. However, these definitions of risk emphasise the possibility of the occurrence of a risk event and the possible adverse outcome but fail to integrate the qualitative attributes of SC risks, such as the sources and location of risks. Ho et al. (2015) reviewed SC risk management literature and provided comprehensive definition of SC risk with quantitative and qualitative characteristics. In line with Ho et al. (2015), this study defines SC risk as

> “*the likelihood and impact of unexpected macro and/or micro level events or conditions that adversely influence any part of a SC leading to operational, tactical, or strategic level failures or irregularities*” (Ho et al., 2015, p. 5035).

Studies have classified SC risks from different perspectives. Jüttner, Peck, and Christopher (2003, p. 200) defined SC risks from SC operations and flows, and classified SC risks into information, material, and production flow risks. A complementary division from Tang and Nurmaya (2011) further summarised SC risks as material, information, and financial flow risks. Tang (2006) divided SC risks into operational risks and disruption risks, where operational risks arise within SC system (e.g., uncertain demand and/or supply) and disruption risks refer to the risks arising from the external environment (e.g., economic crises, terrorist attacks). Focusing on focal firm level (rather than the entire SC), Kumar et al. (2010) classified SC risks from a relatively micro perspective, and broke down SC risks into inbound risk (supply risk), process risk (within the firm), and shipment risk. Liu et al. (2018) summarised 29 measures of SC risks and categorised them into five categories: demand-side risk, supply-side risk, regulatory, legal, and bureaucratic risk, infrastructure risk, and disaster risk. **Table 5** provided different classifications of SC risks.

Table 5 Classification of SC risks

Selected articles	Risk types
Jüttner, Peck, and Christopher (2003)	• Environmental risk • Network-related risk • Organisational risk
Christopher and Peck (2004)	• External to the network: environmental risk • External to the firm but internal to the supply chain network: demand and supply risks • Internal to the firm: process and control risks
Tang (2006a)	• Operational risks: uncertain customer demand, uncertain supply and uncertain cost • Disruption risks: earthquakes, floods, hurricanes, terrorist attacks, economics crises
Wu, Blackhurst, and Chidambaram (2006)	• Internal risks: internal controllable, internal partially controllable, internal uncontrollable • External risks: external controllable, external partially controllable, external uncontrollable
Trkman and McCormack (2009)	• Endogenous risks: market and technology turbulence • Exogenous risks: discrete events (e.g. terrorist attacks, contagious diseases, workers' strikes) and continuous risks (e.g. inflation rate, consumer price index changes)
Kumar, Tiwari, and Babiceanu (2010)	• Internal operational risks: demand, production and distribution, supply risks • External operational risks: terrorist attacks, natural disasters, exchange rate fluctuations

Olson and Wu (2010)	• Internal risks: available capacity, internal operation, information system risks • External risks: nature, political system, competitor, and market risks
Ravindran et al. (2010)	• Value-at-risk: labour strike, terrorist attack, natural disaster • Miss-the-target: late delivery, missing quality requirements
Tang and Nurmaya (2011)	• Material risk • Information risk • Financial flow risks
Lin and Zhou (2011)	• Risk in the external environment • Risk within the supply chain • Internal risk
Sreedevi and Saranga (2017)	• Supply risk • Manufacturing process risk • Delivery risk
Brusset and Teller (2017)	• Internal SC risks • External SC risks
Truong Quang and Hara (2018)	• Macro SC risks • Micro SC risks
Liu et al. (2018)	• Demand-side risk • Supply-side risk • Regulatory, legal, and bureaucratic risk • Infrastructure risk • Disaster risk

Source: updated from Ho et al. (2015)

Given **Table 5**, the risk characteristics could provide frameworks (see **Table 6**) to breakdown SC risks, such as the impacts of risks (Truong Quang and Hara, 2018) or called the risk-affected objectives (i.e., efficiency and effectiveness) (Heckmann, Comes and Nickel, 2015), location of risks (Liu et al., 2018), sources of risks (Lin and Zhou, 201; Brusset and Teller, 2017).

Table 6 Risk characteristics for classification

Risk characteristics for classification	Example articles
Impacts of risks	Heckmann, Comes and Nickel, (2015); Ravindran et al. (2010); Tang (2006); Truong Quang and Hara (2018); Wicaksana et al. (2022)
Sources of risks	Brusset and Teller (2017); Christopher and Peck (2004); Jüttner, Peck, and Christopher (2003); Kumar, Tiwari, and Babiceanu (2010); Olson and Wu (2010); Trkman and McCormack (2009); Wicaksana et al. (2022); Wu, Blackhurst, and Chidambaram (2006)
Location of risks	Liu et al., (2018); Tang and Nurmaya (2011); Sreedevi and Saranga (2017)

Source: Author.

The dominant classification of SC risks is based on the location of SC risks and the sources of SC risks (Wicaksana et al., 2022). The former emphasises the structure and flow of the location of SC risks in SC network (Brusset and Teller, 2017), where SC risks are categorised into SC stages (e.g., demand, manufacturing and supply risks) and different types of flow (e.g., information, transportation and financial risks). From this perspective, the most common SC risk types can be seen in **Table 7**, which summarises the most common SC risks and related risk factors. However, this classification may cause overlap among SC risk categories and is not an exclusive framework.

Table 7 Common SC risks and related risk factors

Type of SC Risk	Definition	Related Risk Factors
Demand risk	Risk of unexpected changes in demand for a product or service	Changes in consumer preferences, introduction of new competitors
Supply risk	Risk of disruptions or delays in the SC that prevent timely delivery of goods or services	Natural disasters, supplier bankruptcy, transportation disruptions, geopolitical risks
Operational risk	Risk of internal breakdowns or failures in the SC, such as equipment failures, production errors, and quality control issues	Equipment failure, human error, quality control issues
Financial risk	Risk of financial losses due to SC disruptions or inefficiencies	Currency fluctuations, payment defaults, supplier insolvency

Regulatory and compliance risk	Risk of legal or regulatory penalties due to non-compliance with laws or regulations	Changes in laws or regulations, lack of transparency, unethical business practices
Reputation and brand risk	Risk of damage to a company's reputation or brand due to SC issues	Labour abuses, environmental violations, product recalls
Cybersecurity and IT risk	Risk of cybersecurity breaches or IT system failures that can disrupt SC operations or compromise sensitive data	Cybersecurity breaches, IT system failures

Source: update from Manuj and Mentzer (2008) and Truong Quang and Hara (2018)

Moreover, the latter one, the source of SC risks, is also a popular characteristic to categorise SC risks, including risks in the firm, risks within the SC, and risks from the external environment of SC. This classification principle of SC risks is exclusive and provides a clear boundary between each category of SC risks. Considering SCM as the research context, the risks' origins are either within SC or/and from the outside environment (Trkman and McCormack, 2009). This study is essentially based on the belief that SC dangers may be divided into two types (Giannakis and Papadopoulos, 2016; Kochan and Nowicki, 2018; Ritchie and Brindley, 2000; Trkman and McCormack, 2009), depending on whether the risk source roots within or beyond the SC scope (see **Figure 6**) (Heckmann, Comes and Nickel, 2015):

(1) Endogenous risk refers to those risks caused by companies' activities within their SCs (e.g., technology risks, demand risks, supply risks) (Giannakis and Papadopoulos, 2016; Trkman and McCormack, 2009),

(2) Exogenous risk refers to those risks from the external environment that they operate, which can be discrete (e.g., terrorist attack, workers' strikes) or continuous (e.g., inflation rate) (Giannakis and Papadopoulos, 2016; Trkman and McCormack, 2009).

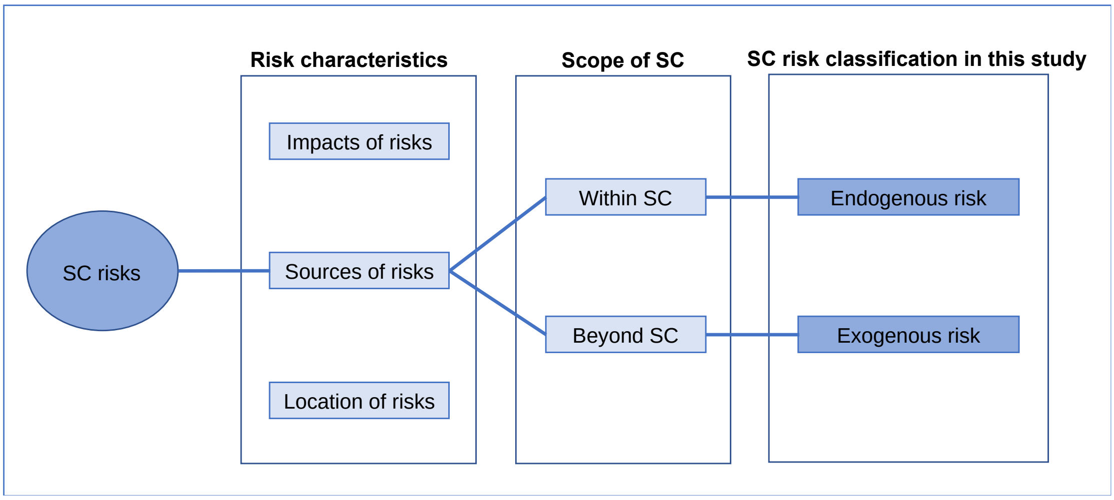

Figure 6 SC risk classification logic in this study

Source: Author.

2.2.4 The merge between SC resilience and SSCM

To remain viable in the current social-ecological-economic environment, SCs must start with operational efficiency but also consider their impacts on society and the ecological environment to meet the expectations of stakeholders (Ivanov, 2020). With a modern understanding of the environment of SC system (Wieland and Durach, 2021), SCs can be viewed as a dynamic system interacting with the social-ecological-economic environment. To enhance competitiveness amid turbulent changes, it is imperative to establish SC resilience that can manage higher levels of disturbance (e.g., natural disasters, strikes, economic crises) and reorganise resources and capabilities to meet the needs of all stakeholders (Shrivastava, 1995). SC resilience empowers SC system in the pursuit of sustainability.

An alternative viewpoint posits that conceptualising SSCM as a distinct capability, it may facilitate the cultivation of resilience within SC system (Silva, Pereira and Hendry, 2022). Beske and Seuring (2014) posit that the mitigation of unsustainable practices necessitates a flexible and responsive approach, wherein companies must formulate more precise strategies that account for the dynamic nature of the business environment. Building upon this assertion, SSCM has undergone a transformation, rendering it more amenable to adaptation over time (Amui et al., 2017). The transforming and adaptive nature of SSCM precedes SC resilience (Rajesh, 2019). Thus, selecting SSCM practices is essential to enhance SC resilience and enable organisations to prepare for potential crises, although it is essential to recognise that trade-offs and synergies may emerge (Fahimnia and Jabbarzadeh, 2016; Negri, Cagno and Colicchia, 2022).

These two primary concerns suggest that resilience and sustainability are not mutually exclusive but complementary objectives for business survival in social-ecological systems. The merge between SSCM and resilience can be witnessed from definitions and core elements.

Some definitions of SSCM include the resilience attributes in the face of evolving social-ecological environment and long-term development (Ahi and Searcy, 2013). Ahi and Searcy (2013) indicated that the characteristics of business sustainability include not only the TBL principles but also resilience focus to meet the expectation of stakeholders in a long-term perspective. According to Srivastava (2007) and Carter and Rogers (2008), a company should manage not just its short-term financial performance, but also the risk considerations associated with its products, environmental waste, and worker and public safety From the definition of Carter and Rogers (2008), managing economic, environmental, and social risks are critical for developing sustainable SCs, from which recent works reflect on risks sources and factors related to sustainability issues. SSCM literature adopts a view of risk management to identify and evaluate sustainability-related challenges for risk control and mitigation and better sustainable performance (da Silva et al., 2020; Giannakis and Papadopoulos, 2016; Rostamzadeh et al., 2018; Xu et al., 2019).

It is also unsurprising that the previous work unintentionally revealed the mutual elements of resilience and sustainability. Beske and Seuring (2014) sorted different practices based on value, structure, and processes in SSCM and grouped them into five categories: orientation, continuity, collaboration, risk management and proactivity. Their understanding of SSCM highlights the alignment between SSCM and SC resilience. SC resilience principles advocate

SC partnership, proactive SC network design, risk management culture, business continuity, and growth (Kamalahmadi and Parast, 2016). Apart from the similarity between the theoretical foundation of the two concepts, growing evidence shows that the core elements of SSCM and resilience contribute to maintain performance under unexpected circumstances (e.g., natural disasters) (Gabler et al., 2017). For instance, SC collaboration, commonly recognised as a SC resilience principle (Christopher and Peck, 2004b), contributes towards sustainability with the evidence from the literature (Chen et al., 2017). **Table 8** compares SC resilience and SSCM regarding classification, major practices, measurement metrics, engaged stakeholders, and management approach.

Table 8 The comparison between SC resilience and SSCM

Feature	SC Resilience	SSCM
Classification	Re-engineering, agility, collaboration, risk management culture	Environmental, social, and economic
Practices	Mitigate disruptions, risk management, redundancy, contingency planning	Resource conservation, waste reduction, social responsibility, stakeholder engagement
Focus	Reliability, risk reduction, recovery	Environmental impact, social impact, long-term viability
Measurement Metrics	Response times, agility, and flexibility	Carbon footprint, energy consumption, waste generation, social and environmental impact assessments
Stakeholders	Customers, suppliers, shareholders	Employees, communities, regulators, NGOs, and future generations
Management Approach	Reactive and adaptive	Proactive and preventive

Source: Author.

To clarify the potential relationships between SC resilience and SSCM, integrating resilience and sustainability knowledge outside SCM is helpful (Pettit, Croxton and Fiksel, 2019). The differentiated relationships between resilience and sustainability have been clarified in environmental management (Marchese et al., 2018), which have also been observed from the complex research status by recent SCM studies (Negri et al., 2021; Sauer, Silva and

Schleper, 2022; Silva, Pereira and Hendry, 2022) after experiencing ongoing systematic turbulences (e.g., the pandemic and political war). Three potential relationships between SC resilience and SSCM are witnessed to guide further analysis (see **Figure 7**):

(1) Separate objectives. SC resilience and SSCM are two separate objectives, which can complement or compete with each other (e.g., the trade-off between environmental performance and risk reduction) (Alikhani, Torabi and Altay, 2019; Azevedo, Carvalho and Cruz-Machado, 2016a; Cabral, Grilo and Cruz-Machado, 2012; Hooks et al., 2017; Mohammed, 2020).

(2) SC resilience for SSCM. SC resilience is a component of SSCM, where sustainability as the primary objective is the broader concept, and SC resilience-related elements are referred as the approach to meet the objective (Ahi and Searcy, 2013; López and Ruiz-Benítez, 2020; Ruiz-Benitez, Lopez and Real, 2019; Ruiz-Benitez, López and Real, 2017).

(3) SSCM for SC resilience. SSCM is a component of SC resilience, where SC resilience is the primary objective, and SSCM is regarded as the strategic approach to achieving SC resilience. In other words, implementing sustainability initiatives (e.g., circular economy, social responsibility activities) helps build a more resilient SC against unforeseen disruptions (Gallear, Ghobadian and He, 2015; Gouda and Saranga, 2018; Park, Sarkis and Wu, 2010).

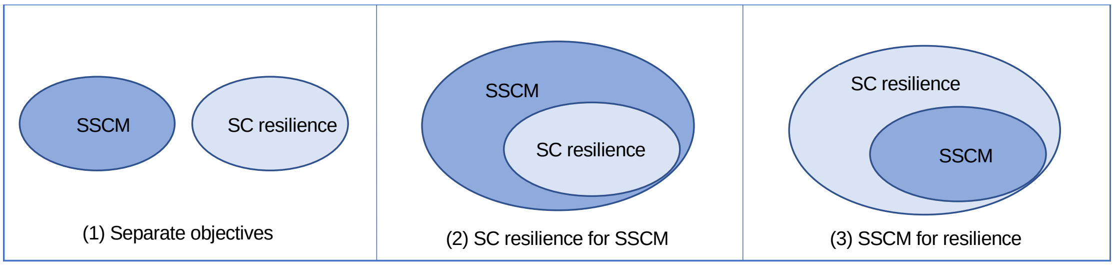

Figure 7 Classification of SSCM - resilience relationships

Source: Author.

2.2.5 Summary

Section 2.2 focuses on the theoretical background of this study, especially for the following systematic literature review. The definition and classification of SC resilience, SSCM, and SC risks are given first, followed by the observation of the merge between SSCM and resilience from the dynamic and adaptive nature, long-term orientation, and risk management principles. The observation of the similarities between SC resilience and SSCM inspires the conduction of a systematic literature review to answer RQ1: what are the common themes of SSCM-resilience research in the extant literature? The following sections demonstrate the procedures and results of the systematic literature review responding to RQ1.

2.3 Process of systematic literature review

To identify the co-concurrence of SC resilience SSCM in the current literature, a systematic literature review is conducted to identify the new terminologies and verify common themes in each cluster of SSCM-resilience relationships from studies in SCM. This review followed the protocol of a systematic literature defined by Tranfield et al. (2003), including three significant phases- planning, conducting, and reporting. By defining the appropriate search terms, databases, and inclusion and exclusion criteria, the relevant articles can be selected for analysis and synthesis, and the outcomes can be reported.

2.3.1 The planning phase

The planning phase consists of the selection of databases, determination of the searching strategy, and design of inclusion and exclusion criteria.

2.3.1.1 Selection of databases

The search was carried out through two primary databases: Scopus and Web of Science. The two well-known databases include independently a large group of peer-reviewed journals in business and management fields, where the comprehensive search can ensure the identification of relevant research. The review focuses on the relevant studies in the SCM stream (see **Figure 8**) consisting of the selection of databases, determination of the searching strategy, and design of inclusion and exclusion criteria.

2.3.1.2 Determination of the searching strategy

Following the previous literature review in management (Rashman, Withers and Hartley, 2009), the systematic search was conducted by using keywords combined with the Boolean logic: "(SC) AND resilience AND sustainability". Following (Bhamra et al., 2011; Pettit et al., 2011; Kamalahmadi and Parast, 2016) (Seuring and Müller, 2008; Chen et al., 2017). The searching keywords (see **Figure 8**) were developed, critiqued, and validated by two professors and two research assistants after the initial identification. The combinations of the keywords, as the searching strategy, were searched in "Title-Abstract-Keywords". The "resilien*" were searched in "All Field" to ensure the article is relatively related to "resilience" stream. Limits imposed on the search options included "English language", "peer-reviewed", and "journal articles" or "review". All the dissertations, books (section), conference proceedings, working papers and publications of government and private firms were excluded. This review adopted the year 2000 as the starting point when the first widespread study of SC resilience was developed following transportation disruptions from fuel protests in 2000.

2.3.1.3 Design of inclusion and exclusion criteria

The papers obtained in the search were analysed and evaluated by firstly selected by the ranking of the journals. Titles and abstracts were screened to exhaustively remove the articles which are not related to the topic (e.g., not in SCM field or only focus on either sustainability or resilience issues). Based on the academic judgement, the full text of the articles left was read carefully to filter out the irrelevant papers. Therefore, the final list of sample articles can be obtained. Detailed inclusion and exclusion criteria were built for filtering articles **(**see **Figure 8)**. Note that this review targets English journal articles and reviews with proper ranking (above 1 star or quartile 4) on the list of Scimago Journal and Country Rank (SJR) or Academic Journal Guide (AJG) ranking (updated 2018).

2.3.2 The conducting phrase

2.3.2.1 Selection process

The conducting phase of this literature review can be viewed from the selection process (**Figure 8)**. After applying the search terms in the two databases, 8140 papers (5088 in Scopus and 3052 in Web of Science) were found across all the disciplines. With the limitation to selected subjects (as mentioned in searching strategies), 2693 English peer-reviewed papers left, and 626 papers were left after checking the research quality and duplication. Furthermore, by applying the inclusion and exclusion criteria, 151 papers were checked with full-text reading. With further cross-checking of the references of the papers, four extra papers were retrieved from this process. The final sample includes 103 papers for content analysis.

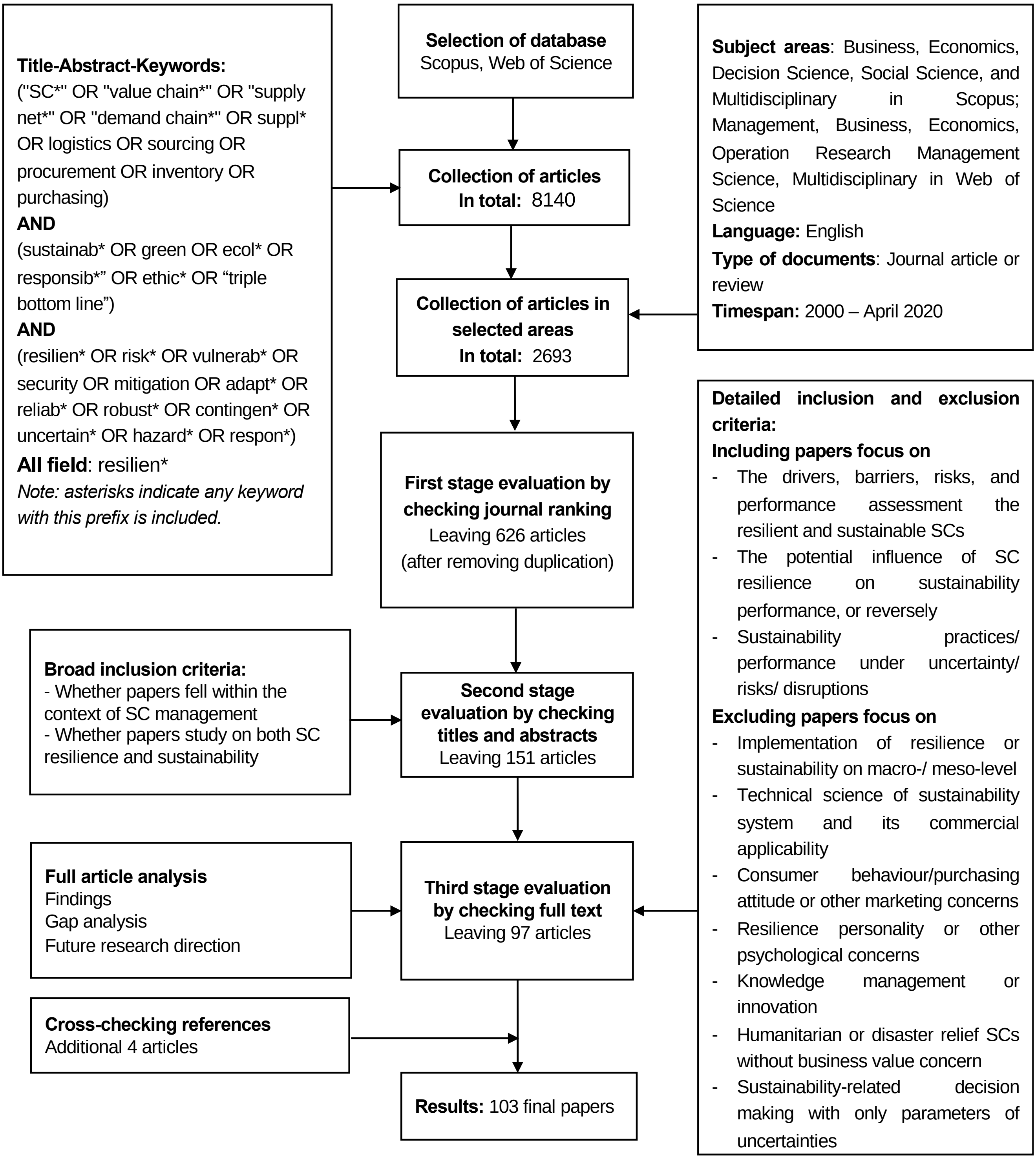

Figure 8 The planning phrase of the systematic literature review

Source: Author.

2.3.2.2 Coding categories

Inconsistent and overlapping terminologies were identified as the components of SC resilience and sustainability. For instance, in SC resilience literature, some authors call them elements (Christopher and Peck, 2004; Peck, 2005), while others refer to antecedents (Ponomarov and Holcomb, 2009), enhancers (Blackhurst et al., 2011), competencies (Wieland and Wallenburg, 2013), enablers (Pereira, Christopher and Da Silva, 2014), or formative capabilities (Pettit et al., 2010 and 2013; Jüttner and Maklan, 2011). This study uses the neutral term "elements" for the literature review to avoid inconsistency. In addition, to describe the combination of SC resilience and SSCM elements, "SC paradigm" is used in short for SSCM-resilience paradigm.

In the review, to capture the complete picture of the interaction between SC resilience and SSCM, categories were inclusively developed based on the definition and classification of SC resilience and SSCM and the research content of each paper. The evidence was then synthesised as the antecedents or driving forces of adopting SC resilience and/or SSCM, elements of SC resilience and/or SSCM, performance outcomes of the implementation of SC resilience and/or SSCM, and the moderating factors. Responding to ***RQ1***, the clusters of SSCM-resilience relationships are also coded for analysis.

To ensure the validity of this study, particularly the correctness and consistency of the categories and coding procedure, the coding file and articles were shared around the research team after coding the first 20 papers to formatively assess the reliability of the research questions. To be specific, the literature review aims not to identify all elements of SC resilience or SSCM, but to capture elements investigated in the concurrence of SC resilience and sustainability. After the coding, the coding table comprising the characteristics of the antecedents, SC resilience or SSCM elements, and performance outcomes were submitted to the study team for additional discussion and to assess the logic and coherence of each cluster. The study group's cross-checking and debate corroborated the findings, raised the coding procedure's validity, and improved the content analysis's dependability. (Potter and Levine-Donnerstein, 1999).

Based on the above process, this study selected the six coding categories (see **Table 9**): SC risk, SC structure, elements of SC resilience, elements of SC sustainability, clusters of SC resilience and SSCM relationships, and performance outcomes. The coding categories align with the content of SC resilience and SSCM studies. Apart from SC paradigms (i.e., SC resilience and SSCM), SC risks, SC structure, and performance outcomes are coded to reflect the interaction mechanism between SC systems and the embedded environment.

As one of the coding categories, SC risks, reflecting the environmental context, are viewed as the sources of dynamism or turbulence. “turbulence” is adopted to avoid confusion with “environmental sustainability”. All SC members interact directly or indirectly with each other for the mutual objective of the whole chain and the local interest and to counter all kinds of SC risks (Yawar and Seuring, 2017). The adoption of different SC paradigms (i.e., SC resilience and SSCM), responding to internal and external challenges, and referring to the mechanism within SC systems, enable the co-evolution and adaptation of SC systems and yield final outcomes.

As an essential characteristic, the structure of a SC system affects the interactions among SC entities and the behaviours of SC systems. The importance of SC network structure for resilience was examined by Hearnshaw and Wilson (2013) and Carter et al. (2015) by applying complex network theory. Forward SC, reverse SC, and close-loop SC (CLSC) are the most common SC structures discussed in SSCM literature. Forward SC is the collection of a series of activities from upstream to downstream of SC to fulfil the customer demand by transforming raw material into final products; however, reverse SC emphasises the process from customers to the origin of SCs (from downstream to upstream) for creating the value of end-of-life products, where repairing, reconditioning, remanufacturing, recycling, and disposing of are the typical processes. CLSC contains both forward and reverse SC to create and capture the value of products from their entire life cycle. Some studies also investigate SC issues at the firm level or node levels in the SC network. Four categories of SC structure characteristics are coded (see **Table 9**): (1) node (focal firm); (2) forward SC; (3) reverse SC; (4) CLSC.

The potential performance outcomes can be captured as the consequences of SC paradigms, therefore, can be divided into two categories: sustainability performance and resilience performance. Sustainability performance refers to the static performance outcome in TBL dimensions (Schaltegger and Burritt, 2014): economic performance (e.g., cost and profit), environmental performance (e.g., energy consumption and waste generation), and social performance (e.g., labour practice) (Varsei et al., 2014). While resilience performance can be captured through dynamic changes (before and after disruptions) (Bag et al., 2019), such as time and variation (Spiegler et al., 2012), disruption occurrence (Zsidisin and Wagner, 2010), risk reduction (Cruz, 2009; Cruz and Wakolbinger, 2008; Gouda and Saranga, 2018), disruption cost (Mari et al., 2016, 2014).

Table 9 **Coding category of systematic literature review**

Coding category	Definition	Sources
SC risks		
Endogenous risk	Endogenous risk refers to those risks caused by companies' activities within their SCs (e.g., technology risks, demand risks, supply risks)	Giannakis and Papadopoulos (2016); Trkman and McCormack (2009)
Exogenous risk	Exogenous risk refers to those risks from external environment in that they operate, which can be discrete (e.g., terrorist attacks, workers' strikes) or continuous (e.g., inflation rate).	Giannakis and Papadopoulos (2016); Trkman and McCormack (2009)
SC structure		
Node	Node refers to "any business operation conducted at a single, definable location" in SC network system.	Bucklin (1970); Carter, Rogers and Choi, (2015); Hearnshaw and Wilson, (2013)
Forward SC	"Forward SC is composed of a series of activities in the process of converting raw materials to finished goods".	Kocabasoglu et al. (2007)
Reverse SC	Reverse SC refers to "the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal".	Meade et al. (2007); Kocabasoglu et al. (2007); Bai and Sarkis (2013); Govindan et al. (2015); Agrawal et al. (2015); Mangla et al. (2016);
CLSC	CLSC refers to "the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time".	Guide and Van Wassenhove (2009); Souza (2013); Govindan et al. (2015); Huang et al., (2013);Choi, Li and Xu, (2013)
SC resilience		
SC re-engineering	SC re-engineering refers to the design of SC with incorporation of resilience, including SC understanding, supply base strategy, and strategic assessment and trade-off between redundancy and efficiency	Christopher and Peck (2004); Kamalahmadi and Parast (2016)

Coding category	Definition	Sources
Collaboration	Collaboration is the capability to work effectively with other entities for mutual benefits, including sharing crucial information and valuable knowledge and establishing joint efforts.	Christopher and Peck (2004); Sheffi and Rice (2005); Ponomarov and Holcomb (2009); Pettit et al. (2010); Juttner and Maklan (2011); Kamalahmadi and Parast (2016)
Agility	Agility is "the ability to respond rapidly to unpredictable changes".	Christopher and Peck, (2004); Pettit et al. (2010); Juttner and Maklan (2011); Kamalahmadi and Parast (2016)
SC risk management culture	SC risk management culture refers to a soft process to create a resilience organization.	Christopher and Peck, (2004); Christopher et al. (2011); Mandal (2017); Soni et al. (2014); Kamalahmadi and Parast (2016)
SSCM		
Environmental sustainability	Environmental/ecological sustainability, refers to the achievement of less impact on the environment, including reduction in greenhouse gas emissions and hazardous material, efficient usage of resources, and green innovation.	Hassan et al. (2018); Luzzini et al. (2015); Zhu and Sarkis, (2004); Zhu et al. (2008); Centobelli et al. (2017)
Social sustainability	Social sustainability refers to "concerns the impacts the organization has on the social systems within which it operates" (GRI, 2013), which typically includes issues related to labour force, health and safety, local community and regulations	GRI, (2013); Andersen and Skjoett-Larsen (2009); Luzzini et al. (2015); Paulraj et al. (2014)
Economic sustainability	Economic sustainability refers to profitability, efficiency, and productivity in general and is the most critical reason for SC management. The measurement of economic sustainability includes growth in sales, profits, market shares, and return on investment.	Cao and Zhang, (2011); Kuei et al. (2015); Flynn et al. (2010)
The clusters of SC resilience and SSCM relationships		
Separate objectives	SC resilience and SSCM are two separate objectives, which can complement or compete.	Alikhani et al. (2019); Azevedo et al. (2016b); Cabral et al. (2012); Hooks et al. (2017); Mohammed (2020)

Coding category	Definition	Sources
SC resilience for SSCM	SC sustainability as the primary objectives is the larger concept and SC resilience elements (e.g., risk management culture) are referred as the means to meet the objective.	Ahi and Searcy (2013); López and Ruiz-Benítez (2020); Ruiz-Benitez et al. (2019); Ruiz-Benitez et al. (2017)
SSCM for SC resilience	SC resilience is the primary objective and SC sustainability is regarded as the strategic approach to achieve SC resilience.	Gallear et al. (2015); Gouda and Saranga (2018); Park et al. (2010)
Performance outcomes		
Economic performance	Economic performance is "an increase in the net shareholder value", which can be measured by costs, new market opportunities, product price increase, profit margin, sales, market share, etc.	Crum et al. (2011); Chen et al. (2017); Rao and Holt (2005)
Environmental performance	Environmental performance refers to the impacts of SC operations on ecological environment, which is normally measured by emission generation, water usage, wastes, energy consumption, use of hazardous and toxic substances, etc.	Vachon and Klassen (2008); Acquaye et al. (2018); Varsei et al. (2014); Ahi and Searcy (2015); Cucchiella et al. (2012); Crum et al. (2011); Chen et al. (2017)
Social performance	Social performance refers to the outcome of SC operations on human safety, welfare, and community development, which is normally captured by the improvement in health and safety of workers, fair treatment of employees, and better working conditions.	Varsei et al. (2014); Ahi and Searcy (2015); Distelhorst et al. (2017); Crum et al. (2011); Chen et al. (2017); Yawar and Seuring, 2017
Resilience performance	Resilience performance refers to the transient response (e.g., recovery time, risk reduction, disruption cost) towards SC disruptions.	Munoz and Dunbar (2015); Rajesh, (2016); Spiegler et al. (2012); Zsidisin and Wagner (2010); Cruz (2009); Cruz and Wakolbinger (2008); Gouda and Saranga (2018); Mari et al. (2014); Mari et al. (2016)

Source: Author.

2.3.3 Plan of the reporting phase

The following diagram (i.e., **Figure 9**) shows the plan of the reporting phase for this literature review, including the descriptive analysis in **section 2.4**, the thematic analysis in **section 2.5**, and the research gap in **section 2.6**.

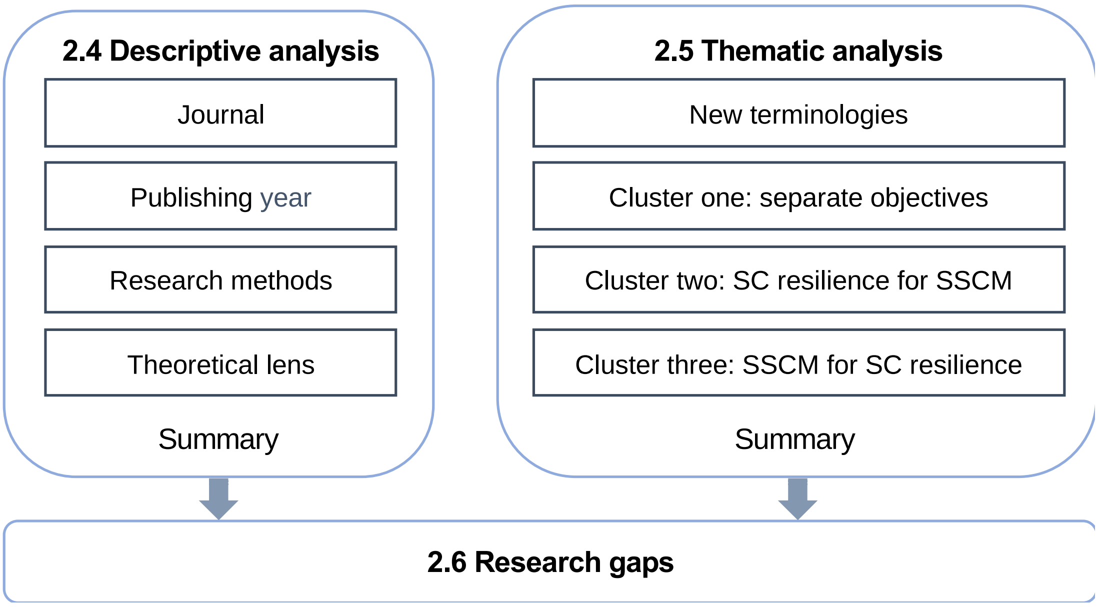

Figure 9 The reporting phase of the systematic literature review

2.4 Descriptive analysis

2.4.1 Distribution of journals

The 103 articles selected were distributed in 30 interdisciplinary journals, as shown in **Table 10.** The top contributing journals in SC resilience and sustainability are *Journal of Cleaner Production* (25 papers), *International Journal of Production Economics* (11 papers), *International Journal of Production Research* (11 papers), and *Sustainability* (Switzerland) (8 papers). These journals in the list cover general management, sustainability, and operation/production, which reveal the complex and multifaced characteristics of resilience and sustainability studies in SCM fields. The integration of resilience and sustainability into SCM studies echoes the call from recent studies (Christopher and Holweg, 2011; Pettit, Croxton and Fiksel, 2019). Apart from the scopes of the journals, the variability of samples can be reflected through the journal rankings. Specifically, the samples were mainly published in two- /three-star journals but rarely in top journals, which confirms the research interest of this study is emerging in SCM field and could be a valuable topic for future research.

Table 10 Overview of journal distribution

Journal	No.
Journal of Cleaner Production	25
International Journal of Production Economics	11
International Journal of Production Research	11
Sustainability (Switzerland)	8
Annals of Operations Research	4
Benchmarking	4
Computers and Industrial Engineering	4
Resources, Conservation and Recycling	4
IEEE Transactions on Engineering Management	3
Transportation Research Part E: Logistics and Transportation Review	3
Global Journal of Flexible Systems Management	2
International Journal of Operations and Production Management	2
International Journal of Physical Distribution and Logistics Management	2
Journal of Purchasing and Supply Management	2
Journal of Supply Chain Management	2
Supply Chain Management	2
British Journal of Management	1
Business Strategy and the Environment	1
Decision Support Systems	1
International Journal of Management Science and Engineering Management	1
International Journal of SC Management	1
Journal of Business and Industrial Marketing	1
Journal of Business Logistics	1
Journal of Modelling in Management	1
Journal of Strategic Marketing	1
Management Decision	1
MIT Sloan Management Review	1
SC Management: An International Journal	1
Systems Research and Behavioral Science	1
Transportation Research Part D: Transport and Environment	1
Total number of reviewed papers	**103**

2.4.2 Distribution of publishing year

Figure 10 shows the distribution of reviewed papers from 2000 to April 2020. In this review, the year 2000 was set as the starting point of the literature search, as the emergency of SC resilience has been captured in the literature since then (Tang and Musa, 2010; Ghadge et al., 2012; Kamalahmadi and Parast, 2016). Based on **Figure 10**, the first paper on the joint consideration of SC resilience and sustainability was published in 2008, several years later than the SC resilience concept. Over eighty percent of the sampled studies (84 papers) were published in the last five years (2016-2020). Besides, more than 20 papers were yearly published in recent years (22 papers in 2018, 23 papers in 2019, and 16 papers in the first half year of 2020), which reveals the emerging interest in the interaction of resilience and sustainability in OSCM research, together with the variable journal distribution.

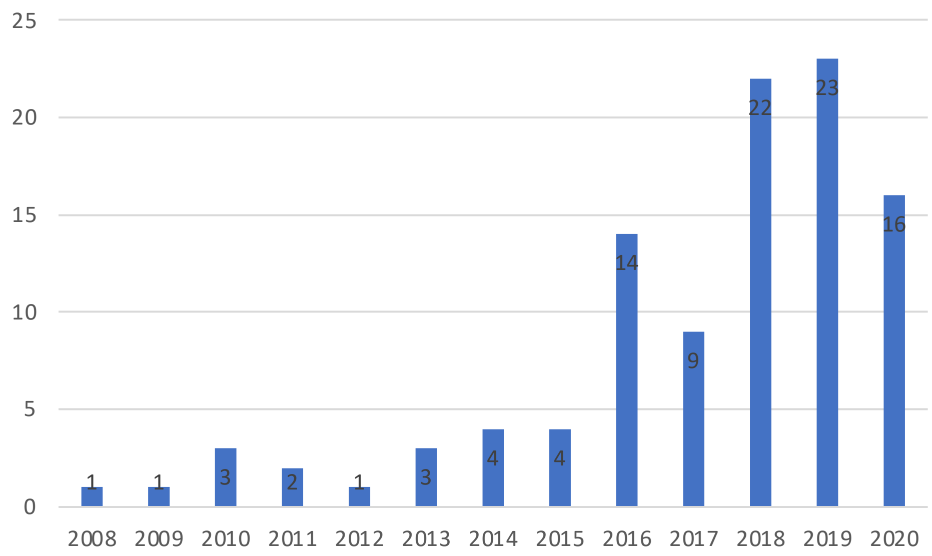

Figure 10 Distribution of the reviewed papers

Source: Author

2.4.3 Distribution of methodologies

Table 11 shows the methodologies adopted in the sampled studies. Dominant research methods in OM/SCM, include review, case study, theoretical/conceptual, survey, and mathematical models (Seuring and Müller, 2008). Generally, empirical studies can be divided into case studies, surveys, and secondary data analyses (Ali et al., 2014). The survey method refers to the interactive study with practitioners through questionnaires/interviews, while those studies adopt secondary data analysis to analyse archival data to verify or develop the theory. In line with Seuring and Müller (2008) and Ali et al. (2014), this study categorises the sample articles into six methodology categories: (1) theoretical and conceptual papers; (2) literature reviews; (3) case studies; (4) mathematical modelling; (5) surveys; and (6) secondary data. Over fifty percent of samples (55 out of 103) used mathematical models, which is followed by a survey (13 papers) and conceptual/theoretical method (12 papers). Review and secondary data are the two least adopted methods in the reviewed sample. Only the primary approach was identified and classified for studies that adopted multiple research methods. The distribution of the methodologies of sample articles implies a precious research gap that empirical studies, especially with case studies and secondary data analysis methods, could contribute mainly to the current knowledge of the interplay between SC resilience and SSCM.

Table 11 Overview of research methods used in reviewed articles

Methods	No.
Mathematical modelling	55
Survey	19
Conceptual/Theoretical	12
Case study	7
Review	5
Secondary data	5
Total number of papers included in this review	**103**

Source: Author

2.4.4 Distribution of theoretical lens

The theoretical lens adopted in sampled studies are presented in **Table 12**. Most studies (72 papers) do not specify the theory. Institutional theory (IT), the resource-based view (RBW), stakeholder theory, the dynamic capability view (DCV), and system theories are the popular theoretical lens in sample articles, which were adopted three times or above. Considering system-related theories (system theory and complex adaptive system theory) are the most frequently used (in 5 articles), systematic thinking is vital in the interplay between SC resilience and SSCM, which implies that system-related theory could be a suitable theoretical lens in the current study. Comparing system theory, complex adaptive systems (CAS) theory emphasises the adaptive and co-evolving process within SC system and between SC system and external resources (Tukamuhabwa et al., 2015). CAS perspective can address the interconnected nature of SC operations and self-organisation, adaptability and co-evolution in SCM, which could bring more systematic and dynamic analysis rigorousness in SC resilience and sustainability research (Nair and Reed-Tsochas, 2019).

Table 12 Overview of theoretical lens used in empirical studies.

Theoretical lens	No.
Institutional theory	4
Resource-based view (RBV)	4
Stakeholder theory	3
Dynamic capability view (DCV)	3
System theory	3
Contingency theory	2
Social exchange theory	2
Complex Adaptive Systems (CAS) Theory	2
Natural resource-based view (NRBV)	2
Collaboration theory	1
Expected utility theory	1
Mindfulness theory	1
Risk management theory	1
Signalling theory	1
Transaction cost theory (TCT)	1
Complementarity theory	1
Path dependence theory	1
Ecological modernization theory (EMT)	1
Knowledge-based view (KBV)	1
Socio-Technical view	1
Governance value analysis (GVA)	1
Socio-Ecological view	1
Not specified	72
Total number of papers included in this review	**103**

Source: Author

2.4.5 Summary

Based on the analysis of descriptive statistics, it is witnessed that most of the related literature was developed during the past five years. The research on the interrelationship between SC resilience and sustainability is still an emerging topic, which has not been widely published in top-ranking journals yet. The complexity of the research subjects makes the articles rooted in interdisciplinary fields and published in different types of journals (e.g., general management, sustainability). For those empirical papers (31 papers), the survey is a more popular approach than case studies and secondary data analysis. Around, seventy percent of articles, adopted non-empirical methodologies, where mathematical modelling is dominant compared to theoretical and conceptual methods. Therefore, it is unsurprising that most papers in the sample did not specify the adopted theories since over half of them are analytical and optimisation modelling papers. To have a look into the theoretical lens, the prevalent theories in general OSCM articles, including resource-based view, natural resource-based view, knowledge-based view, dynamic capability view, and contingency theory) provide the theoretical support for some sampled articles. However, system-related theories (e.g., system theory, CAS), which is more frequently seen in SC resilience literature), show the popularity in this research field on the co-occurrence of SC resilience and sustainability.

2.5 Thematic analysis

The above section summarises a descriptive analysis of sample articles, and this section concludes scenarios of the co-concurrence of SC resilience and SSCM. With the observation of the relationships between SC resilience and SSCM, the following part of this section clarifies three clusters of SC resilience and SSCM relationships: (1) SC resilience and sustainability as separate objectives; (2) SC resilience as a component of sustainability; (3) SC sustainability as a component of resilience. To demonstrate the main findings of common themes under each cluster, this section summarises the findings from the four common themes based on coding categories: SC risks, SC structure, SC paradigms, and performance outcomes.

2.5.1 Cluster one: separate objectives

In this cluster, SC resilience and SSCM are treated as distinct objectives within SCM, as observed in 32 of the 103 sampled articles (see **Table 13** at the end of

Section 2.5.1). Adaptable SCs should be designed with a focus on combined performance outcomes rather than solely targeting a single aspect (e.g., cost reduction) for competitiveness in the marketplace (Melnyk et al., 2010; Edgeman and Wu, 2016). Multiple performance outcomes, such as operational efficiency, profitability, sustainability, resilience, and robustness, are not mutually exclusive; instead, they often form hybrids (Melnyk et al., 2010; Edgeman and Wu, 2016). Consequently, integrating sustainability and resilience objectives may prove complementary, as the practices and resources needed for achieving sustainability can also support resilient SCs.

2.5.1.1 SC risks

Within this cluster, 50% of the articles (16 papers) do not explicitly identify risk factors related to sustainable and resilient objectives. Although the driving forces behind risk factors are briefly discussed with examples of risk sources, a comprehensive analysis is lacking. Man-made and natural disasters are cited as representative risk sources in five articles (Mari, Lee and Memon, 2016; Arabsheybani, Paydar and Safaei, 2018; Mohammed et al., 2020; Hosseini and Barker, 2016; Mishra and Singh, 2020).

Internal risks, such as demand and supply risks and disruption risks, are given more attention (15 papers) compared to external risks (9 papers), including natural disasters, political variability, and technology malfunction. Among these, demand and supply risks are the most commonly addressed (in 7 modelling papers). Although half of the papers mention either the sources or types of risks, the majority fail to specify risk identification or assess the potential impacts of risks. This lack of comprehensive risk analysis calls into question the depth of understanding in the existing literature.

The only exception is Olson and Swenseth (2014), who summarised four lists of risk factors based on previous literature and ranked them by importance. Two of these lists categorised risk elements into groups according to their primary influences (e.g., cost, quality, service, flexibility, confidence, management capability). This approach provides a more structured and critical examination of risk factors, which could inform future research in the field.

2.5.1.2 SC structure

Within this cluster, six out of 33 articles examined node firms exclusively, three papers explored CLSC structures, and the remaining 24 studies focused on forward SC structures. Notably, four of these papers cantered on the upstream SC, which is closer to the inbound supply side. For instance, Mohammed et al.(2020) investigated an Original Equipment Manufacturer (OEM) of laboratory instrumentation and its process of selecting and evaluating current suppliers based on sustainability and resilience criteria. Vahidi, Torabi and Ramezankhani (2018) considered a SC comprising one manufacturer and main and backup suppliers, categorising suppliers according to the resilience performance of the supply network, i.e., fully-disrupted suppliers and partially-disrupted suppliers. Two other papers examined multi-tier supply networks, such as Malek, Ebrahimnejad and Tavakkoli-Moghaddam (2017), who evaluated the supply network, including the second and third tiers of suppliers concerning environmental and resilience factors. Ramezankhani, Torabi and Vahidi (2018) focused on two three-echelon automobile SCs, each of which includes one tier-two supplier, one tier-one supplier, and one manufacturer.

The three studies investigating CLSC structures focus on SC networks design issues, such as facility location and production distribution (Mishra and Singh, 2020; Mari, Lee and Memon, 2016) and location-allocation-routing optimisation (Ebrahimi, 2018). Six papers examining forward SCs did not detail the structural components of the SCs. In contrast, seven papers primarily concentrated on the three-echelon SC structure, which typically comprises one supplier, one manufacturer, and one customer/distributor/retailer (Cruz and Wakolbinger, 2008; Cabral, Grilo and Cruz-Machado, 2012; Ramirez-Peña et al., 2020; Azevedo et al., 2013; Wong, 2020; Arabsheybani, Paydar and Safaei, 2018; Azevedo, Carvalho and Cruz-Machado, 2016b). A limited number of papers delved into SC networks with more than three echelons, such as Hooks et al. (2017) and Pavlov et al. (2019), or examined dyadic relations exclusively, as seen in Jabbarzadeh, Fahimnia and Rastegar (2019) and Zahiri, Zhuang and Mohammadi (2017).

This analysis highlights the need for a more comprehensive understanding of SC structures and their relationship with sustainability and resilience performance. Future research could explore a broader range of SC structures, focusing on multi-echelon networks and the impact of various structural components on sustainability and resilience practices.

2.5.1.3 Internal mechanism: SC paradigms

The integration of sustainability and resilience elements into SC strategies has been crucial for enhancing sustainable competitiveness. Research in this area has focused on identifying the most effective SC paradigms that align with both resilience and sustainability objectives. The identified SC paradigms are used as criteria to monitor performance outcomes in supplier selection scenarios. In the ever-changing business environment, a combination of SC strategies and Lean, Agile, Resilient, and Green (LARG) paradigms can contribute to a distinct competitive advantage (Duarte and Machado 2011). Although earlier studies rarely combined sustainability thinking with resilience capabilities in selecting SC practices, subsequent research has sought to determine the optimal composition of SC paradigms, such as LARG paradigms (Duarte and Machado, 2011).

Pioneering studies on the LARG paradigm by Cabral et al. (2012), Azevedo et al. (2013), and Azevedo et al. (2016) identified critical green and resilience practices using traditional performance indicators (cost, service level, time, quality of product). These indicators can be used to evaluate the implementation level of individual SC practices (e.g., green and resilient practices) and assess the behaviour of single or multiple SC echelons. The selection of SC paradigms incorporating sustainability and resilience elements is designed to minimise adverse environmental impacts and enhance the SC's ability to manage disturbances.

However, it has been observed that resilience and environmental sustainability paradigms have differing priorities regarding performance outcomes. For example, Azevedo et al. (2013) and Azevedo et al. (2016) found that the Portuguese automotive industry prioritises resilience over greenness for superior performance. Building upon this foundation, more recent studies have examined the interconnections among different SC paradigms and their influence on performance outcomes. Sen, Datta and Mahapatra (2018) expanded upon Azevedo et al. (2013)'s work using Interpretive Structural Modeling (ISM) to uncover the interrelationships among various green and resilience SC paradigms. In this study, some resilience and greenness practices (e.g., lead time reduction and reverse logistics) would profoundly affect other practices (e.g., strategic stock). (Divsalar, Ahmadi and Nemati, 2022) revealed that lean and agile paradigms could build bridges between resilient and green practices. Different categories of performance criteria for SC paradigms were proposed in the literature, including classical performance indicators (e.g., cost, service level, time, quality of product) (Cabral et al., 2012; Azevedo et al., 2016), the Green SCOR model (e.g., reliability, responsiveness, agility, SC cost, asset management) (Divsalar et al., 2020), and sustainability-related indicators (e.g., economic, environmental, social, functional, energy efficiency) (Ramirez-Peña et al., 2020). Ramirez-Peña et al. (2020) examined all three aspects of the sustainability performance of LARG paradigms in the ship-building industry. All three aspects of the sustainability performance of LARG paradigms in the shipbuilding industry. Their study suggested that lean and green paradigms could meet all performance outcome aspects (economic, environmental, social, functional, and energy efficiency); agile paradigms are unrelated to energy and environmental performance; and resilient SC paradigms only contribute to social sustainability and functional performance.

2.5.1.4 Performance outcomes

Assessing the performance outcomes of composite SC paradigms can be complex and challenging, as both sustainability-related and resilience-related performance outcomes must be considered under a unified framework (Melnyk et al., 2010; Edgeman and Wu, 2016). Although risk mitigation may appear to conflict with short-term SC profitability, it is entirely compatible with long-term profitability (Olson and Swenseth, 2014). In other words, the two separate objectives of SC sustainability and resilience would potentially reach harmony in the long term (Hooks et al., 2017; Olson and Swenseth, 2014).

Both sustainability and resilience criteria have been adopted to measure performance outcomes such as dynamic manufacturing performance (Ramezankhani, Torabi and Vahidi, 2018), particularly in Multi-Criteria Decision-Making (MCDM) models for supplier evaluation. Green/ecological sustainability criteria were more commonly used for supplier evaluation and selection than social sustainability criteria. Hosseini and Barker (2016), Mohammed (2020), Mohammed et al. (2020), Malek et al. (2017), and Costa et al. (2018) all emphasise the criteria related to resilience and environmental sustainability but neglect social impacts of suppliers behaviours. Three articles on supplier selection encompassed all three TBL aspects of sustainability performance along with resilience performance (Kaur et al., 2016; Amindoust, 2018; Alikhani et al., 2019). However, the classification of sustainability criteria and the identification of resilience criteria have not been standardized in the literature. For example, economic sustainability criteria are treated as separate general criteria in Amindoust (2018) but are integrated into sustainability criteria in Alikhani, Torabi and Altay (2019). Resilience-related criteria are not selected based on different strategic measures (Hosseini and Barker, 2016; Malek et al., 2017) or operational measures (Ramezankhani et al., 2018), which may cover risk factors and/or risk attitudes of decision-makers (Alikhani et al., 2019; Costa et al., 2018). Resilience-related criteria selection varies based on different strategic measures (Hosseini and Barker, 2016; Malek et al., 2017) or operational measures (Ramezankhani et al., 2018), which may encompass risk factors and/or decision-makers risk attitudes (Alikhani et al., 2019; Costa et al., 2018). Resilience capabilities are frequently used to evaluate resilience from a strategic viewpoint, but the selection of resilience capabilities can differ (Hosseini and Barker, 2016; Mohammed, 2020; Mohammed et al., 2020; Malek et al., 2017). For instance, Hosseini and Barker (2016) classified resilience criteria into three subgroups: absorptive capacity, adaptive capacity, and restorative capacity, while Malek et al. (2017) selected collaboration, risk, agility, redundancy, and flexibility as resilience criteria based on the framework of Christopher and Peck (2004).

Besides performance evaluation criteria, sustainability and resilience, can also be integrated as optimisation models for supplier portfolio selection or SC network design. Two papers demonstrated that resilience and sustainability performance could be modelled within constraints (Mishra and Singh, 2020) or scenario settings (Fahimnia, Jabbarzadeh and Sarkis, 2018). The majority of studies incorporated sustainability and resilience performance into objective functions. Three articles employed optimisation models for solving supplier selection-related problems (Vahidi et al., 2018; Arabsheybani et al., 2018; Wong, 2020), while eleven papers investigated SC network design problems with both sustainability and resilience objectives. For sustainability objective, ecological sustainability in optimisation models is mostly reflected as carbon emissions, embodied carbon footprints, and environmental costs (Mari et al., 2014; Mari et al., 2016; Zahiri et al., 2017; Ebrahimi, 2018; Jabbarzadeh et al., 2019). However, social sustainability has not yet been incorporated into objective functions, and no research has measured TBL sustainability in the proposed optimisation models. Furthermore, resilience objectives are typically represented by minimising the cost or penalty of reduced resilience or maximising the value of resilience attributes. Resilience measures adopted in optimisation models include disruption cost (Mari et al., 2014; Mari et al., 2016), risk or risk reduction (Wong, 2020; Arabsheybani, Paydar and Safaei, 2018), network resilience (Vahidi et al., 2018; Jabbarzadeh et al., 2019; Pavlov et al., 2019), SC de-resiliency (Zahiri et al., 2017), and resilience pillars (e.g., redundancy, agility, leanness, and flexibility) (Mohammed et al., 2019).

In conclusion, the integration of sustainability and resilience elements in SC paradigms has become increasingly crucial for achieving sustainable competitiveness. Although research has made progress in understanding and assessing the performance outcomes of these paradigms, further work is needed to standardise the classification of sustainability criteria, the identification of resilience criteria, and the integration of social sustainability aspects. Moreover, future research should explore the harmonisation of SC sustainability and resilience objectives over the long term and develop comprehensive frameworks for systematically assessing the performance outcomes of composite SC paradigms. There is also a call for empirical evidence to verify the analytical and modelling results.

Table 13 Coding summary of articles in Cluster 1: separate objectives

	Year	SC structure	SC risks	Resilience paradigm	SSCM paradigm	General performance	Resilience performance	SSCM performance
Melnyk, SA; Davis, EW; Spekman, RE; Sandor, J	2010	F	*	*	*	X	X	X
Duarte S., Machado V.C.	2011	F	*	R, A, C	Eco	*	*	*
Cabral I., Grilo A., Cruz-Machado V.	2012	F	*	R, A	Eco	X	X	*
Azevedo S.G., Govindan K., Carvalho H., Cruz-Machado V.	2013	F	*	R, A, C, SCRMC	Eco	*	*	*

	Year	SC structure	SC risks	Resilience paradigm	SSCM paradigm	General performance	Resilience performance	SSCM performance
Mari S.I., Lee Y.H., Memon M.S.	2014	F	Exo	*	*	Y	Y	Y-Eco
Olson D.L., Swenseth S.R.	2014	F	End & Exo	*	*	X	X	X-Eco
Azevedo, et al.	2016	F	*	R, A, C	Eco	*	*	*
Cruz J.M., Wakolbinger T.	2008	F	*	*	Soc	Y	Y	Y-Eco
Edgeman R., Wu Z.	2016	F	*	*	*	X	X	X-TBL
Hosseini S., Barker K.	2016	N	End & Exo	*	*	X	X	X-Eco
Kaur H., Singh S.P., Glardon R.	2016	N	*	*	*	X	X	X-TBL
Mari S.I., Lee Y.H., Memon M.S	2016	CLSC	End & Exo	*	*	Y	Y	Y-Eco
Hooks T., Macken-Walsh Á., McCarthy O., Power C.	2017	F	End	C, SCRMC	Soc	*	*	*
Malek A., Ebrahimnejad S., Tavakkoli-Moghaddam R.	2017	F	*	*	*	X	X	X-TBL
Zahiri B., Zhuang J., Mohammadi M.	2017	F	End & Exo	*	*	Y	Y	Y-Eco-Soc
Amindoust, A	2018	N	*	*	*	X	X	X-TBL
Arabsheybani A., Paydar M.M., Safaei A.S.	2018	F	End & Exo	R	Eco	X	X	X-TBL
Costa A.S., Govindan K., Figueira J.R.	2018	N	*	*	*	X	X	X-Eco
Ebrahimi S.B.	2018	CLSC	*	*	*	Y	Y	Y-Eco
Fahimnia B., Jabbarzadeh A., Sarkis J.	2018	F	End	R	Eco	Y	*	*
Ramezankhani, MJ; Torabi, SA; Vahidi, F	2018	F	*	*	*	X	X	X-TBL
Sen D.K., Datta S., Mahapatra S.S.	2018	F	*	R, A, C	Eco	*	*	*
Vahidi F., Torabi S.A., Ramezankhani M.J.	2018	F	End	*	*	X	X	X-TBL

	Year	SC structure	SC risks	Resilience paradigm	SSCM paradigm	General performance	Resilience performance	SSCM performance
Alikhani R., Torabi S.A., Altay N.	2019	N	End & Exo	*	*	X	X	X-TBL
Jabbarzadeh A., Fahimnia B., Rastegar S.	2019	F	End	*	*	Y	Y	Y-Eco
Mohammed, et al.	2019	F	End	*	*	Y	Y	Y-Eco
Pavlov, et al.	2019	F	End	R	*	Y	Y	Y-Eco
Divsalar M., Ahmadi M., Nemati Y.	2020	F	*	R, A, C	Eco	X	X	X-Eco
Mishra and Singh	2020	CLSC	End	R	*	Y	*	Y-Eco
Mohammed	2020	N	End & Exo	*	*	X	X	X-Eco
Mohammed A., Harris I., Soroka A., Naim M., Ramjaun T., Yazdani M.	2020	F	*	*	*	X	X	X-Eco
Ramirez-Peña M., Sánchez Sotano A.J., Pérez-Fernandez V., Abad F.J., Batista M.	2020	F	*	Resilience, A	Eco	X	*	X-TBL
Wong J.-T.	2020	F	End & Exo	*	*	Y	Y	Y-Eco

Note: "N": node; "F": forward SC; "CLSC": closed-loop SC; "Exo": exogenous risks; "End": endogenous risks; "R": SC re-engineering; "A": SC agility; "C": SC collaboration; "SCRMC": SC risk management culture; "Eco": environmental sustainability; "Sco": social sustainability; "TBL": TBL sustainability. "X": indicators for performance; "Y": objectives for performance. "*": not mentioned.

2.5.2 Cluster two: SC resilience for SSCM

A total of 53 out of 103 papers (refer to **Table 14**) were classified under this cluster, in which SC resilience is considered a vital component of SC sustainability. Resilience thinking, encompassing business continuity against uncertainty and recovery planning in the face of SC disruptions, is conceptualised as a crucial characteristic in two definitions of SC sustainability (Ahi and Searcy, 2013; Closs et al., 2011). Furthermore, two conceptual papers emphasise the significance of resilience strategies in developing sustainable SC networks (Do Souza et al., 2019) and sustainable collaborative governance (Wang and Ran, 2018), respectively. As evident in the above-mentioned SC sustainability-related concepts and frameworks, SC resilience is a foundational role in SSCM. Like Cluster one, SC risks, internal mechanisms, SC structure, and performance outcomes are three subclusters explored in this category.

2.5.2.1 SC risks

In this cluster, most articles (38 out of 53 papers) investigate risk factors in SCM, with 31 papers mentioning risks stemming from SC internal operations and 26 papers detecting risks from external SC activities. Uncertainties or perturbations create a turbulent environment for SC operations, necessitating the implementation of proactive and resilient strategies to maintain SC performance without significant alterations. On this basis, SC risk factors serve as antecedents for adaptive decision-making and action mechanisms across entire SC networks.

These papers indicate that supply risk (16 papers), demand risk (15 papers), and process and operation risk (12 papers) are the top three internal risk factors, all of which originate from internal SC processes or stages. First, supply risk refers to the fluctuation in supply costs/quality/capacity, inflexibility of supply source, supplier failure and supply commitment (Xu et al., 2019; Lo and Shiah, 2016). An uncertain supply of materials or services could potentially deviate order fulfilment and affect SC operations' sustainability (e.g., unethical suppliers). Second, demand risks, such as inadequate forecasting techniques, shifting customer preferences, and short product lifecycles, are also recognised as impacting sustainable and resilient strategies (e.g., sustainable procurement and production, SC network design) (Jabbarzadeh, Fahimnia and Rastegar, 2019; Kaur et al., 2020a). Third, process and operation risks primarily pertain to setbacks in internal processes, such as machine failure, labour strikes, product quality issues, and transportation risks (Majumdar et al., 2020), potentially impacting economic, environmental, and social performance (Rostamzadeh et al., 2018).

Exogenous events (e.g., man-made or natural disasters) can also induce unexpected disruptions within SCs, as highlighted in the literature, such as political instability (Rostamzadeh et al., 2018), adverse macroeconomic conditions (Apaydin et al., 2020; Majumdar et al., 2020), and man-made or natural disasters (He et al., 2020; Mithun Ali et al., 2019; Simangunsong, Hendry and Stevenson, 2016). Several studies use the term “environmental dynamism” or “environmental uncertainties” to describe changes in technology, customer preferences, and fluctuations in product demand or supply of materials (Zhang et al., 2019; Lo and Shiah, 2016; Simangunsong, Hendry and Stevenson, 2016), which is viewed as endogenous risks, within SCs but outside of firm boundary. To avoid ambiguity, this study uses "external risks" and "exogenous risks" interchangeably for those risks generated from external events outside SCs, which is opposite to "internal risks" or "endogenous risks" for those originated within SCs or focal firms.

Risk factors were pointed out but not analysed in detail for risk identification and risk assessment. Several works offer the classification of SC risks in a different context and evaluated the priority and interconnections among risk factors (Christopher et al., 2011a; Simangunsong, Hendry and Stevenson, 2016; Mithun Ali et al., 2019; He et al., 2020; Giannakis and Papadopoulos, 2016; Rostamzadeh et al., 2018; Wu et al., 2017). For instance, Christopher et al. (2011) classified global sourcing risks into four groups (i.e., supply risk, process and control risk, demand risk, and environmental and sustainability risk). Simangunsong, Hendry and Stevenson (2016) identified 14 types of risk factors and aligned each risk factor with two categories of SC resilience strategies (i.e., coping with uncertainty strategies and reducing uncertainty strategies) to enhance overall SC performance. Mithun Ali et al. (2019) examined 19 operational risks in food SCs and identified the five most significant risks (i.e., a lack of skilled personnel, poor leadership, failure in the IT system, capacity, and poor customer relationship), assessing their cause-and-effect relationships and developing risk mitigation strategies. Similarly, He et al. (2020) investigated the interconnections among 11 risk factors and identified the top four risk factors with high influence-importance (market share reduction, natural disaster, demand and supply uncertainty, environmental pollution), aligning with previous findings. Wu et al. (2017) assessed seven risks (i.e., capacity, cost, operations, products, controllability, organisation) and suggested that capacity and operation risks strongly influence decisive attributes.

These risk identifications and classifications above-mentioned are mainly based on a classical perspective to cluster SC risks by their sources or location of process or flow. However, an emerging perspective contends that SC risks must be linked to sustainability considerations to support SCs in diagnosing risks and reducing complexities (Wu et al., 2017; Giannakis and Papadopoulos, 2016). Evaluating the attributes of SC risks facilitates the specification of SC risks' influence on SC sustainability (Wu et al., 2017). This research views SC risks based on their potential consequences or impacts, including ecological risks (Mithun Ali et al., 2019; Levner and Ptuskin, 2018; Rostamzadeh et al., 2018) and ethical/social risks (Chen and Baddam, 2015), which would result in adverse environmental and social sustainability. In some studies use the term “sustainability risks” or sustainability-related SC risks as the general designation for risk factors in SSCM (Giannakis and Papadopoulos, 2016; Song, Ming and Liu, 2017).

Different from the representative perspective, this classification of SC risks from the TBL view of sustainability involves economic/financial risks (e.g., inflexibility of supply source, poor quality of products, information sharing risks, bribery, boycotts), environmental risks (e.g., natural disasters, inefficient use of resources, environmental pollution, hazardous waste generation) and social risks (e.g., unhealthy/dangerous working environment, violation of human rights, failure to fulfil the social commitment, violation of business ethics, pandemic, social instability) (Giannakis and Papadopoulos, 2016; Rostamzadeh et al., 2018; Levner and Ptuskin, 2018). This approach distinguishes itself from the classic classification by exposing the links between risk factors and their consequences on sustainability concerns. Only one paper in the examined sample provided a two-way view of risk classification, wherein SC risks are classified into six groups from two dimensions: the scope of risks (i.e., within/outside SCs) and the sustainability impacts (i.e., the TBL dimensions) (Giannakis and Papadopoulos, 2016). This risk classification implies the links between SC risks, risk mitigation, and SC sustainability.

Although identifying sustainability risks represents the combination of resilience thinking and sustainability theory by proactively analysing potential risks for SSCM, fewer papers analyse or examine the potential consequences of risk factors on SC sustainability. In the sample, four exceptions can be found. Sanchez-Rodrigues, Potter and Naim (2010) investigated logistics uncertainties in four industries and identified the top four transportation risks (delays, variable demand/poor information, delivery constraints and insufficient SC integration) would adversely impact operation efficiency as well as environmental and economic sustainability, for which the impacts were analysed for customised mitigation strategies. Lo and Shiah (2016) that demand uncertainty motivates the adoption of green practices to build a sustainability advantage over competitors, and focal firms under high competition uncertainty are less motivated to go green. Simangunsong, Hendry and Stevenson (2016) highlighted that unethical practices (i.e., creating artificial shortages and competitor abuse of power) lead to more excellent supply and demand uncertainty, which in turn results in poor SC performance. They recommended effective resilience strategies (i.e., joint purchasing, multiple suppliers) to reduce ethical uncertainty at its source and lessen the negative impacts of unethical practices. Syed et al. (2019) demonstrated the impacts of three types of sustainable risks (sustainable supply risks, sustainable demand risks, firm's internal risks) on a firm's financial performance by influencing three different practices of integration (as one of the resilience strategies).

SC risk factors were discussed more frequently in this cluster than in cluster one. Some studies only provided examples of SC risks or uncertainties, while others offered extended risk identification and evaluation analyses from both the classical and TBL perspectives. Fewer papers attempted to examine the interactions between SC risks and sustainability, shedding light on the importance of resilience thinking for maintaining sustainability objectives. It is not always possible to address all types of risk factors simultaneously, but further research should delve into the impacts of key risk factors on the hybrid implementation of SC resilience and SSCM, how multiple risk factors (e.g., internal non-sustainability risks and external sustainability risks) can be addressed by the same strategy (e.g., SC resilience capabilities or SSCM practices), and highlight the effective mitigation approaches for various risks.

2.5.2.2 SC structure

Among 53 papers in this cluster, eighteen studies examined focal firms operating in a single SC stage, and two articles investigated CLSC structure (Sudarto, Takahashi and Morikawa, 2017b; Yavari and Zaker, 2019). Notably, over 60% of the articles (32 papers) concentrated on forward SCs. Among these, 12 papers did not specify the SC structure being studied, 11 papers were dedicated to upstream SCs, and three papers explored downstream SCs. Downstream designs typically encompass warehouses, hubs, distributors, or retailers (Mani et al., 2017; Darom et al., 2018; Maiyar and Thakkar, 2019).

Six of the 11 papers that examined upstream SCs involved multi-tier suppliers, signifying the presence of intricate supply networks. The remaining papers that investigated forward SC structures primarily delved into multiple SC stages, from suppliers to markets. For instance, Jabbarzadeh, Haughton and Pourmehdi (2019) formulated a four-stage SC network of multiple suppliers, manufacturing plants, distribution centres, and markets. Although a significant portion of sample articles has focused on the focal firm level, there appears to be a lack of attention given to the informal and formal connections between different SC stages.

Supply network or SC network has garnered considerable interest in recent years (López and Ruiz-Benítez, 2020; Ruiz-Benitez, Lopez and Real, 2019; Chen and Baddam, 2015; Ruiz-Benitez, Lopez and Real, 2017; Levner and Ptuskin, 2018; Awasthi, Govindan and Gold, 2018). A noteworthy observation is that the differences in SC structures were captured across the studies in this cluster, potentially offering valuable insights into the diverse effects of SC resilience strategies on sustainability performance.

2.5.2.3 Internal mechanism: SC paradigms

Within this cluster, 34 out of 53 papers examine specific resilience solutions for sustainability performance. This study classifies SC resilience into four groups: SC re-engineering, SC collaboration, agility, and risk management culture (SCRMC). According to this classification, nine studies cover all four streams of SC resilience paradigms, with four investigating the impacts of SC paradigms (i.e., LARG/ecosilient paradigms) on sustainability performance (López and Ruiz-Benítez, 2020; Ruiz-Benitez, Lopez and Real, 2019, 2017; Govindan et al., 2014). Another eight articles discuss SC collaboration (e.g., customer cooperation, SC integration, and IT information sharing). SC collaboration may encourage the adoption of green practices (Green et al., 2019) by mitigating environmental risks (e.g., conceptual voids regarding environmental standards) (Rauer and Kaufmann, 2015). Sustainability risks can serve as antecedents of SC collaboration, motivating other SC resilience strategies (e.g., supplier relationship management on flexibility) (Bag et al., 2018).

Moreover, eleven papers propose SC re-engineering strategies (e.g., redundancy strategy, flexible supply bases/capacities/transportation, inventory surplus/safety stock, backup suppliers, postponement strategy). Different re-engineering strategies can have varying impacts on sustainability dimensions; for example, flexible sourcing affects economic sustainability, while flexible transportation influences economic and environmental sustainability (Govindan et al., 2014). SC re-engineering could contribute to ecological (Rauer and Kaufmann, 2015) and TBL sustainability(Jabbarzadeh, Sabouhi and Fahimnia, 2018; Bag, Gupta and Telukdarie, 2018; Govindan et al., 2014)). SCRMC strategies investigated in 13 other studies include innovation (Bag et al., 2018), SC risk management (Govindan et al., 2014), SC risk analysis and mitigation practices (Mithun Ali et al., 2019). Eight out of 13 papers emphasised identifying, analysing, and mitigating sustainability-related risks(Christopher et al., 2011; Busse et al., 2016; Mani et al., 2017; Syed et al., 2019), which are considered the antecedents of resilience practices. Only three additional papers discuss SC agility strategies, such as agile production (Green et al., 2019), SC responsiveness, and just-in-time (Govindan et al., 2014). SC agility strategies can be influenced by other resilience elements (e.g., SC collaboration) (Green et al., 2019) and subsequently impact operational and social performance (Green et al., 2019; Govindan et al., 2014).

The literature reviewed implies that different groups of SC resilience paradigms may result in different sustainability performance outcomes. Furthermore, resilience strategies within the same category could yield various sustainability performances (e.g., flexible transportation and sourcing). These resilience strategies may interconnect, aligning with previous SC resilience reviews (Kamalahmadi and Parast, 2016). Certain practices, such as sustainable customer cooperation (Zhang et al., 2019), sustainable integration (Syed et al., 2019), green supplier development (Bag, Gupta and Telukdarie, 2018), ecological resilience (Korhonen and Snäkin, 2015), and sustainable risk management (Rajesh, 2019), integrate attributes of both resilience and sustainability. One article treats SC resilience as a composite construct (Thaiprayoon, Mitprasat and Jermsittiparsert, 2019), where SC resilience significantly impacts sustainability performance through the mediating effect of sustainability consciousness.

2.5.2.4 Performance outcomes

In this theme, sustainability as the primary objective is a higher-level performance outcome than SC resilience. SC resilience criteria sometimes serve as one aspect of green SCM criteria (Tseng et al., 2018). For instance, the related standards on risk compliance/resilience capability is one of seven sub-criteria for selecting sustainable partners.(Kumar and Dixit, 2019).

On this basis, SC resilience strategies, considered as the antecedents of SC sustainability, would impact TBL sustainability performance, among which environmental sustainability received the most attention. Economic and environmental sustainability performance were simultaneously investigated as performance consequences (Gokarn and Kuthambalayan, 2019), indicators(Fraccascia et al., 2020) and optimisation objectives (Jabbarzadeh, Haughton and Pourmehdi, 2019; Yavari and Zaker, 2019; Ahmed and Sarkar, 2018). In this cluster of sample articles, economic sustainability also refers to corporate financial performance (Apaydin et al., 2020; Syed et al., 2019; Zhang et al., 2019), buyer economic performance (Busse, 2016), and operational performance (Green et al., 2019), can be usually measured as return on asset, growth of sales, return on investment, development in return on investment and profit margin on sales (Zhang et al., 2019; Syed et al., 2019). Environmental sustainability implies the environmental effects or benefits of SC practices (Ndubisi and Al-Shuridah, 2019), which can be measured by the reduction of emissions and waste (Ruiz-Benitez, Lopez and Real, 2017; Mithun Ali et al., 2019), compliance with environmental standards(Rauer and Kaufmann, 2015), an increase of recycled materials, decrease of energy consumption, and decrease of environmental accidents(Ruiz-Benitez, Lopez and Real, 2017). Social sustainability can include various aspects of human welfare and rights (Cimprich et al., 2017; Jabbarzadeh, Sabouhi and Fahimnia, 2018) and business practices (Jabbarzadeh, Sabouhi and Fahimnia, 2018; Govindan et al., 2014). Eleven out of 53 articles have developed social sustainability as one dimension of performance measurement (Eltantawy, 2016a; Sudarto, Takahashi and Morikawa, 2017a), such as social cost (Dubey, Chavas and Veeramani, 2018; Maiyar and Thakkar, 2019; Darom et al., 2018), health and safety (He et al., 2020), legislation compliance (He et al., 2020), and local culture compliance (He et al., 2020). Notably, ten out of eleven investigate all three dimensions of TBL sustainability, and only one paper focuses explicitly on social performance (Cimprich et al., 2017).

Two papers provided novel viewpoints on sustainability performance (Eltantawy, 2016a, 2016b). One is Eltantawy (2016b), who proposes supply management resilience as a multidimensional dynamic capability defined by two opposing components of stability (engineering and ecological resilience) that assist the buyer's company in adapting and transforming ambidextrously in unstable settings. This work views sustainability performance as balanced exploitative (efficiency and persistence) and explorative (constancy through change towards the future) goals. Building on Eltantawy (2016b), Eltantawy (2016a) integrates the classic TBL sustainability perspective with resilience thinking. It classifies supply management sustainability into cross-sectional sustainability (i.e., adapt to maintain performance) and temporal sustainability (i.e., transform to maintain longevity). This proposed framework for sustainability measurement systematically integrates the attributes of SC resilience and stakeholders' expectations (i.e., TBL sustainability) and calls for its application in empirical analysis.

In conclusion, the sample articles on SC resilience and SSCM performance reveal that different SC resilience strategies can have varying impacts on sustainability performance outcomes. Additionally, resilience paradigms within the same category (e.g., flexible transportation and flexible sourcing) may interconnect and yield diverse sustainability performance results. The tendency shows the merge of SC resilience and SSCM paradigms, which is seen from the integration of resilience and sustainability attributes in the new classification of SSCM dimensions (Eltantawy, 2016a; 2016b) and some practices, including sustainable customer cooperation (Zhang et al., 2019), sustainable integration (Syed et al., 2019), green supplier development (Bag, Gupta, and Telukdarie, 2018), ecological resilience Eltantawy (2016b), and sustainable risk management (Rajesh, 2019). The comprehensive understanding of these interconnections among SC paradigms and integrated practices contributes to developing more effective strategies for achieving sustainability performance. Further research should empirically validate the proposed frameworks and identify additional interconnections between SC resilience strategies and sustainability performance outcomes.

Table 14 Coding summary of articles in Cluster 2: SC resilience for SSCM

Authors	Year	SC structure	SC risks	Resilience paradigm	SSCM paradigm	General performance	Resilience performance	SSCM performance
Bag S., Gupta S., Telukdarie A.	2018	N	Exo	R	Eco	*	*	X-TBL
Sanchez-Rodrigues V., Potter A., Naim M.M.	2010	N	End & Exo (Sus)	R, A, C, SCRMC	*	*	*	*
Ahmed W., Sarkar B.	2018	F	End	*	*	Y	*	Y-Eco
Majumdar A., Sinha S.K., Shaw M., Mathiyazhagan K.	2020	F	End & Exo	*	*	*	*	*
Apaydin M., Jiang G.F., Demirbag M., Jamali D.	2020	N	Exo	*	Eco, Soc	X	*	*
López C., Ruiz-Benítez R.	2020	F	*	R	Eco	*	*	X-TBL
Lo S.M., Shiah Y.-A.	2016	N	*	*	Eco	*	*	*
Solomon A., Ketikidis P., Koh S.C.L.	2019	N	*	R, A, C, SCRMC	Eco	*	*	X-TBL
Lopez, C; Ruiz-Benitez, R	2020	F	*	R, A, C, SCRMC	Eco	X	*	X-Eco
Ruiz-Benitez R., López C., Real J.C.	2019	F	*	R, A, C, SCRMC	*	X	*	X-Eco
Simangunsong E., Hendry L.C., Stevenson M.	2016	F	End & Exo	R, A, C, SCRMC	*	*	*	*
Giannakis and Papadopoulos	2016	F	End & Exo (Sus)	*	*	*	*	*
Xu M., Cui Y., Hu M., Xu X., Zhang Z., Liang S., Qu S.	2019	F	End & Exo (Sus)	*	*	*	*	*
Ndubisi N.O., Al-Shuridah O.	2019	N	Exo	SCRMC	*	*	*	X-Eco
Song W., Ming X., Liu H.-C.	2017	N	End & Exo (Sus)	SCRMC	*	*	*	*
Rajesh R.	2019	F	End & Exo (Sus)	SCRMC	Eco, Soc	*	*	*
Chen and Baddam	2015	F	End (Sus)	SCRMC	*	*	*	*

Maiyar L.M., Thakkar J.J.	2019	F	End	R	*	*	*	Y-Eco-Soc
Ruiz-Benitez R., López C., Real J.C.	2017	F	End	R, A, C, SCRMC	Eco	*	*	X-Eco
Eltantawy	2016	N	*	SCRMC	**Eco**	*	*	X-Sustainability
Green K.W., Inman R.A., Sower V.E., Zelbst P.J.	2019	F	*	A, C	Eco	X	*	*
Christopher M., Mena C., Khan O., Yurt O.	2011	F	End & Exo	R, A, C, SCRMC	*	*	*	*
Darom N.A., Hishamuddin H., Ramli R., Mat Nopiah Z.	2018	F	End	R	*	*	Y	Y-Eco
Levner E., Ptuskin A.	2018	F	End & Exo	*	*	*	*	*
Rostamzadeh R., Ghorabaee M.K., Govindan K., Esmaeili A., Nobar H.B.K.	2018	N	End & Exo	*	*	*	*	*
Thaiprayoon K., Mitprasat M., Jermsittiparsert K.	2019	N	*	Resilience	Sustainability	*	*	X-Sustainability
Wu K.-J., Liao C.-J., Tseng M.-L., Lim M.K., Hu J., Tan K.	2017	N	End & Exo	R, C, SCRMC	Eco, Soc	*	*	*****
He L., Wu Z., Xiang W., Goh M., Xu Z., Song W., Ming X., Wu X.	2020	N	End & Exo (Sus)	R, A, C, SCRMC	Eco, Soc	*	*	X-TBL
Mani V., Delgado C., Hazen B.T., Patel P.	2017	F	End & Exo (Sus)	A, C	*****	*	*	*****
Mangla S.K., Kumar P., Barua M.K.	2014	F	*	R, A, C, SCRMC	Soc	*	*	*****
Rauer J., Kaufmann L.	2015	F	End & Exo	R, C, SCRMC	Eco	*	*	X-Eco
Syed M.W., Li J.Z., Junaid M., Ye X., Ziaullah M.	2019	F	End (Sus)	C	*****	X	*	*****
da Silva E.M., Ramos M.O.,	2020	F	*(Sus)	SCRMC	*****	*	*	*****

Alexander A., Jabbour C.J.C.								
Busse C., Kach A.P., Bode C.	2016	F	*	*	*	*	*	*
Govindan K., Azevedo S.G., Carvalho H., Cruz-Machado V.	2014	F	End & Exo	R, C, SCRMC	Eco	*	*	*
Eltantawy R.A.	2016	N	Exo	SCRMC	**Eco**	*	*	X-Sustainability
Busse C.	2016	*	End (Sus)	C, SCRMC	*	X	*	*
Gokarn S., Kuthambalayan T.S.	2019	F	End & Exo	*	*	X	X	X-Eco
Zhang M., Tse Y.K., Dai J., Chan H.K.	2019	N	Exo	C	Eco	X	*	*
Li, et al.	2015	N	Exo	*	Eco, Soc	X	*	*
Cimprich A., Young S.B., Helbig C., Gemechu E.D., Thorenz A., Tuma A., Sonnemann G.	2017	F	End	*	Eco	*	*	X-Soc
Sudarto S., Takahashi K., Morikawa K.	2017	CLSC	End	R	*	*	*	Y-Eco-Soc
Yavari M., Zaker H.	2019	CLSC	End	R	*	*	*	Y-Eco
Mithun Ali S., Moktadir M.A., Kabir G., Chakma J., Rumi M.J.U., Islam M.T.	2019	N	End & Exo	SCRMC	*	*	*	X-Eco
Jabbarzadeh A., Fahimnia B., Sabouhi F.	2018	F	End	R	*	*	*	Y-Eco-Soc
Tseng M.-L., Lim M., Wu K.-J., Zhou L., Bui D.T.D.	2018	N	*	*	*	X	X	X-Eco
Jabbarzadeh A., Haughton M., Pourmehdi F.	2019	F	End	R	*	*	*	Y-Eco
Fraccascia, L; Yazan, DM; Albino, V; Zijm, H	2020	F	End & Exo	R	Eco	X	*	X-Eco
Dubey V.K., Chavas J.-P., Veeramani D.	2018	F	End & Exo (Sus)	*	*	*	*	X-TBL
Ahi P., Searcy C.	2013	F	*	*	*	*	*	*

Wang J., Ran B.	2018	F	*	*	*	*	*	*
de Souza V., Bloemhof-Ruwaard J., Borsato M.	2019	F	*	*	*	*	*	*
Kumar A., Dixit G.	2019	N	*	*	*	*	X	X-TBL

Note: "N": node; "F": forward SC; "CLSC": closed-loop SC; "Exo": exogenous risks; "End": endogenous risks; "Sus": sustainability risks; "R": SC re-engineering; "A": SC agility; "C": SC collaboration; "SCRMC": SC risk management culture; "Eco": environmental sustainability; "Sco": social sustainability; "TBL": TBL sustainability. "X": indicators for performance; "Y": objectives for performance; "*": not mentioned.

2.5.3 Cluster three: SSCM for SC resilience

In total, 16 out of 103 papers indicated that SC sustainability strategies would impact SC resilience performance (see **Table 15**). Some scholars discussed general sustainable activities, while others focused on specific sustainability-related activities (e.g., sustainable procurement, reverse SC). Notably, CSR and circular economy activities are two prevalent sustainability initiatives that may contribute to enhancing SC resilience (e.g., risk reduction). Within this stream of literature, SC resilience is commonly operationalised as the performance of risk reduction, encompassing general SC risks, financial risks, operational risks, and reputational risks. In this cluster, SC risks are primarily mentioned as motivators for sustainable and resilient strategies. Still, they are more emphasised as performance outcomes—a measure of SC resilience performance (e.g., risk mitigation).

2.5.3.1 SC risks

Among the 16 papers, seven articles involved external risks, and 11 papers addressed internal risks. Three studies did not mention specific SC risks or the sources of SC risks within their research context (Bag, Gupta and Foropon, 2019; Shin and Park, 2019; Ivanov, 2018). Supply risks and demand risks remain the top two types of risks, both emphasised in three articles. Other risks, such as capacity risks (Kaur and Singh, 2019; Kaur et al., 2020), operational risks (Hallikas, Lintukangas and Kähkönen, 2020), process and production risks (Cruz, 2009; Gouda and Saranga, 2018), transportation risks (Cruz, 2009; Gouda and Saranga, 2018) and reputational risks (Hallikas, Lintukangas and Kähkönen, 2020), have also been discussed. Two representative studies should be highlighted due to their different perspectives, identifying risk factors (within and outside SCs) with sustainability concerns (e.g., social and reputational risks). Hallikas, Lintukangas, and Kähkönen (2020) posited that upstream disruptions and negative reactions from stakeholders could result in potential SC risks, classified into two main categories: operational and reputational risks. Cruz (2013) divided SC risks into four groups (i.e., supply-side risks, demand-side risks, exchange rate risks, and social risks) in global trading.

2.5.3.2 SC structure

In this theme, the research objects of five papers are focal firms, whereas only one paper is related to reverse SC structure (Özçelik, Faruk Yılmaz and Betül Yeni, 2020). Among the nine papers investigating forward or general SCs, two papers cover both upstream and downstream stages from suppliers and factories to distribution centres (and markets). Five articles exhibit research interest in either upstream or downstream forward SCs. The other two papers do not specify the forward structure in detail. For instance, Cruz (2009, 2013) investigated the resilience effects of CSR activities in the downstream SC network of manufacturers and retailers (or customers). Kaur and Singh (2019) and Kaur et al. (2020) primarily investigated sustainable procurement and logistics for resilient SC, where the SC upstream network comprising suppliers, carriers, and focal firms forms the fundamental research scheme. Surprisingly, the Closed-Loop SC (CLSC) structure is not investigated in this cluster, as seen in the previous two clusters. Although Gaustad et al. (2018) and Bae et al. (2019) are two studies examining the resilience impacts of circular economy principles, their research objectives primarily involve focal firms. Moreover, only one paper discussed reverse SC, not only in this cluster but also among all the sampled articles. The reverse SC network proposed by Özçelik, Faruk Yılmaz and Betül Yeni (2020) includes a set of customers, possible primary collection centres, secondary collection centres, and recycling centres, encompassing the recycling flows of used products but not the remanufacturing process. Compared to the previous two clusters, studies in this cluster appear to concentrate on a narrower scope of SC networks rather than entire SC networks, as identified in prior clusters.

2.5.3.3 Internal mechanism: SC paradigms

In this cluster, sustainable practices are perceived as the means to achieve the primary objective of SC resilience. The literature suggests that both environmental and social sustainability practices (e.g., CSR activities and circular economy practices) aid in addressing SC risks and maintaining SC resilience. Cruz and Wakolbinger (2008), Cruz (2009), and Cruz (2013) have investigated the effects of CSR activities on risk reduction within complex SC network structures (including multiple manufacturers and retailers). These studies posit that CSR can be a costly sustainability investment while offering long-term benefits for SC economical, environmental, and resilience performance (i.e., risk reduction). Specifically, CSR activities are capable of increasing profit, reducing risk and environmental impacts, decreasing production inefficiencies, reducing cost and risk, and simultaneously allowing companies to increase sales, access to capital, new markets, and brand recognition under multiple risks (e.g., production uncertainty, network-related risks, and social-political risks; supply-side disruption risks, demand-side risks, exchange rate risk, and social risk).

Environmentally sound practices also contribute to SC resilience (Park et al., 2010; Gaustad et al., 2018). Park et al. (2010) proposed a framework of business value streams in circular economy strategies with evidence from three Chinese electronic case companies. Gaustad et al. (2018) suggested five principles (recycling, remanufacturing, reuse, collection, lean principles, dematerialisation, diversity) as effective approaches for reducing SC vulnerability. In the SC design model by Özçelik et al. (2020), reverse channels create innovative sourcing options and could mitigate the adverse impacts of risk propagation. The importance of environmentally sound practices was empirically examined by Bae et al. (2019), which indicated that developing dynamic remanufacturing capabilities enables the enhancement of SC resilience in a highly volatile business environment (i.e., South Africa). Circular economy practices can significantly improve the availability of materials and maintain supply channels by reusing, reclaiming, and recycling product components (Park et al., 2010). Additionally, environmentally sound practices could build organisational legitimacy and enhance public image, benefiting informal interrelationships with other organisations (e.g., suppliers). Although circular economy practices are theoretically advantageous to SC resilience, empirical evidence is anticipated in future research.

Similarly, sustainable procurement strategies contribute to SC resilience by complying with necessary regulatory and market standards for purchased products. Kaur and Singh (2019) and Kaur et al. (2020) investigated sustainable procurement decision-making in response to supply and cost deviations caused by unforeseen disastrous events. These studies revealed that sustainable procurement strategies combined with resilience thinking (i.e., proactive SC network design) could contribute to a more efficient and resilient SC (Kaur and Singh, 2019; Kaur et al., 2020b). Hallikas et al. (2020) answered the question of how sustainable purchasing practices contribute to SC resilience with survey data from the upper stream of Finnish SCs. Sustainable sourcing initiatives are thought to improve SC resilience by limiting operational and reputational SC risks (for example, product availability, delayed orders, quality, pricing and prices, supplier insolvency, brand and image, ownership of co-created inventions, and knowledge and know-how preservation).

General sustainable practices enable SCs to effectively manage operational, regulatory, and environmental risks. Generals. Lam (2018) empirically confirmed that sustainable SC practices could help firms reduce financial risks using secondary longitudinal data and suggested that the risk reduction of sustainable SC practices is more remarkable for firms with more complex and efficient SCs. Without limiting themselves to financial risks, Gouda and Saranga (2018) posited that sustainability efforts could help reduce general SC risks, particularly in emerging market contexts. Both studies emphasise the impact of sustainability efforts and SC complexity but estimate different sustainability-resilience relationships. Specifically, sustainability efforts function as the independent variable in Lam (2018), while they act as a moderator in Gouda and Saranga (2018).

In conclusion, this cluster highlights the significance of sustainable practices in achieving SC resilience. The literature demonstrates that CSR activities, circular economy principles, and sustainable procurement strategies can contribute to risk reduction and enhanced resilience within SCs. While some empirical evidence exists, there is still room for future research to provide more concrete evidence on the relationship between sustainability efforts and SC resilience. This could include examining the interplay between different sustainability practices, investigating the contextual factors that influence the effectiveness of these practices, and exploring the role of technological advancements in promoting sustainable and resilient SCs.

2.5.3.4 Performance outcomes

In this cluster, SC resilience is considered a higher-level objective than SC sustainability. Shin and Park (2019) identified sustainability as one of the 24 SC resilience capabilities. In other words, SC resilience could be an outcome of SC sustainability, as suggested by the studies as mentioned above. Consequently, SC resilience and sustainability performance are interrelated.

Distinct from the previous two clusters, SC risk factors often measure SC resilience performance. Changes in financial risks (Lam, 2018), general SC risks (Gouda and Saranga, 2018), operational and reputational risks (Hallikas, Lintukangas and Kähkönen, 2020), supplier partnership risks (Gallear, Ghobadian and He, 2015), and ripple effects (Ivanov, 2018; Özçelik, Faruk Yılmaz and Betül Yeni, 2020) have been employed to estimate resilience performance in the face of uncertainties. It captures the adaptation and co-evolution process between SCs and their surrounding environment. Various SC risks motivate the implementation of internal mechanisms (e.g., SC paradigms), which, in turn, shape the contextual environment (for both focal firms and SCs) by impacting the SC risks. Only one paper views the value of SC resilience as performance benefits, measured as a composite (Bag, Gupta and Foropon, 2019).

Following previous clusters, the alignment of sustainability and resilience performance can be harmonised in most cases. Still, the priority or importance should be carefully balanced for optimal performance outcomes based on stakeholders' expectations. TBL sustainability (four papers) and ecological sustainability performance (four papers) have been discussed alongside SC resilience performance. Most optimisation models integrate ecological sustainability into objectives (Kaur et al., 2020a; Kaur and Singh, 2019; Cruz, 2009; Özçelik, Faruk Yılmaz and Betül Yeni, 2020), with only Fahimnia and Jabbarzadeh (2016) investigating TBL sustainability analysis. Fahimnia and Jabbarzadeh (2016) conducted a dynamic TBL sustainability trade-off analysis under different scenarios (i.e., business-as-usual and disruption situations) to examine the optimal solution for maintaining SC resilience and sustainability performance. The conflicts between sustainability and resilience performance objectives have only been scarcely explored. Ivanov (2018) serves as an exception, examining the impacts of three different sustainability practices (i.e., sustainable sourcing practices, reduction of storage facilities, and reinforcing employers' facilities) on sustainability (e.g., customer service level) and resilience levels (e.g., ripple effect) under both disruption and disruption-free scenarios. The results illustrated that sustainable efforts may not always contribute to SC resilience performance, and the mutual objectives could be harmonised through specific sustainability initiatives (e.g., reinforcing employers' facilities in this case).

In conclusion, the third cluster views SC resilience as a higher-level objective than SSCM, with SC risk factors often serving as a measure of SC resilience performance. Various SC risks motivate the implementation of internal mechanisms (i.e., SC paradigms), which shape the contextual environment and impact SC risks. The alignment of sustainability and resilience performance can be harmonized, but the priority or importance should be carefully balanced for optimal performance outcomes based on stakeholders' expectations. TBL sustainability and ecological sustainability performance are discussed alongside SC resilience performance. Most optimisation models integrate environmental sustainability into objectives, with only one paper investigating TBL sustainability analysis. Conflicts between sustainability and resilience performance objectives have been scarcely explored, but sustainable efforts may not always contribute to SC resilience performance.

Table 15 Coding summary of articles in Cluster 3: SSCM for SC resilience

Authors	Year	SC structure	SC risks	Resilience paradigm	SSCM paradigm	General performance	Resilience performance	SSCM performance
Kaur, H; Singh, SP; Garza-Reyes, JA; Mishra, N	2020	F	End	*	*	Y	*	Y-Eco
Özçelik G., Faruk Yılmaz Ö., Betül Yeni F.	2020	R	End	R	Eco	*	Y	Y-Eco
Bag S., Gupta S., Foropon C.	2019	N	*	R	Eco	*	**X**	*
Gouda S.K., Saranga H.	2018	N	End	SCRMC	Eco & Soc	*	X	*

Hallikas J., Lintukangas K., Kähkönen A.-K.	2020	N	End & Exo	*	Eco	**X**	X	*
Shin N., Park S.	2019	F	*	R, A, C, SCRMC	X	*	*	*
Kaur and Singh	2019	F	End & Exo	*	*	Y	*	Y-Eco
Gaustad, et al.	2018	N	End	*	Eco	X	X	X-Eco
Cruz J.M.	2009	F	End & Exo	*	Soc	Y	Y	Y-Eco
Gallear D., Ghobadian A., He Q.	2015	F	End & Exo	C	Eco & Soc	*	X	*
Lam H.K.S.	2018	N	End	*	X	*	X	*
Park J., Sarkis J., Wu Z.	2010	F	Exo	*	Eco	*	X	X-TBL
Fahimnia B., Jabbarzadeh A.	2016	F	End	R	X	*	Y	Y-TBL
				*	*	*	*	*
Cruz J.M.	2013	F	End & Exo	*	Soc	Y	Y	*
Ivanov D.	2018	F	*	R	Soc	*	X	X
Cruz J.M., Wakolbinger T.	2008	F	End & Exo	*	Soc	*	Y	Y-Eco
Awasthi A., Govindan K., Gold S.	2018	F	Exo	*	*	*	X	X-TBL

Note: “N”: node; “F”: forward SC; “CLSC”: closed-loop SC; “Exo”: exogenous risks; “End”: endogenous risks; “R”: SC re-engineering; “A”: SC agility; “C”: SC collaboration; “SCRMC”: SC risk management culture; “Eco”: environmental sustainability; “Sco”: social sustainability; “TBL”: TBL sustainability. “X”: indicators for performance; “Y”: objectives for performance. “*”: not mentioned.

2.5.4 Summary

Reviewed articles in three clusters of SSCM-resilience relationships share common themes but with different emphasises. **Table 16** summarises the main patterns of each cluster of SC resilience-sustainability relationships regarding SC risks, SC structure, SC paradigms, and performance outcomes.

Table 16 Summary of thematic analysis

	Cluster 1: sperate objectives	**Cluster 2: SC resilience for SSCM**	**Cluster 3: SSCM for SC resilience**
SC Risks	• Majority did not explicitly identify risk factors. • Risk sources are mainly given as examples but not investigated in-depth for sustainable and resilient supplier selection. • Endogenous risks (e.g., demand, supply, and disruption risks) received more attention than exogenous risks (e.g., natural disasters, political variability, and technology malfunction) • Risk factors are mentioned in half of the papers, but risk identification and assessment process are neglected except one article focusing on risk classification.	• Majority investigated endogenous and exogenous risks, while supply, demand, and operation risks. • Risk factors are investigated in sustainable SC network design, sustainable procurement. • Risk identification and risk assessment. • Risk classification, interconnection, and cause-and-effect relationships. • The classification of risk is not consistent but mainly focus on the location of risks (i.e., SC process or flow). • Sustainability risks is identified as a subset of SC risks. can be categorized based on the sustainability impacts (i.e., social, ecological, and economic dimensions) or the location of risks (i.e., sustainable supply risks, sustainable demand risks, firm's internal risks). • SC risks including sustainability-related risks emphasise the importance of resilience thinking in SSCM.	• Most papers have involved SC risks, though internal risks are investigated more than internal risks. • Supply and demand risks are highlighted among other risks, including reputational risks, which are less mentioned in the other two clusters. • New classifications of SC risks offer integrative frameworks to include traditional SC risks with sustainability concerns (e.g., operational and reputational risks), although the categories are not necessarily exclusive.

SC Structure	• Focus on forward SC, mainly two-echelon but also three-echelon SC. • Few investigated CLSC structure • Not really involved multi-echelon SC network or exclusively studies dyadic relations.	• Focusing on single SC stage (i.e., focal firms) or forward SC, where upstream SCs received more attentions than downstream SCs. • Multi-tier suppliers are emphasized more in this cluster. • Supply network design is considered as the approach enabling SC resilience and SSCM, which emphasise the importance of the role of SC structure.	• Focusing on forward SCs, mainly either on upstream or downstream SCs. • One paper focus on reverse SC, but CLSC is not investigated in this cluster. • Narrower scope of SC networks rather than entire SC networks.
SC Paradigms	• The selection of SC paradigms incorporating sustainability and resilience elements, such as LARG practices. • SSCM and resilience paradigms have differing priorities regarding performances. • SSCM and resilience paradigms have interconnections, such as lean and agile practices can bridge the gap between resilience green practices. • SC paradigms are used as performance indicators.	• Different combinations of SC resilience paradigm were investigated with the impacts on sustainability identified. • SC re-engineering, SCRMC, and collaboration received more attention than agility. • There are interactions between the four dimensions of SC resilience paradigm, such as collaboration affect the adoption of agility practices. • Sustainability risks is one of the antecedents of the adoption of SCRMC paradigm (e.g., innovation). • Different SC resilience paradigms result different sustainability performance outcomes. • There is a merge between SC resilience and SSCM paradigms, such as sustainable customer cooperation, sustainable integration, green supplier development, sustainable risk management.	• SSCM paradigms could offer long-term benefits regarding TBL and risk reduction performance in specific context (e.g., Finland and South Africa). • SSCM paradigms enable SCs to manage operational, regulatory, and environmental risks more effectively. • Among all SSCM paradigms, CSR, circular economy, and sustainable procurement practices are highlighted. • CSR activities can increase multiple benefits and decreasing multiple risks including social and operational risks. • Circular economy with reverse channels mitigates supply risks regarding innovative sourcing options and legitimacy and public reputation. • Sustainable procurement practices embedded with proactive thinking contribute to SC resilience by mitigating operational and reputational risks.

Performance outcomes	• TBL sustainability and resilience criteria are used jointly as performance evaluation criteria or optimization objectives. • There is no common performance metrics integrating sustainability and resilience criteria. • Social sustainability is overlooked than environmental sustainability criteria, resilience criteria is inconsistent. • Resilience performance is mainly measured from strategic level capabilities for performance evaluation purpose, operational level of resilience performance is evaluated by the effectiveness of risk (impacts) reduction.	• SC resilience criteria can serve as a sub-criterion for sustainable performance measurement. • Performance outcomes focuses on economic sustainability and environmental sustainability aspects, though social sustainability dimension have received growing attention. • New understanding of sustainability performance considers the resilience attributes (i.e., efficiency and persistence, constancy through change towards the future) and temporal attributes of sustainability (i.e., adapt to maintain cross-sectional sustainability and, transform to maintain longevity). • New systematic classification of sustainability performance can combine the attributes of adaptation, transformation, and long-term orientation of sustainability, which should combine multiple dimensions other than single dimensions (i.e., TBL).	• SSCM performance is intertwined with SC resilience performance. Sustainability is embedded as one of the antecedents of SC resilience. • Multiple risks can be used as the measurement of resilience performance, though SC resilience performance is also proposed as a composite variable. • Most optimization models integrate ecological sustainability along with resilience dimensions into objectives. • There could be a trade-off between sustainability and resilience performance, implying the priority should be balanced between resilience and sustainability. • Harmonisation is witnessed between resilience and sustainability performance with the existence of specific sustainability initiatives.

Source: Author

2.6 Research gaps

The interactions between SC resilience and SSCM have been a topic of increasing interest in recent years. Based on a review of the relevant literature, this paper identifies six major gaps related to the interaction between SC resilience and sustainability (also summarised in **Table 17**).

First, while both SC resilience and sustainability have been extensively researched as separate objectives, their relationship remains complex and requires further investigation. Although three clusters of SC resilience and SSCM relationship can be identified, the interplay between resilience and sustainability within each type need to be clarified and call for further examination. Most studies have concentrated on SC resilience and SSCM paradigms simultaneously under the performance monitoring scenarios without paying enough attention to the internal mechanisms (i.e., why and how). For instance, future research can address how SC resilience paradigms can influence SSCM paradigms and vice versa. Future research could also examine how to merge SC resilience and SSCM paradigms as a formulation towards environmental turbulence and sustainability concerns. In addition to identifying the pattern of the sustainability-resilience relationships, further research could investigate trade-offs between sustainability and resilience performance with empirical evidence.

Second, the literature indicates that SC risk factors are crucial in the interaction between SC resilience and SSCM. However, the existing studies have mixed up the sources and types of risks. Some studies only briefly mention risk factors in the research background without proper analysis. Those that do analyse risk classifications, tend to cluster them according to the sources and location of risks. Nevertheless, considering the consequences of risk factors from the sustainability perspective, SC risks can be categorised as TBL sustainability risks, which incorporate both resilience thinking and sustainability concerns. Future research could develop a new classification of SC risks with an enlarged scope regarding sustainability concerns. Future research could build up the SC risk classification framework with joint consideration of the sources of risks and the TBL impacts of risks. Such a framework should also investigate how the consequences of risk factors vary in terms of their types (e.g., operational efficiency, cost, flexibility, social welfare) and extent (e.g., slight, medium, strong) in order to identify the critical risk factors. Moreover, future studies should explore the interconnections among all risk factors, including sustainability risks, to assess their impact on SC resilience and sustainability, which still needs to be adequately addressed in the literature.

Third, optimisation models in sample articles often consider internal risks, such as demand and supply risks but tend to neglect external risks. While it is common sense that risk factors impact SC paradigms and decision-making processes, few studies have examined the impacts of risk factors on the implementation of sustainability and/or resilience strategies with empirical evidence. Existing empirical frameworks typically treat risk factors as a composite construct (e.g., environmental turbulence/uncertainties) without sub-constructs. Consequently, the current research has only scantily investigated how different types of risks affect implementing sustainable/resilience practices or overall performance outcomes. Thus, it is recommended that future research should delve deeper into the specific relationships among various internal and external risks and resilience/sustainability strategies. More empirical studies are needed to investigate the potential direct and/or indirect impacts of SC risk factors on the specific sustainability-resilience relationships.

Fourth, in addition to the complexity of SC risk factors, the reviewed literature reveals a variation in the investigated SC structures in terms of the number of players, the number of echelons, the distance to supply bases/markets, and the involvement of reverse channels. Most studies focus on either focal firms or forward SCs, with only a few papers discussing reverse or closed-loop SC structures. However, the inclusion of reverse channels for recycling, remanufacturing, and reusing used products has the potential to strengthen SC resilience and mitigate SC risks and risk propagation (Gaustad et al., 2018; Özçelik et al., 2020; Park et al., 2010), although a further empirical investigation is needed to validate this claim. Another critical point is the lack of discussion on the interrelationships among SC members, despite the complexity of SC network structures, which calls for attention to the relational status among SC members. Based on the complex adaptive system theory, the complexity of SC structures could also impact the specific sustainability-resilience relationships. Two recent studies by Gouda and Saranga (2018) and Lam (2018) provide examples in this respect. However, the existing research has largely ignored the impacts of SC structures on the association between SC sustainability and SC resilience.

Fifth, this review highlights the lack of unified patterns in the internal mechanisms for sustainability and resilience objectives. Although previous studies have examined the relationship between SC resilience and sustainability, most of them have focused on the integration of resilience and sustainability practices without clarifying the linkages between risk factors and SC paradigms, as well as potential performance outcomes. The selection of specific SC paradigms is mainly based on general criteria, such as cost, delivery, service, and flexibility, rather than sustainability or resilience criteria. It relies on the subjective judgments of decision-makers. Given the significant role of SC paradigms, future research could explore the selection criteria of SC practices and the interconnections among them. While resilience and sustainability have different effects on specific performance outcomes, the causality of these differences has not been explored. Future work could compare the performance effects and priorities of different practices for the objectives of resilient and sustainable SC development objectives. Additionally, no study has empirically examined the internal mechanisms of how two groups of controversial and/or complementary SC practices, i.e., resilience and sustainability, could impact specific performance outcomes under different contexts, such as different SC risks and network structures.

Sixth, while sustainable performance has been extensively studied, sustainability performance measurement is relatively more systematic than resilience performance. Among the three pillars of sustainability performance, there have been fewer studies on social sustainability than on environmental and economic sustainability in optimisation, conceptual, and conceptual models. However, the measurement of resilience identified in the literature is even more complex than the sustainability measurement. The measurement of resilience can be developed at both the operational level (e.g., inventory surplus, disruption cost, supplier risks) and the strategic level (e.g., absorptive/adaptive/restorative capacity, pillars of resilience capabilities). The measurement of resilience could be based on the beneficial outcomes of resilience attributes or the adverse impacts of de-resilience. Some measures of resilience integrate the risk attitudes of decision-makers by involving risk-related criteria (e.g., supplier risks, production risks, sustainability risks) as well as the characteristics of the SC network structure (e.g., node complexity, flow complexity, network criticality). Similar to sustainability, the measure of SC resilience needs to be systematically integrated into future research. Another point is that longitudinal studies may be needed to test resilience performance further empirically by comparing disruption and non-disruption occasions (e.g., Fahimnia and Jabbarzadeh, 2016; Lam, 2018; Ivanov, 2018). The trade-off analysis between sustainability and resilience would change in different periods (short-term or long-term).

Table 17 Research gaps from the literature review

No.	Research gaps identified from the literature review
1	Although SC sustainability and resilience are well-researched, their relationships are complex and need further investigation.
2	SC risk factors are important contextual factors of the interaction mechanism of SC resilience and sustainability, but existing literature has not comprehensively classified all risk factors with joint consideration of causes and effects.
3	Few studies have examined the impacts of risk factors on the implementation of sustainability and/or resilience strategies with empirical evidence.
4	The investigated SC structures in extant literature are various and the interrelationships among SC members were seldom discussed.
5	There is the lack of unified patterns in the internal mechanisms for sustainability and resilience objectives, no in-depth discussion on how to merge SC resilience and SSCM paradigms.
6	While sustainability performance has been extensively investigated, the measurement of resilience performance is relatively more complex and needs to be systematically integrated into future research.

Source: Author.

2.7 Summary

This chapter provides the theoretical foundation and systematic literature review for theoretical framework building in the following chapter. The literature review aims to contribute to understanding the interrelationship of resilience and sustainability in SCM literature and address ***RQ1*** by answering **what are common themes currently developed in the joint research of SC resilience and SSCM in the extant literature**.

The review analysed 103 relevant articles to identify the general research status through descriptive analysis of the sample articles regarding the journal, publishing year, methodology, and theoretical lens. Moreover, the common patterns – SC risks, SC paradigms (SC resilience and SSCM practices), SC structure, and performance outcomes- are discussed and compared for three types of SC resilience and SSCM relationships, including SC resilience and SSCM as separate objectives, SSCM as the primary objective, and SC resilience as the primary objective. Therefore, an integrated theoretical framework in the following chapter and the research gaps are identified for further studies.

Chapter 3 Theoretical Framework

3.1 Introduction

Based on the themes identified from literature in **Chapter 2**, this chapter proposes a theoretical framework to integrate the interaction mechanisms between SSCM and SC resilience. Drawn upon CAS (complex adaptative systems) theory and SNT (social network theory), the theoretical framework is proposed to respond to ***RQ2: How SC resilience and SSCM can be integrated under the framework of CAS and SNT?***

Therefore, **Chapter 3** is organised as follows in **Figure 11**: first, **Section 3.2** demonstrates the theoretical underpinnings of CAS, SNT and the complementary of CAS and SNT; second, **Section 3.3** proposes hypotheses regarding the interactions among SC risks, SC paradigms (i.e., SC resilience paradigms and SSCM paradigms), and performance outcomes; third, **Section 3.4** provides a summary of **Chapter 3**.

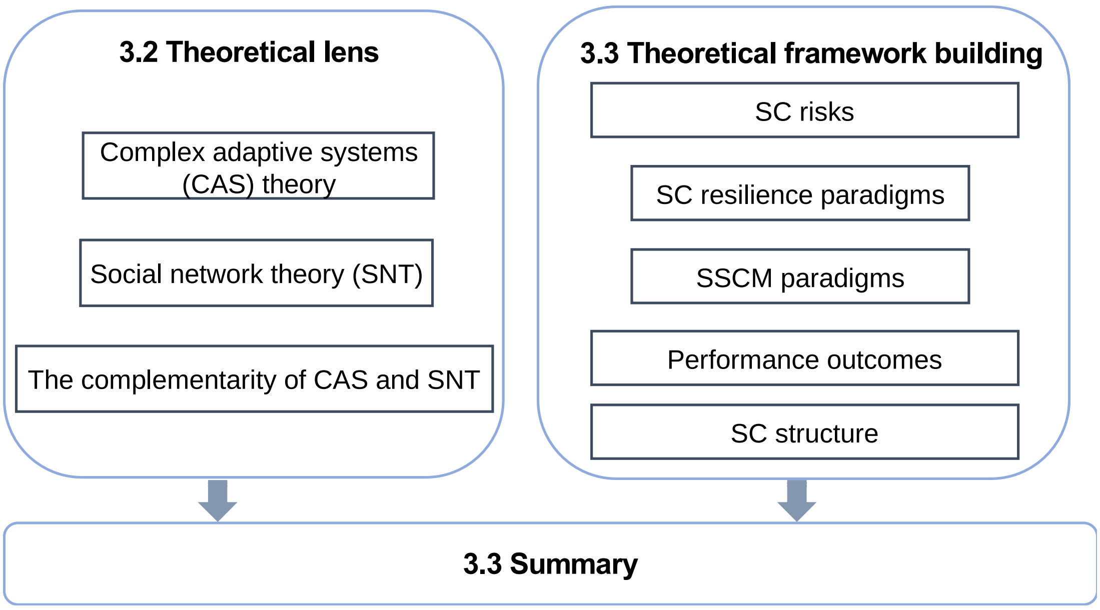

Figure 11 **The structure of Chapter 3**

3.2 Theoretical lenses

This section illustrates the adoption of CAS and SNT as theoretical lenses and the complementary of the two theories for the development of the theoretical framework.

3.2.1 Complex adaptative systems (CAS) theory

The internal dynamics of a system, whether natural or artificial, are complex and arise from nonlinear spatiotemporal interactions among its components. A CAS operates far from dynamic equilibrium, but without a single global controller, it self-organises and adapts over time into a more coherent form (Holland and Mimnaugh, H., 1996). This complexity arises from the fact that a CAS operates in a dynamic network of interacting agents. System-level behaviour emerges from the interactions among these agents, making it difficult to predict using a reductionist approach. Moreover, a CAS is adaptive because its systemic behaviours change and self-organise over time in response to internal events or external disturbances (Levin, 1998). Choi et al. (2001) characterise a CAS as a self-organising system that adapts through interactions of nodes within the network and evolves. Pathak et al. (2007) noted that a CAS is characterised by a dynamic, co-evolutionary process between the system and its environment, where the internal mechanisms, environment, and co-evolution are the major constituents of CAS. The internal mechanism comprises agents, self-organisation, emergence, connectivity, and dimensionality. On the other hand, the environment is marked by dynamism and a rugged landscape. Quasi-equilibrium and state change, nonlinear changes, and non-random future characterise the co-evolution of system along with dynamic environment.

SCs are regarded as complex systems, with collective, dynamic, and non-linear interactions between firms along the SC and with their environment in an adaptive way (Tukamuhabwa et al., 2015). A supply network is considered a typical case of CAS due to its interconnected nature and the adaptive behaviour of its entities in response to internal and external changes (Pathak et al., 2007). Nair and Reed-Tsochas (2019) proposed a CAS-based conceptual framework by summarising all the CAS research in SCM and confirmed the importance of CAS in coming SCM research.

A CAS lens allows an SC network to be viewed as a complex system where individual firms can adapt and restructure their networks in the face of an SC disruption (Zhao, Zuo and Blackhurst, 2019). Unexpected SC disruptions, ranging from natural disasters to terrorist attacks, would severely impact businesses and communities. SCM scholars examined the resilience mechanism (e.g., flexible supply bases and strategic SC network design) under uncertainties (Fahimnia and Jabbarzadeh, 2016;

Mari, Lee and Memon, 2016; Pavlov et al., 2019), where SC resilience can be proposed as a dynamic and systematic approach. Tukamuhabwa et al. (2015) compared CSA with other dominant theories in SCM literature (e.g., resource-based view, dynamic capability view, and system theory) and demonstrated the suitability and application of CSA in SC resilience research from the aspects of resource (internal or external, separable or synergic), level of analysis (firm or system), interaction with the environment (adaptation and co-evolvement). CSA theory has been advocated in recent studies (Yaroson et al., 2021; Zhao, Zuo and Blackhurst, 2019; Novak, Wu and Dooley, 2021), where the dynamic and non-linear nature of SC networks is captured for analysing the system's behaviour.

In addition, the principles of emergence and adaptation that are central to CAS theory are especially relevant to SSCM. This is because adopting a long-term perspective on sustainability, which involves considering environmental, social, and economic factors in decision-making, requires a holistic approach that makes CAS theory well-suited (Braz and Marotti de Mello, 2022). Emergence refers to how new properties or behaviours can emerge from the interactions of individual components in a system (Braz and Marotti de Mello, 2022). For example, in the context of SSCM, sustainability goals can emerge from the interactions of individual suppliers, manufacturers, and distributors in the SC. Adaptation, on the other hand, refers to the ability of a system to adapt and evolve in response to changing conditions, including changing regulations, consumer preferences, and environmental conditions (Braz and Marotti de Mello, 2022).

Aligning resilience and sustainability into SCM studies requires a holistic understanding of the dynamic and adaptive network's behaviours by considering the interactions of its components over time. The CAS lens provides a theoretical framework for exploring the adaptive and self-organising behaviour of the system in response to sustainability-related risks and opportunities (Bag et al., 2019). Pettit, Croxton and Fiksel (2019) indicated SC resilience as the emergent property of dynamic systems that create triple value in human societies, industrial economies, and ecosystems (Fiksel et al., 2014). A dynamic and methodical methodology is required to examine the relationship between SC resilience and SSCM, especially given the rising demand to fulfil sustainability targets while ensuring operational continuity in the face of disruptions (Wieland, 2021). **Table 18** summarises the core concepts of CAS theory with their application in pursuing SC resilience and SSCM. Considering the suitability and application of CAS, this study primarily follows the suggestion of previous studies (Choi, Dooley and Rungtusanatham, 2001; Tukamuhabwa et al., 2015; Zhao, Zuo and Blackhurst, 2019) and adopts CAS theory as one of the theoretical lenses to capture the nature of SC resilience and sustainability.

Table 18 CAS concepts in SC resilience and SSCM

CAS Concepts	Definition	CAS in SC resilience and SSCM
Emergence	The process by which new properties or behaviours can emerge from the interactions of individual components in a system.	Resilience properties and SSCM behaviours may emerge from the interactions of individual suppliers, manufacturers, and distributors in SC system.
Adaptation (Dynamics)	The ability of a system to adjust and evolve over time in response to changing internal and external conditions.	Adapt to changing market conditions, SC disruptions, regulations, consumer preferences, and environmental and social conditions to remain resilient and sustainable.
Nonlinearity	The property of systems in which the relationship between cause and effect is not proportional or predictable.	Exhibit nonlinear interactions between suppliers, manufacturers, and distributors that can lead to effective responses and unpredictable outcomes to disruptions.
Self-organisation	The process by which a system can organise itself without the need for a central controller.	Self-organise to respond to disruptions, optimize the allocation of resources, improve overall efficiency, productivity, and TBL sustainability such as by redistributing inventory or finding alternative sustainable suppliers.
Agent	An individual component of a system that interacts with other agents to produce emergent behaviours.	Suppliers, manufacturers, and distributors are all agents that interact with one another to produce emergent behaviours at the system level that are resilient, adaptable, and financially, environmentally, and socially responsible.
Link	The connections between agents that allow for interactions and the emergence of system-level behaviours.	Interactions and the emergence of system-level behaviours with resilience and sustainability orientation.

System-level behaviour	The emergent properties or behaviours that arise from the interactions of individual components in a system.	Redundancy, flexibility, responsiveness, and continuity of operations in the face of disruptions. Resource efficiency, productivity, environmental and social responsibility.
Feedback	The process by which information about the system is transmitted and used to modify the behaviour of individual agents.	Detect and respond to SC disruptions, such as by alerting managers to inventory shortages, delays in transportation, or other potential issues. Optimise resource allocation, increase overall efficiency, and enhance sustainable performance.

Source: updated from Choi, Dooley and Rungtusanatham (2001); Tukamuhabwa et al. (2015); Zhao, Zuo and Blackhurst (2019).

3.2.2 Social network theory (SNT)

Originating in sociology and anthropology in the mid-twentieth century, SNT has since been applied across various fields, including business, management, and SCM (Wichmann and Kaufmann, 2016). It is based on the idea that social relationships are fundamental to human behaviour and shape how people interact, share information, and create knowledge (Easton and Rosenzweig, 2015). At its core, SNT views relationships between actors as crucial determinants of behaviour and outcomes (Borgatti and Li, 2009). In other words, SNT concerns the patterns of social ties and interactions within a given network of individuals or organisations. These ties may take various forms, such as communication channels, collaborative relationships, or power dynamics (Galaskiewicz, 2011). The network can be analysed in terms of its structural properties, such as its size, density, centrality, and modularity, as well as the individual aspects of its members, such as their expertise, reputation, and influence (Han, Caldwell and Ghadge, 2020).

The SC is a complex system of interrelated activities that involve multiple organisations, including suppliers, manufacturers, distributors, retailers, and customers (Choi, Dooley and Rungtusanatham, 2001). Therefore, understanding the nature and structure of relationships among these actors can help understand the structure-based capabilities, assess the information and knowledge flows among different actors, evaluate the strength of the network structure and predict how changes in the network structure might affect overall performance (Nikookar and Yanadori, 2022).

SNT offers several key concepts that are particularly relevant to complex SC systems. First, nodes refer to individual actors in the network, such as suppliers, manufacturers, distributors, and customers, while ties represent the connections between nodes, such as contracts, partnerships, or information flows (Borgatti and Li, 2009). Network structure refers to the overall pattern of ties between nodes in the SC (Borgatti and Li, 2009). Understanding the structure, including the number and type of nodes, the nature of the ties between nodes, and the overall design of the network, can help identify critical actors and assess the general resilience and efficiency of the SC. Finally, centrality refers to the degree to which a particular node is connected to other nodes in the network, which implies that vital players have a more substantial impact on changes to the network structure (Borgatti and Li, 2009). Therefore, SNT can be used to understand the structure and dynamics of inter-organisational relationships within and between firms. It can enhance the dissemination of information and knowledge throughout the SC network and manage SC risks and stakeholder pressure more efficiently.

SNT provides a valuable lens for comprehending the network structures and relationships within the SC network that underpin sustainable and resilient SCM. **Table 19** shows the reflection of SNT core concepts in SCM, which can be applied to developing SC resilience and SSCM, respectively. For example, a sustainable SC network may involve collaboration between suppliers, manufacturers, and distributors to optimise resource allocation, reduce waste, and enhance social responsibility (Lu et al., 2018). The network structure analysis can be utilised to promote the circular economy, monitor power imbalances within the SC network, and address social and environmental concerns (Lu et al., 2018). Likewise, a resilient SC network may involve redundancy, flexibility, and adaptability to respond to SC disruptions such as natural disasters, political instability, or pandemics (Nikookar and Yanadori, 2022). SNT can aid in identifying the critical pathways and interdependencies within the SC network, as well as the resilience-enhancing attributes of focal firms and network structure (Wichmann and Kaufmann, 2016), which is necessary for developing risk mitigation techniques (e.g., contingency plans for unexpected events).

Table 19 SNT concepts in SCM

Concept	Definition	Reflection on SCM
Network	A set of actors (individuals, groups, organisations, etc.) connected by a set of social relationships or ties.	A set of organisations that are connected by a set of interdependent relationships and interactions in the flow of goods, services, information, and money.
Node	An individual actor within a network. Nodes can be people, groups, organisations, or any other type of social entity.	A specific organisation, supplier, or customer that is part of a SC network.
Tie	A connection or relationship between two nodes in a network. Ties can be of different types, such as friendship, collaboration, information exchange, etc.	A business relationship or link between two organisations in a SC, such as a supplier-customer relationship or a logistics partnership.
Degree	The number of ties that a node has in a network. A node with a high degree is considered more central or influential within the network.	The number of direct connections or links that an organisation has with other organisations in the SC network.
Centrality	A measure of how important or influential a node is within a network. Centrality can be based on various factors, such as degree, closeness, betweenness, etc.	The relative importance or power of an organisation in the SC network, based on its position, resources, capabilities, and relationships with other organisations.
Clustering	The tendency for nodes in a network to form clusters or groups. Clustering can be based on shared attributes, interests, or ties between nodes.	The formation of clusters or groups of organisations in the SC network, based on common interests, goals, or characteristics.

Source: Borgatti and Li (2009) and Han, Caldwell and Ghadge (2020).

3.2.3 The complementarity between CAS and SNT

SNT and CAS theories offer complementary theoretical underpinnings for understanding these interdependencies and developing ways to improve SC resilience and SSCM. SC resilience and SSCM are critical criteria for the long-term success of organisations functioning in today's complex and ever-changing business environment (Choudhary et al., 2022; Cotta et al., 2023; Ivanov, 2023). To improve the resilience and sustainability of their SCs, organisations need to embrace a holistic approach that considers the interdependencies between different agents within the system.

SNT emphasises the importance of relationships and interactions between different agents within the SC (Galaskiewicz, 2011). It provides a framework for understanding how information, knowledge, and resources flow through the SC network and how disruptions propagate (Galaskiewicz, 2011). By analysing the structure of the SC network, SNT can identify critical nodes and relationships that are key to the performance and resilience of the SC (Fung et al., 2021). SNT also provides insights into how firms can build resilient and sustainable SCs by fostering strong relationships with key partners, promoting collaboration and knowledge sharing, and mitigating the impact of disruptions (Han, Caldwell and Ghadge, 2020). On the other hand, CAS theory emphasises the self-organising and adaptive nature of SC systems (Choi, Dooley and Rungtusanatham, 2001). It provides a framework for understanding how the behaviour of individual agents within the SC can lead to emergent patterns and behaviours at the system level (Wycisk, McKelvey and Hülsmann, 2008). By analysing the dynamics of the SC system, CAS theory can identify opportunities for enhancing SC resilience and sustainability by fostering adaptive and self-organising behaviour among SC agents (Braz and Marotti de Mello, 2022). SNT and CAS theory provide complementary theoretical frameworks for apprehending the interdependencies and dynamics of SC systems and developing strategies for enhancing SC resilience and SSCM at individual firm and system level (see **Table 20**).

SNT contributes to a detailed knowledge of the SC network's links and interactions among SC members (Han, Caldwell and Ghadge, 2020). On the other hand, CAS theory explains how these interactions might result in emergent behaviours and patterns at the system level (Zhao, Zuo and Blackhurst, 2019). SNT emphasises the structural dynamism within the system (Alinaghian, Qiu and Razmdoost, 2021), whereas CAS investigates the system-level dynamism and the interaction with system environment (Yaroson et al., 2021). SNT examines the micro-level activities among SC members, while CAS provides macro-level guidance of system evolvement. In general, the complementary adoption of CAS and SNT can be seen from the scale of research focus:

- CAS focuses on system-level analysis, including assessing the environmental and social impacts at the SC system level and identifying the adaptive capacity of an SC network during disruptions.
- SNT focuses on the analysis within the SC system, including identifying key actors and partnerships that can help build SC resilience, analysing the structure and dynamics of an SC network, and promoting collaboration and resource sharing among the different actors in the SC system.

Table 20 The complementarity between SNT and CAS in SCM Research

	SNT	**CAS**
Focus	Relationships and interactions between different agents within the SC network	Self-organising and adaptive nature of SC systems and emergent properties of complex systems that arise from interactions among elements
Components	Nodes (individuals, groups, or organisations), ties (relationships), and network structure	Elements (organisms, agents, or components), interactions, feedback loops, and system dynamics
Characteristics	Static or dynamic network structure, centrality measures, information diffusion, collective action	Self-organisation, adaptation, evolution, resilience, robustness, and complexity

Applications	Social media analysis, organisational analysis, diffusion of innovations, social capital, network interventions	Ecology, economics, urban planning, transportation, health, and social systems

Source: Update from Borgatti and Li (2009), Choi, Dooley and Rungtusanatham (2001), and Han, Caldwell and Ghadge, (2020).

The complementary use of CAS and SNT shed light on the potential explanation of the association of SC resilience and sustainability, both of which are embraced in the mutual target of SC systems, by examining the structural and behavioural aspects of the relationships within the network. Through this combined theoretical lens, SC is perceived as a CAS with evolving structures. This allows the SC to align with common objectives by continually adapting layers of its network structures, modifying flows among SC participants, dyads, sub-networks, and the overarching system (Han, Caldwell and Ghadge, 2020). Drawing upon SNT and CAS theory, the scales of SC network-structured systems can be defined with a clear boundary with the interactive system environment. The SC actors within the systems are aligned by multifaceted mutual targets. With the adjusting process of network relations and flows, the internal network structures can adapt to the dynamic environment, contributing to the SC system's dynamic nature (Han, Caldwell and Ghadge, 2020).

3.3 Theoretical framework developing

This study uses CAS and SNT as the theoretical lens to provide a holistic understanding of SC systems. CAS can help identify emergent properties and build adaptive capacity. SNT can help to analyse network structure and identify key actors and their roles. This section proposed a theoretical framework (see **Figure 12**) with the following hypotheses development.

3.3.1 Relationships between SC risks and SC paradigms

In the literature, multiple sources could trigger SC risks within or outside SC systems/networks. These turbulences influence SCs' propensity to implement proactive or reactive strategies to handle foreseen adverse situations (Lo and Shiah, 2016). It is witnessed that various risks trigger different internal mechanisms regarding the adoption of SSCM practices and the adaptation of SC resilience capabilities (Fan, Stevenson and Li, 2020; Gouda and Saranga, 2018; K. Roehrich, Grosvold and U. Hoejmose, 2014). For instance, regulatory pressure, such as the restriction from different environmental regulations, drives the adoption of green practices (i.e., green design and green purchasing) in resource-dependent SCs to cope proactively with the potential adverse environmental effects (Zhang et al., 2019). On the other hand, demand and/or supply risks within the SC system require redesigning the SC network (e.g., facility and order allocation) for multi objectives (i.e., operation efficiency, profitability, environmental impacts or social welfare) (Tsolakis et al., 2021). It implies a fit between risk factors and adopting SC paradigms (i.e., resilient and/or SSCM practices). Therefore, SC risk can be regarded as a decisive factor in SC's strategic business strategies, and SCs would select different strategies with facing different types of uncertainties or disturbances.

This study does not focus on traditional risk management procedures, including risk identification, evaluation, and mitigation processes, but instead on the triggering mechanism of SC risks towards SC resilience and SSCM. Drawn upon CAS and SNT, SC risks, as an essential attribute of the system environment in this study, can disrupt operations, undermine their capability to maintain functions, and implement SSCM for short-term or long-term goals. To maintain consistency, the theoretical framework employs the same classification of SC risks as the coding categories, with SC risks classified as endogenous or exogenous in terms of their origins. However, different from the classical view, the scope of SC risks considered in this study is enlarged by considering sustainability risks.

Based on the literature view, sustainability-related risk is an emerging concept in SSCM-resilience studies, which consider the consequences or impacts of risks from the sustainability perspective. SC risks related to demand volatility require agility, flexibility, and responsiveness capabilities. In contrast, sustainability risks related to climate change require sustainable practices such as reducing carbon emissions and investing in renewable energy. Similarly, SC risks related to supply disruptions require collaboration and alignment capabilities. In contrast, sustainability risks related to labour standards require sustainable practices such as promoting ethical sourcing and ensuring fair labour practices (Pournader, Kach and Talluri, 2020). Nevertheless, there is an interdependence between traditional/classical SC risks and sustainability risks

(Gouda and Saranga, 2018). For example, SC disruptions caused by environmental disasters can affect SC operations and significantly impact the environment and the communities in which they operate (Gunessee, Subramanian and Ning, 2018). Similarly, sustainability risks such as social responsibility issues can affect SC operations by undermining supplier relationships and damaging the brand reputation (Azadegan et al., 2020).

The complex and interactional relationships between classical SC risks and sustainability risks require a systemic approach that takes into account the complex interdependencies between risk factors and SC players in SC. SNT provides a valuable lens for understanding these interdependencies and the importance of stakeholder collaboration and cooperation. CAS emphasises the system-level impacts of the external environment, which would affect the behaviours and connections of SC partners. Facing various triggering events (e.g., economic hardship and political instability), SC players are aligned to respond to common objectives collaboratively to reduce the adverse impacts. Effective management of SC risks, including sustainability risks, requires adopting SC resilience capabilities and SSCM practices to enhance their adaptability and flexibility to change towards internal and external SC risks. For instance, the uncertainty of demand offers an incentive for SC players to interact effectively and create radical innovations (e.g., green customer cooperation) in high environmental turbulence (Cabeza-Pullés, Fernández-Pérez and Roldán-Bravo, 2020).

Therefore, SC risks trigger the internal mechanism - resilience paradigm and SSCM paradigm- within SC systems to maintain superior performance in the turbulent environment. Specifically, it is proposed that SC paradigms are the portfolio of resilience capabilities and SSCM practices. Although researchers have identified mainly and assessed SC risk factors for resilient and sustainable SCs and the selection of a portfolio of SC paradigms for multifaced SC risks (e.g., endogenous or exogenous risks, sustainability or non-sustainability risks) is less investigated (Syed et al., 2019). Based on CAS and SNT theory that the external context of the system influences the decision process and strategies within the SC system, three hypotheses are formulated as follows:

Proposition 1a: Endogenous risks are positively associated with the adoption of SC paradigms: (i) resilience paradigm; (ii) sustainable paradigm.

Proposition 1a: Endogenous risks are positively associated with the adoption of SC paradigms: (i) resilience paradigm; (ii) sustainable paradigm.

Proposition 1b: Exogenous risks are positively associated with the adoption of SC paradigms: (i) resilience paradigm; (ii) sustainable paradigm.

Proposition 1c: Endogenous and exogenous risks have a different association with the adoption of SC paradigms: (i) resilience paradigm; (ii) sustainable paradigm.

3.3.2 Interactions between SSCM and SC resilience paradigms

SC paradigms in this study, as the internal mechanism of SC network-structured system, cover SC resilience and SSCM. The relationships between resilience and sustainability paradigm have yet to be thoroughly discussed, but the interconnection has been witnessed. Four core elements of resilience paradigms are recognised as SC re-engineering, collaboration among SC partners, agility towards the changes of supply bases and market demands, and SC risk management culture via innovation and trust (Pettit, Croxton and Fiksel, 2019; Christopher and Peck, 2004). Facing endogenous and exogenous risks (e.g., market and technological changes), these resilience capabilities are embedded within the cooperation among SC partners (Chowdhury, Quaddus and Agarwal, 2019; Gu, Yang and Huo, 2021). Through collaborative efforts within the SC network, SCs can be adapted structurally and systematically to anticipate and mitigate risks. This enables them to evolve towards the future adaptively and exploratively, and exploitatively to develop long-term relationships (Hall et al., 2012).

Another brunch of the SC paradigm is SSCM practices, incorporating sustainability considerations into all aspects of SC stages. SSCM paradigm by ensuring environmental and social responsibility is essential for addressing sustainability risks (Gouda and Saranga, 2018). Specifically, by implementing GSCM practices, companies can improve resource efficiency, reduce waste, and minimise environmental impacts towards reinforced environmental regulations (Lo and Shiah, 2016). Similarly, social practices can help companies enhance their reputation, build trust with stakeholders, and address social issues, such as labour rights and community development (Lu et al., 2018). Stakeholder engagement and collaboration are integral and indispensable for SSCM implementation.

Resilience and sustainability paradigms are mutually reinforcing, as risk management (Gouda and Saranga, 2018) and collaboration (Sharma et al., 2022) are crucial elements of both, for which CAS and SNT theory provides the theoretical explanation that the internal mechanism of SC systems is continuously adapted towards the internal and/or external stimuli. With embracing long-term orientations, SC systems need to adaptively adjust the priority of resources for SC resilience capabilities and SSCM practices for continuity. Facing endogenous and exogenous risks related to (non-)sustainability challenges, SC members within the system self-organise themselves towards the mutual orientation of developing sustainable and resilient SCs. Implementing SC paradigms brings benefits locally and along the whole system regarding long-term exposure against environmental turbulence.

On this basis, SC resilient paradigm is a catalyst for sustainable paradigms. The interwoven risk factors prompt SC adaptation in collaboration relationships. Trust and informal collaborative relationship among SC partners would be necessary to ensure the design of sustainable SC remain unaffected or minimally affected in a dynamic environment (Zhang et al., 2019). A flexible production system paves the way for adopting GSCM practices (Green et al., 2019), contributing to superior operational performance. For instance, Ruiz-Benitez, Lopez, and Real (2017) found that flexible supply bases, a resilience practice, can improve social and environmental performance outcomes by facilitating the communication of environmental criteria and reducing waste. It suggests that SC resilience and sustainability paradigms should be pursued simultaneously for optimal performance.

Conversely, SC sustainable paradigm would promote the SC resilient paradigm for risk reduction (Gouda and Saranga, 2018). Moreover, the sustainable capabilities of suppliers could bring dyadic collaboration benefits in safeguarding the buyer's economic performance towards the regulations (Busse, 2016). Innovativeness can also be motivated while developing an eco-friendly supplier base and maintaining a green sourcing strategy (Bag et al., 2018), where sustainable practices are a source of innovation for developing resilience towards the regulation turbulence. In the same context, Bag et al. (2018) highlights that innovation and flexibility contribute to sustainability in the entire supply network, where SC resilience can be regarded as the practical approach for the sustainability paradigm.

Indeed, the interaction between resilience and SSCM paradigms would be complicated with the consideration of standard practices, such as increasing visibility, engaging with stakeholders, and committing to continuous improvement (Beske, Land and Seuring, 2014). SC resilience and sustainability require visibility across the SC to identify potential risks, vulnerabilities, and environmental and social impacts. Improving visibility can help companies identify areas for improvement and implement appropriate measures to mitigate risks and reduce environmental and social effects (Taghizadeh, Venkatachalam and Chinnam, 2021; Wu, Liang and Zhang, 2020; Kraft, Valdés and Zheng, 2020). It is also critical to build resilience and sustainability by engaging with stakeholders, which can help companies understand their concerns and expectations, improve transparency (Gualandris et al., 2021), and build trust (Dubey et al., 2020). A viable SC requires a commitment to continuous improvement to identify areas for improvement, set targets, and monitor progress, where reducing environmental and social impacts and improving SC resilience are principal (Ivanov, 2020).

Based on the discussion above, the following proposition is provided:

Proposition 2: Resilience paradigm and SSCM paradigm are intertwined.

3.3.3 SC paradigms on performance outcomes

SC resilience and SSCM are interrelated and interdependent concepts crucial to effective SCM. These two paradigms share significant similarities, as both emphasise risk management, collaboration, and the ability to adapt to changing circumstances. In fact, they are mutually reinforcing, as efforts to improve SC resilience can positively impact sustainability performance and vice versa.

The resilience paradigm, in particular, has emerged as a key strategy for achieving sustainable performance in SCM. Recent research has highlighted the significant impact of both resilient and green paradigms on green and social sustainability performance (López and Ruiz-Benítez, 2020). For instance, contingency planning has been identified as a promising approach to decrease the consumption of hazardous or toxic materials and the frequency of environmental accidents, ultimately leading to better environmental and social performance outcomes (Ruiz-Benitez, Lopez, and Real, 2017). Similarly, a flexible supply base, as one of resilience paradigms, could decrease the fee for waste treatment (for superior economic performance) (Ruiz-Benitez, Lopez and Real, 2019), facilitate the communication of environmental criteria (for better environmental performance) (Ruiz-Benitez, Lopez and Real, 2017) and increase in safety and healthy working environment (as social performance measure) via the development of disaster recovery plan (López and Ruiz-Benítez, 2020).

The resilience paradigm is considered crucial for an SC's survival. Business continuity and integration of the resilience and sustainability paradigm can benefit the ecological environment and social welfare. Moreover, when SC undertakes resilience practices related to sustainable development, those activities increase economic performance and benefit the ecological environment and social welfare. Gimenez, Sierra, and Rodon (2012) illustrated the positive impacts of SC collaboration (i.e., implementation of supplier development) for product and process innovation on TBL sustainable performance. Resilience practices would enhance resilience (e.g., risk reduction) and TBL's sustainable performance.

On the other hand, sustainability paradigms contribute to SC resilience performance. Conducting social or environmentally sound initiatives would enable SC systems to keep pace with a competitive and ever-changing environment. On this basis, SSCM can contribute to resilience performance by reducing the likelihood and impact of disruptions and increasing the flexibility of the SC. From the perspective of risk appreciation, environmental and ethical behaviour (i.e., internal awareness, monitoring, and sharing of best practices) would facilitate the appreciation of both relational and performance risks (Gallear et al., 2015). Cruz and Wakolbinger (2008), Cruz (2009) and Curz (2013) have mathematically examined the effects of CSR activities on risk reduction within complex SC network structures.

Circular economy, sustainable sourcing, and eco-design approaches may all have a good influence on SC resilience. The circular economy idea, which includes dynamic remanufacturing capabilities (Bag, Gupta and Foropon, 2019), would also be seen as an important method for achieving SC resilience (Gaustad et al., 2018; Park, Sarkis and Wu, 2010). Sustainable sourcing can promote supplier diversity and reduce the risk of SC disruption (Chiang, Kocabasoglu-Hillmer and Suresh, 2012; Fan, Stevenson and Li, 2020). Likewise, eco-design practices can improve product quality, reduce material usage, and enhance the durability of products, thereby reducing the need for repairs and replacements (Bag, Gupta and Foropon, 2019; Dangelico, Pujari and Pontrandolfo, 2017). recognised that two types of risk management performance could be positively and directly affected by multiple sustainable purchasing practices in various Finnish industries. Resilience efforts (e.g., reactive risk mitigation practices) may not be effective on their own, but the interaction with sustainability efforts (e.g., sustainable supplier development, Gouda and Saranga, 2018; multiple sustainable purchasing practices, Hallikas, Lintukangas and Kähkönen, 2020) would bring unexpected benefits (Gouda and Saranga, 2018).

In a sense, either SC resilient or SSCM paradigm could yield composite SC performance. However, the impacts would be different due to the priority of SC paradigm. For instance, SSCM may be incompatible with resilience objectives, such as maintaining flexibility and responsiveness to unexpected events. SSCM practices may be associated with increased costs, longer lead times, and reduced flexibility, thereby increasing the vulnerability of the SC to disruptions (Huo et al., 2016).

Based on the discussion above, this study considers the SC paradigms integrating SC resilience and SSCM, are the direct driver for composite performance outcomes. The following propositions are proposed:

Proposition 3a: SC resilient paradigm have a positive impact on (i) resilient performance and (ii) sustainable performance.

Proposition 3b: SC sustainable paradigm have a positive impact on (i) resilient performance and (ii) sustainable performance.

Proposition 3c: The performance outcomes of SC resilient paradigm are different from SC sustainable paradigm.

3.3.4 Moderating effects of SC structures

Based on the literature review, the extant research investigated multiple types of SC structures as the research setting but mostly ignored the consequences of SC structures on the association between SC paradigms and performance outcomes. Among the four structures identified (i.e., SC node, forward SC, reverse SC, and CLSC), reverse flows of goods and services attract less attention from OM scholars.

However, reverse structure, reflecting the circular economy principle, would strengthen SC resilience by reducing the critical materials' disruption risks via recycling/remanufacturing/reusing used products (Gaustad et al., 2018; Park et al., 2010). It is also convinced that reverse channel would help to mitigate SC risks/risk propagation (Özçelik et al., 2020), which needs to be validated by further empirical investigation.

Building upon the foundations of CAS and SNT, SC structure plays a pivotal role in determining the effectiveness of internal mechanisms in attaining targeted performance goals. SC structure, as an embodiment of the intricate relationships and interconnections within the SC, fosters enhanced visibility and transparency by facilitating seamless information sharing (Gualandris et al., 2021). Additionally, it supports robust vertical and horizontal collaboration (Schilling and Phelps, 2007; Sharma et al., 2022) and stimulates the generation and dissemination of valuable knowledge throughout the network (Bellamy, Ghosh and Hora, 2014).

Effective communication and information flow between different actors in the SC can be achieved through the (re)design of SC structure, leading to increased visibility and transparency. This is particularly crucial in geographically dispersed SCs or when there is limited visibility into upstream or downstream activities. The creation of a transparent and visible SC structure facilitates information sharing, allowing for a better understanding of the risks and vulnerabilities present in the SC system (Gualandris et al., 2021). Such transparency and information sharing can promote better coordination and collaboration between different actors in the SC, which is essential for effective risk management and the creation of more sustainable and resilient SCs (Maghsoudi and Pazirandeh, 2016). Both vertical and horizontal collaboration can be facilitated by the SC structure, enabling coordination and cooperation between different stages of the SC and between other actors in the same stage. Such collaboration can foster innovation and enhance communication and coordination in response to unexpected events. Additionally, the SC structure can promote knowledge creation and transmission, enabling the flow of knowledge and ideas between different actors in the SC system, and leading to the development of new processes and products.

These influential factors contribute significantly to the SC's overall resilience and sustainability performance. However, it is crucial to recogniserecognize that the SC structure does not directly function as a driver or barrier to SC paradigms. Instead, it acts as a contingency factor, moderating the relationship between SC paradigms and their subsequent performance outcomes. This underlines the importance of understanding the intricate interplay between structural attributes and various SC paradigms to optimise resilience and sustainability performance.

In accordance with the previous literature, the following hypothesis is proposed:

Proposition 4: The relationship between SC paradigms and performance outcome is moderated by SC structure.

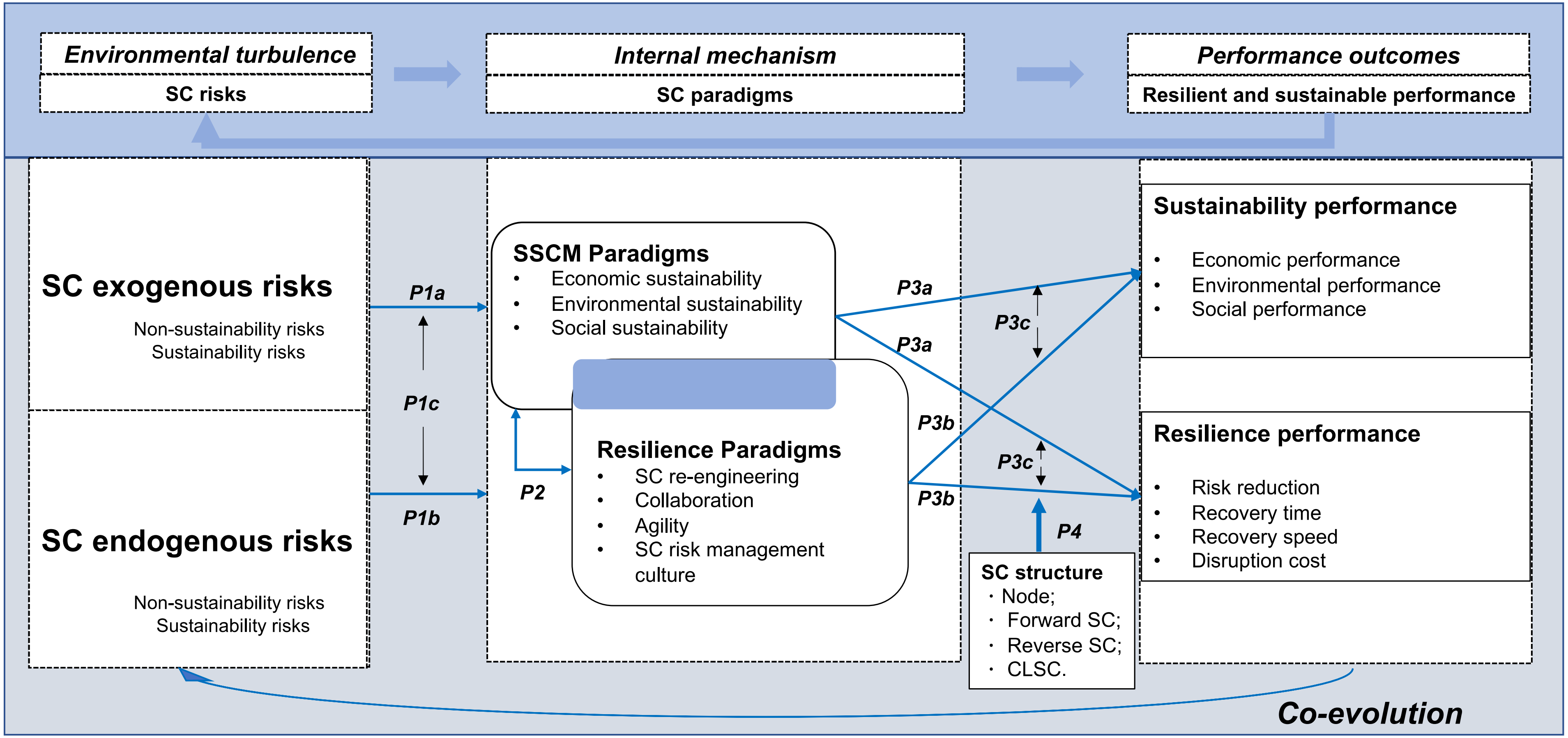

Figure 12 Theoretical framework

3.4 Summary

Chapter 3 functions as a bridge between the literature evidence of the SSCM-resilience interaction mechanism (i.e., **Chapter 2**) and the conceptual framework for empirical testing (i.e., **Chapter 5**). The aim of this chapter is twofold: 1) to address **RQ2** and serve as a theoretical foundation which integrates SC resilience and SSCM; 2) to provide a guideline for proposing a theoretical framework for empirical testing.

This chapter seeks to justify the suitability and complementarity of employing CAS and SNT as theoretical lenses in **Section 3.2**. By leveraging the core concepts of CAS and SNT, this chapter establishes the basis for the integrative theoretical framework proposed in **Section 3.3**. The theoretical framework investigates the driving forces of SC risks, encompassing both sustainability and non-sustainability hazards originated from internal and external SCs, and how they connect to the implementation of SC paradigms. The framework, in particular, posits interconnections between the resilience and SSCM paradigms, as well as their influence on potential performance outcomes. Furthermore, in the theoretical framework, SC structure is seen as a contingency element for the SC paradigms-performance connection to reflect the co-evolution of the SC system and its system environment.

By developing a set of hypotheses in **Section 3.3**, this chapter proposes an integrative theoretical framework that highlights the intricate relationship between SC resilience and SSCM. Specifically, the framework seeks to elucidate the mechanisms through which SC risks impact the adoption of SC paradigms and how these paradigms, in turn, affect composite performance outcomes. This chapter advances the understanding of the complex interplay between SC resilience and SSCM and serves as the theoretical foundation for the subsequent empirical study in **Chapter 5**.

Chapter 4 Conceptual Framework and Hypotheses

4.1 Introduction

Chapter 4 provides the conceptual frameworks for general empirical studies and develops hypotheses for the current empirical study on the interplay between SC resilience and SSCM practices, where both concepts have equal dominance. Section 4.2 demonstrates the streams of empirical studies of the interaction of SC resilience and SSCM by first analysing the formulation of conceptual frameworks and therefore the positioning of this empirical study is identified. Section 4.3 develops hypotheses on relationships among SC resilience, SSCM practices, and firm performance with the consideration of dimensions of SSCM and scales of SC resilience. The hypotheses development serves as the foundation of the empirical examination in Chapter 5.

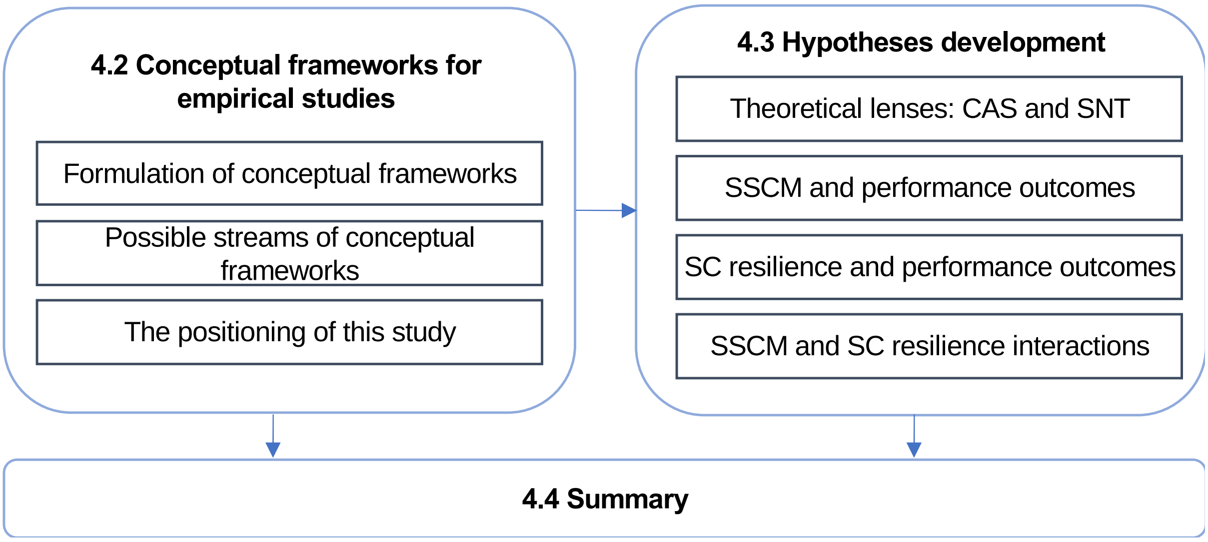

Figure 13 Structure of Chapter 4

4.2 Conceptual frameworks for empirical studies

4.2.1 The formulation of conceptual frameworks

The theoretical framework drawn upon CAS and SNT provides a holistic view of the interaction mechanism between SSCM and SC resilience, referring to the internal mechanisms within SC network-structured systems in response to environmental turbulences for desirable performance outcomes. It investigates SSCM and SC resilience as distinct yet overlapping SC paradigms, incorporating attributes from both perspectives. Although new overlapping concepts between SSCM and SC resilience are emerging, this study concentrates on investigating their interaction mechanisms as distinct paradigms. Three aspects of the interaction mechanism – the types of interaction mechanism, the focus of interactions, and the extension mechanism – are investigated to develop a conceptual framework that guides future empirical research.

The form of interaction mechanism implies the interaction types between SSCM and SC resilience in empirical studies. From this perspective, two types of interaction mechanisms are discussed – moderation and mediation. In the context of this research, a moderation interaction implies that the relationships of SSCM practices (or SC resilience) on performance outcomes are contingent upon the presence or degree of SC resilience (or SSCM practices), known as a moderator. For instance, the influence of SSCM practices on financial performance might be stronger or weaker depending on the level of SC resilience. Conversely, mediation interaction occurs when the main relationship between two variables (e.g., SSCM practices and financial performance) is explained or facilitated by one or more intervening variables (e.g., SC resilience), known as mediators. A mediation interaction between SSCM practices and SC resilience suggests that the association between the two constructs is facilitated by either SSCM practices or SC resilience acting as a mediating variable. The conceptual frameworks could offer a more nuanced understanding of the potential interplay between SSCM and SC resilience for empirical studies by differentiating between moderation and mediation interactions. Therefore, mediation and moderation are the two forms of interaction mechanisms considered in the formulation of conceptual frameworks.

The interaction mechanism focuses on the principal variable or construct under investigation in empirical studies, typically represented by the independent variable(s) in empirical models. The focus of interactions can centre on the exploration of SSCM practices or SC resilience. Specifically, two types of focus emphasise the investigation of SSCM practices and the potential effects of SC resilience on SSCM practices and vice versa. Therefore, this study promotes the equal prominence of SSCM practices and SC resilience in the investigation of interaction mechanism.

The extension mechanism, an additional interaction mechanism operating alongside the SSCM-resilience interplay, alludes to other factors that shape the interaction mechanism between SSCM practices and SC resilience. Based on the theoretical framework, two extension streams can be proposed, encompassing the driving forces and performance outcomes. The driving force extension refers to various external and internal factors that motivate or facilitate the interaction between SSCM practices and SC resilience. In this context, the driving force encompasses SC risks derived from internal and external SCs concerning sustainability and non-sustainability issues. The performance outcome extension focuses on the subsequent consequences of SSCM-resilience interactions and can help identify the potential benefits of aligning SC resilience and SSCM initiatives. Therefore, this study considers risk-driven and performance-driven extensions.

4.2.2 Possible streams of conceptual frameworks

To better understand the interplay between SSCM and SC resilience, conceptual frameworks can be developed by characterising the interplay between SSCM and SC resilience from different types of interactions (i.e., mediation and moderation), depending on the emphasis of the interaction mechanism (i.e., resilience- or SSCM-focused), and the extension of interaction mechanism regarding driving forces (i.e., SC risks) and performance outcomes. Conceptual frameworks of SSCM-resilience interactions can be summarised in two main streams based on this approach. **Figure 14** and **Figure 15** demonstrate potential mediation and moderation interactions between SSCM and SC resilience, respectively. Given that only direct moderation and mediation pathways are included in the figures.

On the one hand, SSCM and SC resilience are intertwined in mediation interactions with the assumption of cause-and-effect relationships. **Figure 14** illustrates the potential mediation interactions, where the left and right parts of the figure represent risk-driven and performance-driven mechanisms, respectively. In each part, SSCM-resilience interactions are classified into a) SSCM-focused and b) resilience-focused. In SSCM-focused interactions, SC resilience is a mediator that facilitates the relationship between the risks-SSCM or SSCM-performance relationship. Alternatively, in resilience-focused interactions, SSCM is a mediator that facilitates the relationship between the risks-SC resilience or SC resilience-performance relationship.

In moderation interactions, the relationship between SSCM and SC resilience is also complex and can have either reinforcing or buffering effects on each other. Similarly, **Figure 15** demonstrates the potential moderation interactions, with the left and right parts of the figure representing risk-driven and performance-driven mechanisms, respectively. The moderator is chosen accordingly to the focus of the interaction mechanism. In SSCM-focused interactions, the emphasis is on how the main relationships of SSCM practices can be moderated by SC resilience on performance outcomes. For example, a high level of SC resilience may buffer the negative effects of inadequate SSCM practices on performance outcomes. In resilience-focused interactions, the emphasis is on how SSCM practices can moderate the main relationship of SC resilience. For instance, a low level of SSCM practices may hinder SC resilience, making the SC more vulnerable to disruptions and reducing performance outcomes.

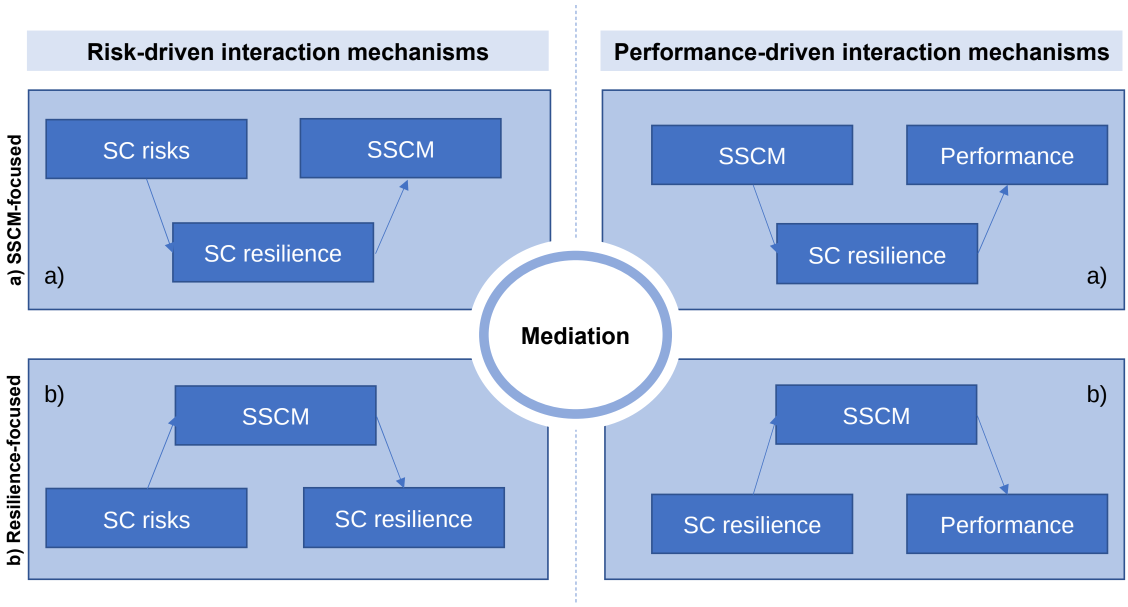

Figure 14 Mediation interactions between SSCM and SC resilience

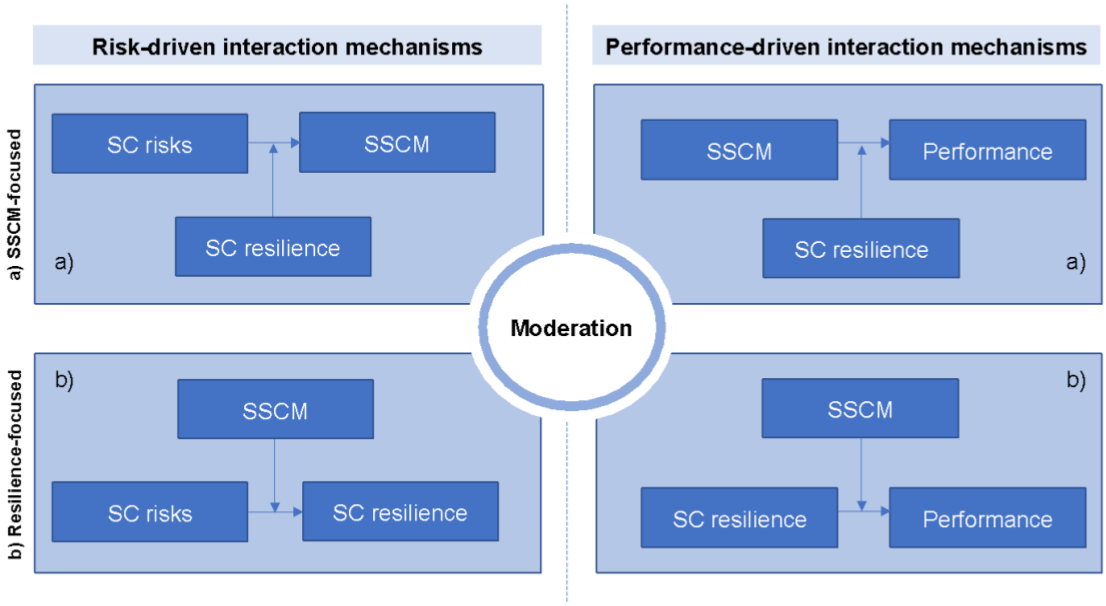

Figure 15 Mediation interactions between SSCM and SC resilience

4.2.3 The positioning of this study

The proposed conceptual frameworks emphasise the nature of the interaction between SSCM and SC resilience, differentiating between mediation and moderation interactions. This study focuses on potential synergies or trade-offs between SSCM and SC resilience (see **Figure 16**), referring to the moderation mechanism rather than cause-effect relationships between the two variables. As such, the research centres on the moderation interaction between SSCM and SC resilience, where the level of SC resilience (or SSCM) may influence the strength or direction of the associations between SSCM (or SC resilience) and performance outcomes.

In response to **RQ3**, the conceptual framework should integrate a performance-driven extension mechanism, enabling the collection of empirical evidence to ascertain whether the interaction between SSCM and SC resilience can be leveraged to improve performance outcomes. To emphasise the significance of sustainability and advocate the benefits of developing sustainable SCs, this study prioritises the interaction mechanism, concentrating on both SC resilience and SSCM practices. This study seeks to provide valuable insights into the performance-driven SSCM-resilience moderation interactions by advocating equal prominence on SC resilience and SSCM.

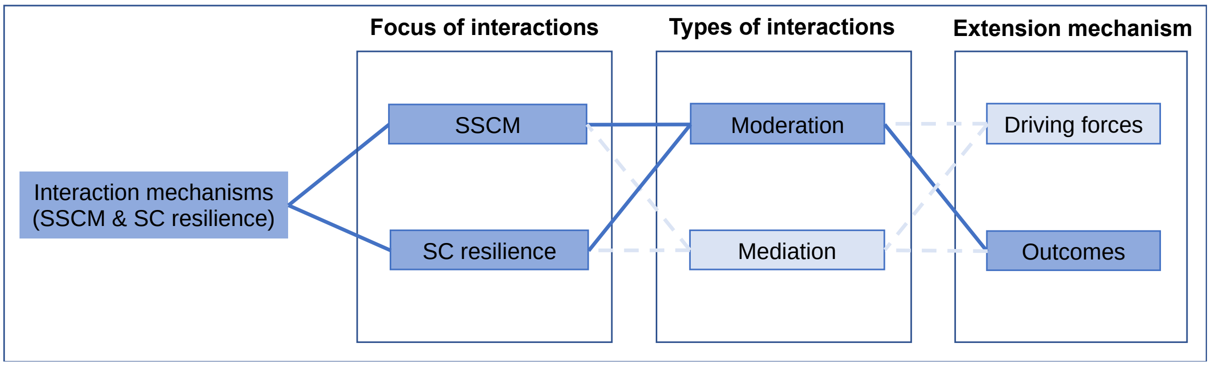

Figure 16 The positioning of this study

Source: Author.

4.3 Hypotheses development

With the support of theoretical lenses and literature evidence on the SSCM-resilience interaction mechanism, hypotheses are formulated in this section for the development of the conceptual framework (see **Figure 17**) and the design of empirical models.

4.3.1 Theoretical lenses: CAS and SNT

Drawn upon CAS and SNT, this study advocates SCs as social network-structured CASs. SCs have been conceptualised as CASs (Choi, Dooley and Rungtusanatham, 2001; Wycisk, McKelvey and Hülsmann, 2008; Braz and Marotti de Mello, 2022), engaging with their surroundings, adjusting and co-evolving. (Wycisk, McKelvey and Hülsmann, 2008). The nature of CASs suggests that individual SC member's choices can contribute to the formation of new dynamism and emergence, even if no individual firm can decide the resilience or sustainability of the entire SC (Abbasi and Varga, 2022). SNT echoes that the complex dynamics can be rooted in the SC structure, which is formulated by relationships and interdependencies among SC actors (Kim et al., 2011; Choi and Wu, 2009). It implies that the importance of network structure as a collaborative foundation for adaptation and co-evolution towards the system environment.

SCs, as network-structured adaptive systems, can use dynamic learning to align with the environment (Wycisk, McKelvey and Hülsmann, 2008). Furthermore, CASs undergo transformations involving radical changes resulting in fundamentally different systems. SNT interprets the transformation through the ties among network actors, which can influence the strength and direction of the flow of information, resources, and knowledge.

SC resilience and SSCM are adaptive phenomena (Adobor and McMullen, 2018; Rammel, Stagl and Wilfing, 2007; Alinaghian, Qiu and Razmdoost, 2021). The characteristics of CASs, as well as the depiction of SCs as a network-structured CASs, imply that resilience in SCs is best understood as a dynamic and nonlinear term since it is a property of such dynamic systems. (Adobor and McMullen, 2018). CAS and SNT theories are applicable to sustainable SCs, which strive to adapt to environmental and societal expectations (Novak, Wu and Dooley, 2021). Sustainability-related issues can be viewed as a distinct system environment of CASs, guiding SCs to launch SSCM initiatives to evolve in response to changing expectations from society and environmental expectations. And SNT explains how these relationships are formed, maintained, and leveraged for sustainability, such as reducing environmental impacts and promoting social responsibility (Beske and Seuring, 2014). Therefore, CAS and SNT are adopted as the theoretical lens for hypothesis development.

4.3.2 SSCM and performance outcomes

SSCM measurement is essential for evaluating the effectiveness of sustainability efforts and practices within SCs. Common measurements include key performance indicators (KPIs) such as energy consumption, water usage, and waste reduction, as well as more comprehensive metrics based on the TBL framework, which evaluates an organisation's social, environmental, and economic performance (Elkington, 1998). SSCM encompasses a wide range of practices promoting social responsibility and environmental sustainability throughout the SC system, including environmental and social SSCM practices. Environmental SSCM practices are defined in this study as a group of actions that improve environmental performance throughout the product or service lifecycle, encompassing development, production, procurement, and distribution, ultimately reaching the end-client through the SC (Golicic and Smith, 2013; Govindan et al., 2020). Furthermore, **social SSCM practices** refer to a variety of approaches that improve social performance such as safety, equity, ethics, human rights, health, and welfare during the creation, procurement, manufacturing, and distribution stages of a product or service inside the SC (Nichols et al., 2019; Govindan et al., 2020).

4.3.2.1 Financial performance

The impacts of SSCM adoptions have evoked much interest among researchers. However, the extant studies exhibit two streams of empirical research that come to opposite conclusions regarding the performance impacts of SSCM practices. While some studies reveal a positive relationship between the SSCM and firm performance; some others indicate a negative relation; and still others establish no relation between SSCM practices and firm performance (e.g., Green et al., 2012; Wong et al., 2017; Zhu et al., 2013). Some studies investigate the interactive mechanism between SSCM non-financial performance (e.g., operational and environmental performance) and financial performance (Liu et al., 2022; Mishra and Suar, 2010; Feng et al., 2018; Maletič, Gomišček and Maletič, 2021), which confirms that SSCM investments can yield positive outcomes through indirect effects on environmental and operational performance (Mishra and Suar, 2010; Yang, Hong and Modi, 2011). The negative direct impacts of environmental SSCM on financial performance could be offset by the indirect positive effect of environmental SSCM on environmental and operational performance (Feng et al., 2018).

Meta-analytical studies have witnessed the common patterns in financial improvement of SSCM initiatives. Golicic and Smith (2013) and Geng, Mansouri and Aktas (2017) focus on green SSCM practices and their performance outcomes. They imply that the association between environmental SSCM practices and financial performance is typically favourable and considerable, particularly in the industrial sectors of rising Asian nations. Wang et al. (2016) and Velte (2021), support the notion that social SSCM enhances financial performance and that firms can "do well by doing good". By incorporating environmental and social SSCM practices under the same meta-analytical framework, Friede, Busch and Bassen (2015) and Govindan et al. (2020) emphasise the benefits of SSCM dimensions on financial performance. As a result, this research anticipates a favourable linkage between SSCM and financial success.

The study's prediction of SSCM's desirable influence on firm performance is consistent with CAS and SNT's logic. SC partners align, cooperate, and co-evolve together within the system context. The adaptive and self-evolving capabilities enable

SC systems to cope with unexpected events (e.g., natural disasters, trade policies and regulations). Particularly, facing the worsening natural environment and the corresponding de-carbonisation regulations, SCs are required to take **environmental SSCM practices** to offset the adverse environmental impacts derived from the business activities and even to build up the positive carbon credit (i.e., do good to the environment). With the emphasis on fairness and humanity in the working environment, **social SSCM efforts** are required to help to improve gender equality, employee rights, etc. The adoption of environmental and social SSCM entitles the flexibility (Liu et al., 2019) within the SC system to cope with the changes in the ecological and social environment, which could potentially contribute to the operation efficiency (Vachon and Klassen, 2008) or competitive advantages against competitors along with the extra cost of launching and implementing sustainability-related initiatives.

CAS highlights the importance of SSCM practices in adapting to the environment by mitigating environmental risks and meeting regulatory requirements. For instance, firms that engage in fair labour practices and prioritise worker safety are better equipped to adapt to new regulations, labour market shifts, and stakeholder expectations (Pagell and Wu, 2009; Montabon, Pagell and Wu, 2016). This adaptability can improve firm performance, as firms can more effectively manage risks and seize opportunities in the ever-changing business landscape (Chaudhuri et al., 2021). Moreover, SNT suggests that organisations with strong social connections are more likely to access valuable resources, information, and opportunities (Borgatti and Li, 2009). By implementing SSCM practices, firms can strengthen their social networks with stakeholders such as customers, employees, suppliers, and communities. These relationships facilitate the exchange of knowledge (E. Cantor et al., 2014), foster trust (Amiraslani et al., 2022), and promote collaboration (Arora et al., 2020), all of which contribute to better financial performance (Liu et al., 2022). The joint view of CAS and SNT suggests that effective SSCM practices enables firms to build stronger social connections (SNT) and enhance their adaptability to environmental changes (CAS), ultimately leading to long-term financial success.

Environmental SSCM may result in financial improvements due to reduction on carbon tax and pollution fines. (Darom et al., 2018), and resource wastage (Sumrin et al., 2021) or by better margins obtained through eco-design products or services in niche markets towards environmentally conscious customers (Cousins et al., 2019). Implementing social SSCM practices has been linked to improved brand reputation, customer satisfaction, and stakeholder engagement, ultimately leading to enhanced financial performance (Velte, 2021; Fatima and Elbanna, 2022; Beske-Janssen, Johnson and Schaltegger, 2015). According to Govindan et al. (2020), this research also looks into s the performance effects of various SSCM practices dimensions. The implementation scale, investment cost, and launch process of each SSCM practice may vary. Implementing social, environmental, and governance SSCM will likely enhance financial outcomes at various levels. .

H1: SSCM improves financial performance.

H1a: Environmental SSCM improves financial performance.

H1b: Social SSCM improves financial performance.

H1c: Governance SSCM improves financial performance.

4.3.3.2 Innovation performance

Moving beyond financial performance, it is crucial to consider innovation performance as another vital aspect of SSCM (Kwak, Seo and Mason, 2018; Nilsson and Göransson, 2021; Wong and Ngai, 2019). SSCM practices that prioritise stakeholder engagement and social responsibility can be potential sources of innovation and business competitiveness (Porter and Kramer, 2006).

SSCM practices drive innovation, as supported by various studies and concepts in the field. SSCM practices drive the innovation process (e.g., new product development) (Fung et al., 2021) and enhance resource efficiency, decreasing waste and expenses (Thapa Karki, Bennett and Mishra, 2021; Arora et al., 2020). Firms adopting SSCM practices can access higher-quality and fully disclosed resources more smoothly, allowing for greater innovation and reduced environmental impact (Arranz, Arguello and Fernández de Arroyabe, 2021). SSCM practices encourage firms to adopt eco-friendly technologies and practices (Sumrin et al., 2021), leading to the establishment of novel products and systems which are both commercially and ecologically sustainable. By embracing SSCM, firms can overcome information asymmetry and better organise their resources in the SC network, (Hsin Chang, Hong Wong and Sheng Chiu, 2019). This enables them to focus on core technologies and innovation activities that prioritise sustainability and long-term growth (Kwak, Seo and Mason, 2018). SSCM fosters a variety of innovation strategies, such as circular economy models (Braz and Marotti de Mello, 2022), collaborative consumption (Małecka et al., 2022), and biomimicry-inspired design (Chen et al., 2022), which inject new momentum into firms' innovation efforts and contribute to a greener, more sustainable future (Ghobakhloo et al., 2021).

The principles of CAS and SNT can extend the understanding of the associations between SSCM and innovation performance. CAS theory highlights the role of adaptability and learning in response to environmental and social changes, fostering innovation as firms develop new processes (Shukla, Vipin and Sengupta, 2022), new products (Fung et al., 2021), and strategies (Arora et al., 2020) to address emerging sustainability challenges (Ghobakhloo et al., 2021). Evidence supports that environmental regulation increases firm innovativeness towards reducing social and environmental harm, also called sustainable innovation or sustainability-oriented innovation (Hansen, Grosse-Dunker and Reichwald, 2009). As firms engage with their partners and stakeholders, they can access valuable resources, information, and opportunities contributing to their innovation outcomes (Broadstock et al., 2020). By integrating CAS and SNT perspectives, this study can explore how the adoption of SSCM practices also drives innovation performance, allowing firms to maintain their competitive edge in the long run.

Concurrently, SNT suggests SSCM practices can facilitate knowledge sharing (Dröge, Claycomb and Germain, 2003) and joint problem-solving (Jääskeläinen, 2021) for innovation through the establishment of strong social ties and the development of organisations' reputations (K. Roehrich, Grosvold and U. Hoejmose, 2014). Firms that engage in stakeholder engagement and social responsibility practices are more likely to have stronger connections with customers, which can result in better communication and collaboration (Andersson et al., 2022). These practices can also help firms build trust and credibility with their stakeholders, which is essential for creating a positive image in the market and attracting potential partners and customers (Das and Hassan, 2021). Moreover, engaging with stakeholders can give firms access to unique perspectives and insights that can inspire the development of innovative products and services (Chatterjee and Chaudhuri, 2021). Firms embedded in networks with other firms prioritising SSCM practices are more likely to adopt SSCM practices themselves and innovate in this area (Touboulic and Walker, 2015; Nair et al., 2016). CAS and SNT have been used to explain how social connections and relationships can facilitate SSCM knowledge-sharing and collaboration for innovation under stakeholder pressures. Therefore, it can be argued that SSCM practices have the potential to impact innovation performance positively.

H2: SSCM improves innovation performance.

H2a: Environmental SSCM improves innovation performance.

H2b: Social SSCM improves innovation performance.

H2c: Governance SSCM improves innovation performance.

4.3.3 SC resilience and performance outcomes

This research investigates the associations between SC resilience and performance outcomes. Limited evidence could be found to clarify the empirical linkages between SC resilience and performance, as some scholars view SC resilience as a consequence (e.g., Btandon-Jones et al., 2014; Pettit et al., 2013) instead of a capability (Gölgeci and Kuivalainen, 2020; Gölgeci and Ponomarov, 2015; Ponomarov and Holcomb, 2009). Existing research indicates that SC resilience improves business performance (Li et al., 2017; Chowdhury, Quaddus and Agarwal, 2019; Li et al., 2017; Akgün and Keskin, 2014), including improving customer value (Wieland and Marcus Wallenburg, 2013; Govindan et al., 2014), SC reconfiguration (Al Naimi et al., 2020), SC performance (Pettit *et al.* 2013), effectiveness in risk management (Wong et al., 2020), organisational efficiency (Essuman, Boso and Annan, 2020), market performance (Wong et al., 2020), and financial performance (Wong et al., 2020; Yu et al., 2019; Gölgeci and Kuivalainen, 2020; Li et al., 2017).

Christopher and Peck (2004) offered a framework of SC resilience principles, identifying SC reengineering, agility, collaboration, and risk management culture as the four pillars of SC resilience. These capabilities have been theoretically and empirically tested as enablers of SC resilience (Delbufalo, 2022; Dubey et al., 2020; Azadegan, Modi and Lucianetti, 2021; Fan, Stevenson and Li, 2020). However, empirical evidence on resilience-performance mechanisms is unclear for two reasons. First, SC resilience as a meta-capability is unobservable, and the scales of resilience formative capabilities lack consensus in the literature (Castillo, 2022). Second, the formative capabilities of SC resilience are intertwined (Braunscheidel and Suresh, 2009; Abeysekara, Wang and Kuruppuarachchi, 2019; Al-Refaie, Al-Tahat and Lepkova, 2020). Therefore, to address these challenges, this study considers SC resilience as a structure-based adaptive capability from the theoretical lenses of CAS and SNT. SC resilience can be viewed at firm, dyads, and network levels. Resilient firms are better equipped to handle disruptions and exploit opportunities. This, in turn, enhances their financial performance and innovation performance.

SC resilience enables improved performance in turbulence and uncertainty (Shashi et al., 2020; Chowdhury, Quaddus and Agarwal, 2019; Kwak, Seo and Mason, 2018; Shamout, 2019; Chinomona and Omoruyi, 2016). Firms that develop resilience at different levels of their SC (i.e., firm level, dyads level, and network level) are better equipped to deal with environmental disturbances, such as sudden changes in demand or SC disruptions (Azadegan, Modi and Lucianetti, 2021). This improved resilience can lead to better financial performance as firms can reduce the costs associated with disruptions and maintain continuity in their operations. Resilience helps reduce the possibility of SC risks or the magnificence of adverse impacts and enables SCs to respond to warnings and signals agilely (Akgün and Keskin, 2014).

Dyads-level resilience emphasises relational management (SNT) (Chowdhury, Quaddus and Agarwal, 2019) and collaborative capabilities (Dubey et al., 2020) within the SC network, which can improve financial and innovation performance. For instance, SC collaboration enables firms to address cooperation and coordination concerns via inter-organizational and relational controls for better collaborative performance, which can enhance the adaptability and flexibility of the SC to cope with uncertain and turbulent environments. It is simpler for focus enterprises to respond to changing end-market trends and eliminate demand-side risks through a cooperative innovation strategy with important customers (Danese and Romano, 2013), leading to improved innovation performance (Fianko et al., 2022). Additionally, redesigning contingency plans and resource slack across the SC network helps SC to be redesigned and reshuffled to reduce vulnerabilities and respond to unintended shocks by examining the trade-offs between efficiency and redundancy (Adobor and McMullen, 2018). Instinctively, firms and SCs could minimise supply risks by maintaining good connections with multiple suppliers and developing backup suppliers to handle disturbances and disruptions in the upper-stream SCs (Golgeci and Y. Ponomarov, 2013; Ambulkar, Blackhurst and Grawe, 2015), leading to improved financial performance, reputation (K. Roehrich, Grosvold and U. Hoejmose, 2014), and competitive advantage (Kwak, Seo and Mason, 2018).

Network-level resilience should be emphasised in the era of uncertainty (Bondeli and Havenvid, 2022), as network structure can be seen as an antecedent of SC resilience (Bode and Wagner, 2015; Bode and Macdonald, 2017; Reyes Levalle and Nof, 2015). Adapting SC network structure to the business environment and maintaining a stable and resilient status is the core content of SC resilience from the perspective of CAS theory. Aligned SC networks enable firms proactively respond to unforeseen risks with the capability to detect changes (Li et al., 2017). The formative capability view of SC resilience cannot guarantee the distinct boundary among SC resilience sub-constructs. From an SC re-configuration perspective, Al Naimi et al. (2020) verified SC agility, collaboration, and risk management culture contribute more to SC resilience than SC integration, which therefore helps the firm to reallocate the resources and restructure the SC network to adapt to the external challenges and risks (Wieland and Marcus Wallenburg, 2013) and bouncing back from the adversity (Bondeli and Havenvid, 2022).

Despite the fact that scholars and practitioners have paid close attention to SC resilience due to the increasing probability of various types of SC disruption in the global environment, there is no agreement on the sub-constructs or impacts of SC resilience as of yet (Kamalahmadi and Parast, 2016). It is valuable to extend current research on the comparison of resilience dimensions regarding performance consequences. Depends on the evidence presented above, it is argued that

H3: SC resilience improves financial performance.

H3(a): Focal-level SC resilience improves financial performance.

H3(b): Dyads-level SC resilience improves financial performance.

H3(c): Network-level SC resilience improves financial performance.

H4: SC resilience improves innovation performance.

H4(a): Firm-level SC resilience improves innovation performance.

H4(b): Dyads-level SC resilience improves innovation performance.

H4(c): Network-level SC resilience improves innovation performance.

4.3.4 SSCM and SC resilience interactions

Recent research suggests that the relationship between SSCM and resilience has not yet been fully explored. There is a need for a more in-depth investigation to understand the complex interplay between the two concepts (Negri et al., 2021). However, it is increasingly recognised that SSCM and resilience are closely connected to the turbulent changes that SCs face (He et al., 2021). These changes are often driven by various risk factors, such as natural disasters, political instability, economic crises, technological disruptions, and social unrest. The intertwined risk drivers and stakeholders' expectation of SC resilience and SSCM implies the interaction between SSCM and resilience.

SC resilience is a complicated notion that necessitates organisations balancing triggering risks and capabilities in a social and ecological context (CAS) (Wieland et al., 2023). It is no longer just a matter of strength or equilibrium but an evolving balance that requires a continuous adaptation to changing circumstances (Wieland et al., 2023; Novak, Wu and Dooley, 2021). Therefore, SSCM practices are vital in supporting organisations to build and maintain their resilience capabilities and influence performance outcomes.

One of the main objectives of SSCM is to manage SC risks effectively. As the scope of SC risks is extended to reflect societal and environmental stakeholders' expectations, it is critical to link SC risks to sustainability considerations to support SCs in diagnosing risks and reducing complexities (Wu et al., 2017; Giannakis and Papadopoulos, 2016). Sustainability risks are categorised on the basis of the potential consequences of risks, including economic or financial risks (e.g. inflexibility of supply source, poor quality of products, information sharing risks, bribery, boycotts), environmental risks (e.g. natural catastrophes, inefficient use of resources, environmental pollution, hazardous waste creation), and social risks (e.g. dangerous working environment, violation of human rights, failure to meet targets) (Hofmann et al., 2014; Giannakis and Papadopoulos, 2016). The success of SSCM practices requires firms' capability to identify, assess, and mitigate these risks effectively, building their resilience capabilities. Resilient SC enables a quick implementation and adaptation of SSCM practices through supplier-customer partnerships and risk mitigation management (Choudhary et al., 2022).

SSCM practices are viewed as the approach for mitigating SC risks and achieving SC resilience. Cruz and Wakolbinger (2008), Cruz (2009) and Curz (2013) have examined the effects of CSR activities on risk reduction within complex SC networks. Social SSCM seems to be a costly sustainability investment, but it also implies a long-term benefit on SC economical, environmental, and SC resilience in terms of proactively reducing potential risks (e.g., production uncertainty, network-related risks, and social-political risks; supply-side disruption risks, demand-side risks, exchange rate risk, and social risk). Environmental sound practices also help to increase SC resilience (Park et al., 2010; Gaustad et al., 2018). Park et al. (2010) and Gaustad et al. (2018) revealed the value of circular economy practices for the reduction of SC vulnerability in terms of supply-related uncertainty, where reverse channels could create innovative sourcing options and could dilute the adverse impacts of risk propagation (Bae et al., 2019; Özçelik et al., 2020). Moreover, environmentally sound practices could build organisational legitimacy and improve public image, benefiting the informal interrelationships with SC partners. Empirical evidence confirmed that sustainable practices enable SCs to manage operational, regulatory, reputational (Rehman, Khan and Rahman, 2020), and environmental risks more effectively (Lam, 2018; Gouda and Saranga, 2018; Hallikas, Lintukangas and Kähkönen, 2020).

SC resilience and sustainability are interconnected concepts vital to achieving long-term success in business operations. While SC resilience primarily focuses on business continuity, sustainability aims to continue the business by doing good for the ecological and social environment. Despite the differences in priorities, recent research suggests that both resilience and sustainability are essential for the long-term success of SCs.

According to CAS and SNT, SC's development goals are dynamic and non-linear. This implies that achieving SC resilience and sustainability can be obtained as prioritised strategic weapons to solve specific temporary problems. It also reflects that SC resilience and sustainability are not competing but complementary. A sustainable approach to supplier selection, for example, can lower the chance of interruption while increasing the SC's resilience. In addition, sustainable customer collaboration demonstrates resilience and sustainability traits in SCM procedures. (Zhang et al., 2019), sustainable integration (Syed et al., 2019), green supplier development (Bag, Gupta and Telukdarie, 2018), eco-innovation (Ch'ng, Cheah and Amran, 2021), dynamic remanufacturing capabilities (Bae et al., 2019), and sustainable risk management (Rajesh, 2019). For instance, sustainable collaboration and cooperation involve collaboration between suppliers and customers to achieve sustainable outcomes and enhance the SC resilience. This approach emphasises the impact of building long-term relationships and creating mutual benefits for all stakeholders. It involves incorporating sustainable practices into SC operations, such as eco-friendly packaging and efficient transportation systems. These practices not only help to reduce environmental impact but also enhance the resilience of the SC by reducing risks associated with environmental regulations and consumer preferences.

SC resilience and SSCM could stimulate each other for superior performance. Especially resilience capabilities show direct and indirect impacts on sustainable performance. According to Govindan et al. (2014), flexible sourcing impacts economic sustainability, while flexible transportation could affect both economic and environmental sustainability. It is proved that firm-level resource redundancy and dyads-level collaboration could contribute to the ecological (Rauer and Kaufmann, 2015) and TBL sustainability (Jabbarzadeh, Sabouhi and Fahimnia, 2018; Bag, Gupta and Telukdarie, 2018; Govindan et al., 2014). SC resilience could motivate the adoption of green practices (Green et al., 2019) by mitigating environmental risks (e.g., conceptual voids regarding environmental standards) (Rauer and Kaufmann, 2015). On the other hand, SC resilience capabilities (e.g., SC partnership) bridge sustainable practices (e.g., CSR) and firm competitiveness (Chinomona and Omoruyi, 2016), and vice versa. The implementation of sustainable initiatives (e.g., circular business model) enable resilience capabilities (e.g., agility) to stimulate the enhancement of sustainable performance (Belhadi et al., 2021). In some specific contexts, sustainable practices cannot directly contribute to sustainable performance but through the indirect path (e.g., resilience-related capabilities) to generate the influence. The evidence could be seen from Edwin Cheng et al. (2021), where SC flexibility fully mediates circular economy practices to SSCM performance.

With the CAS and SNT thinking, SC resilience and sustainability as complementary strategies could complement each other to yield better performance consequences in front of various risks. As a result, the following hypotheses are developed:

H5: SC resilience positively moderates impacts SSCM-performance relationships.

H5a: SC resilience positively moderates on SSCM-financial performance relationships.

H5b: SC resilience positively moderates on SSCM-innovation performance relationships.

H6: SSCM positively moderates impacts SC resilience-performance relationships.

H6a: SSCM positively moderates on SC resilience-financial performance relationships.

H6b: SSCM positively moderates on SC resilience-innovation performance relationships.

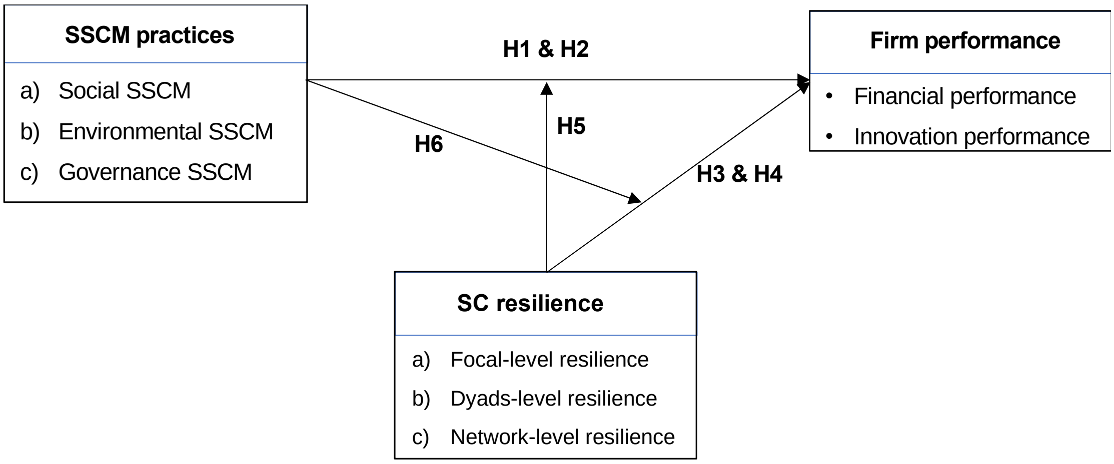

Figure 17 Conceptual framework for this study

Source: Author.

4.4 Summary

Chapter 4 serves as the theoretical foundation for the following chapters of empirical studies. The general conceptual frameworks are proposed initially for overall empirical research on the intersection of SC resilience and sustainability, among which the current empirical study treats SC resilience and sustainability with equal importance and focuses on the moderation effects deprived from hypotheses. The direct and moderating effects of SC resilience and SSCM practices on two types of firm performance (i.e., financial, and innovation performance).

Chapter 5 Research Methodology

5.1 Introduction

This chapter discusses the research philosophy and approach undertaken in this study. By comparing the major philosophical stances regarding ontology, epistemology, and methodology, the research philosophy in this study is selected in **Section 5.2**. The research design is justified in **Section 5.3**, where the deductive logic of the quantitative empirical study is proposed for this study with detailed procedures for sample selection (i.e., country and industry contexts) and data collection. The data dataset is constructed for the measurement of selected variables in **Section 5.4**. Therefore, the sample dataset is ready for empirical analysis in **Chapter 6**.

5.2 Research philosophy

5.2.1 Attributes of major philosophical stances

The classification of philosophical stances is typically based on three interconnected elements: ontology, epistemology, and methodology. These elements shape the researchers' fundamental assumptions and worldview, which guide their research design and methods (Crotty, 1998; Creswell, 2014). Ontology pertains to the researcher's underlying assumptions regarding the nature of reality; epistemology refers to how the researcher obtains, justifies, and evaluates knowledge; methodology involves systematic techniques and rigorous processes to gather and analyse data (Guba and Lincoln, 1994). Various methodological positions in research, like positivism, post-positivism, critical theory, and constructivism, differ in their assumptions about reality, the researcher's role, the nature of knowledge, and the techniques employed for data collection and analysis (Guba and Lincoln, 1994). Therefore, the abovementioned philosophical stances will be compared from ontological, epistemological, and methodological positions, along with key features, advantages, and disadvantages (Crotty, 1998; Bryman, 2012).

Ontology refers to how the researcher perceives the nature of reality and its functioning (Saunders et al., 2011). The two primary aspects of ontology typically discussed are objectivism and subjectivism, which are crucial in producing authentic and reliable information. Objectivism proposes that social structures exist independently of social actors and their concerns, whereas subjectivism asserts that social entities exist based on the perspectives and actions of social actors (Collis and Hussey, 2013).

Epistemology is linked with the nature and types of knowledge and entails comprehending the interplay between knowledge seekers and the capacity for knowledge (Guba and Lincoln, 1994). Epistemology is also concerned with the forms of knowledge that a research project will investigate and produce, which is linked to the research outcomes and the contribution to knowledge in a particular field of study. It deals with questions such as how knowledge is acquired, what constitutes evidence, and what distinguishes justified belief from opinion (Guba and Lincoln, 1994). Epistemology covers different philosophical perspectives on the attributes and credibility of knowledge claims. The central positions in epistemology include objectivism, which asserts that knowledge is objective and independent of the knower, and epistemological scepticism, which questions the possibility of specific knowledge (Guba and Lincoln, 1994). Subjectivism holds that knowledge is subjective and depends on the knower's perspective, while constructivism asserts that individuals actively construct knowledge. Reflexivity emphasises the interplay between the knower and the known, while post-positivism recognises the role of the observer in the construction of knowledge.

Methodology is a fundamental element of research that pertains to the structured approach of gathering and analysing data to address research inquiries or validate hypotheses (Creswell, 2014). The choice of methodology is closely related to the researcher's ontological and epistemological positions (Johnson and Christensen, 2012). Methodology can be divided into two primary classifications: deductive and inductive (Saunders, Lewis, and Thornhill, 2016). Deductive methodology involves testing a theory or hypothesis developed based on existing knowledge or literature. This approach typically starts with a hypothesis or theory and tests it through empirical observation and data collection (Creswell, 2014). In contrast, inductive methodology involves developing a theory or hypothesis based on empirical observations or data collected from the research participants. This approach usually starts with data collection and observation, followed by the development of a theory or hypothesis to explain the findings. Another classification of methodology is quantitative and qualitative (Johnson and Christensen, 2012). The quantitative methodology involves collecting of numerical data, often through statistical methods, to establish relationships or causality between variables (Saunders et al., 2016). This approach is often used in positivist research, which assumes an objective reality that can be measured and quantified. Qualitative methodology, on the other hand, encompasses compiling and examining non-numeric data, such as language, visuals, or observations, to attain a more profound comprehension of the research phenomenon (Johnson and Christensen, 2012). This approach is often used in interpretive research, which assumes that reality is subjective and constructed through social and cultural practices (Saunders et al., 2016).

5.2.2 Comparisons of major philosophical stances

Positivism holds an objectivist ontology, which suggests that the world exists independently of human perception, and an empiricist epistemology, which holds that knowledge can be gained through direct observation and experience (Crotty, 1998). Positivism's methodology relies heavily on quantitative data and deductive reasoning (Bryman, 2012). The key features of positivism include a focus on observable and measurable phenomena, the use of objective data and statistical methods, and the aim of generalising findings to a larger population (Creswell, 2014). The advantages of positivism include the ability to produce reliable and replicable results, the use of rigorous methods, moreover the skill to recognise the relationship between cause and effect (Bryman, 2012). However, the limitations of positivism include its inability to account for social and cultural norms and experiences, its lack of consideration for subjective interpretations, and the potential for bias during the gathering and evaluation of data (Guba and Lincoln, 1994).

Post-positivism, also known as critical realism, is a modified version of positivism that recognises the limitations of purely objective and empirical research (Phillips and Burbules, 2000). Post-positivism holds a critical realist ontology, which posits that underlying causal mechanisms give rise to observable phenomena (Bhaskar, 1975), and an epistemological scepticism acknowledges the potential for biases and values to influence research (Lincoln, Lynham, and Guba, 2011). Post-positivism's methodology includes a blend of quantitative and qualitative approaches, inductive and deductive reasoning, and an emphasis on theory development (Maxwell, 2012). The key features of post-positivism include a focus on uncovering underlying causal mechanisms, the use of mixed methods, and an emphasis on theory development (Creswell, 2014). The advantages of post-positivism include its ability to address the limitations of positivism, its openness to multiple ways of knowing, and its ability to generate rich and nuanced explanations (Mertens, 2014). However, the limitations of post-positivism include its potential for subjectivity and bias, its lack of an explicit methodological framework, and the difficulty in combining quantitative and qualitative data (Tashakkori and Teddlie, 2010).

Critical theory, on the other hand, is rooted in a more radical perspective that challenges the status quo and aims to bring about social change (Horkheimer, 1982). The critical theory views reality as socially constructed and seeks to expose and challenge the power structures and systems that maintain the status quo (Habermas, 1984). Critical theorists reject the idea of objective reality and instead argue that knowledge is subjective and context-dependent (Kincheloe and McLaren, 2005). The critical theory emphasises reflexivity, which involves questioning one's assumptions and biases and engaging in a continuous process of self-reflection and critique (Cohen, Manion, and Morrison, 2013). In terms of methodology, critical theory supports qualitative research methods, such as ethnography and critical discourse analysis, which allow for a deep exploration of individuals' and groups' subjective experiences and perspectives (Fairclough, 2013).

Finally, **constructivism** posits that reality is socially constructed through individual and collective experiences and interactions (Berger and Luckmann, 1966). Constructivists reject the idea of objective reality and instead argue that knowledge is subjective and context-dependent (Guba and Lincoln, 1994). Constructivism emphasises reflexivity, which involves reflecting on one's assumptions and biases and being transparent about how they shape the research process (Mertens, 2015). Regarding methodology, constructivism supports qualitative research methods, such as grounded theory (Charmaz, 2006) and narrative inquiry (Clandinin and Connelly, 2000), which allow for an exploration of the subjective experiences and perspectives of individuals and groups.

The choice of philosophical stance in SCM research depends on the research question and the complexity of the research issue. Positivism is well-suited for quantitative studies that utilise pre-existing data, while post-positivism supports mixed methods research that recognises the limitations of positivism. The critical theory challenges the status quo and aims to bring about social change, while constructivism emphasises reality's subjective and context-dependent nature.

5.2.3 Philosophical approach of this study

Based on the comparison**,** positivism, with its objective and value-free approach, is deemed suitable for quantitative nature of this study. The adoption of the positivism approach in this study is highly relevant to the research topics of SC resilience and sustainability. This choice of philosophy dictates how knowledge is investigated and linked to the selected field. This study aims to seek the causal relations between SC resilience and SSCM. By taking the positivism approach, this study can provide a valid presentation of research social interactions by reviewing existing theories, developing hypotheses, and testing such hypotheses using quantifiable and observable data. With the observable evidence, it is feasible to reconstruct and evaluate conceptual models that clarify the connections between the constructs under investigation scientifically or statistically.

According to Aastrup and Halldórsson (2008), positivism is the prevailing research paradigm in the SCM field. This philosophical stance assumes that the world can be observed and measured through empirical means, and that data and analysis are independent of the researcher's perspective. Therefore, it is applicable in empirical research, where data can be gathered through surveys, questionnaires, and databases. Moreover, the ability of positivism to generalise findings from a sample to a population makes it ideal for this study, where the research aim is to establish generalisations about the interaction phenomena between SC resilience and sustainability. Although positivism may fall short in dealing with complex social phenomena involving humans, social and cultural norms, and social experience, this study focuses on the objective evidence of formal transactions among firms within SC systems to reveal the generalised pattern. The assumptions of philosophical foundation shed light on the selection of quantitative research methods carried out in this research.

Positivism, as the prevailing research paradigm in the field of SCM, aligns well with the objective of seeking causal relationships between these constructs. **Ontologically,** the positivism approach in this study relies on the objective reality that can be observed and measured. For instance, the study could measure objective variables like transaction ratios, profitability, patent numbers, resource redundancy, and SSCM initiatives within the SCs of the companies studied. Using a positivist stance, it quantifies and analyses these aspects to understand how resilience capabilities like SC concentration strategies and sustainability initiatives like employee welfare influence firm performance.

Epistemologically, while acknowledging that true objectivity may be challenging due to inherent biases, the study takes steps to mitigate these biases and achieve as much objectivity as possible. For instance, it evaluates existing theories on the impact of resilient SCs on the relationships between SSCM practices and financial performance or the role of SSCM practices in enhancing financial and innovation performance outcomes of resilience capability in SC networks. These theories are then tested through hypotheses, which are formulated based on the observed patterns in the collected data. The hypotheses are then validated or refuted using quantifiable data, such as data extracted from financial statements and corporate social responsibility reports. This approach facilitates the extraction of knowledge that is as independent as possible from the researcher's perspective, further reinforcing the objectivity of the research findings.

Methodologically, the study uses quantitative research methods aligned with the positivism approach. Methodologically, positivism approach enables this study to use primary and secondary data analysis with data collected from questionnaires or databases to understand the level of adoption of sustainability initiatives across different organisations, their resilience strategies, and the perceived impact on their financial and innovation performance. For instance, the use of secondary data involves the analysis of pre-existing data such as financial statements and sustainability reports from companies in the selected industrial sectors. This approach supports the positivist principle of seeking out measurable, empirical evidence, allowing the study to draw connections between quantitative measures of SC resilience (such as concentration of suppliers and customers or redundancy of capacities, inventories, and cash flow, etc.), sustainability practices (like sustainability rating), and performance outcomes (like profitability and patent numbers). By employing a positivism approach and a quantitative methodology, the study aims to provide a robust understanding of how SC resilience and SSCM initiatives jointly influence financial and innovation outcomes.

By adopting the positivism approach, the study provides a comprehensive understanding of the impact of resilience practices and sustainability initiatives on firm performance. Specifically, this study aims to understand how specific SC resilience practices and SSCM initiatives jointly influence financial and innovation outcomes. This methodological choice has enhanced the validity and reliability of the findings regarding specific mechanisms and factors driving performance improvements.

5.3 Research design

Positivism entails a deductive and objective stance, which is essential for examining causal relationships among constructs in complex and contingent contexts (Perren and Ram, 2004). Therefore, this research takes a deductive and objective stance to empirically examine the roles of SC resilience in the relationship between SSCM and performance outcomes. The objective stance is also more advantageous considering the research inquiries and context of the study, as it would enhance its practical and theoretical contributions. An objective approach may help reduce complexity and facilitate the exploration of causal relationships among constructs, as Perren and Ram (2004) proposed. This study aims to bridge the gaps between two streams of studies in the SCM domain. Since it is one of the first attempts, an objective stance is preferable based on the research questions and study context, allowing for a better contribution to practice and theory.

The deductive approach bears similarities to the scientific method of experimentation. This approach entails crafting hypotheses (theory), which are subsequently scrutinized via rigorous analytical techniques (Collis and Hussey, 2013). The deductive approach involves a top-down strategy that commences with a hypothesis or theory and subsequently endeavours to validate it with empirical evidence, which can be particularly useful when investigating complex phenomena such as those in SCM. This approach is particularly suited to this study as it allows for a clear and structured approach to examining the relationships between SC resilience, SSCM, and performance outcomes. A deductive approach is indicated when hypotheses are rooted in a theoretical framework and tested independently using empirical evidence. The deductive approach allows this study to analyse if the empirical findings support the proposed relationships (among SSCM, performance and the moderation effects of SC resilience) derived from existing theory. To assess the validity and reliability of the theories under investigation, this study follows the five stages of the deductive approach that Bell and Bryman (2007) suggested (see **Figure 18**).

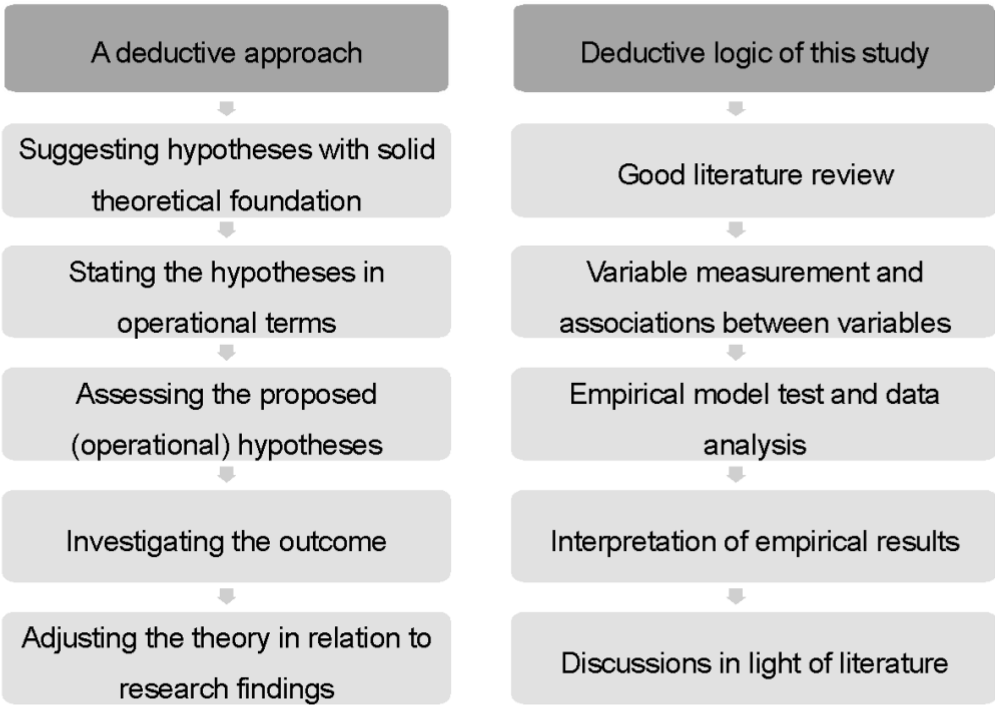

Figure 18 Deductive logic of the empirical study

Source: Author, updated from Bell and Bryman (2007).

The development of a research methodology is a crucial component of any research project, and it is important to understand the distinction between research methodology and research methods. Research methodology involves a systematic approach to resolving a research problem, whereas research methods pertain to the specific techniques used to conduct the research (Crotty, 1998). Therefore, outlining the research methodology is essential since it enables the researcher to determine the appropriate study method.

Research designs could be grouped into two: qualitative (e.g., face-to-face interview) and quantitative (e.g., survey and secondary data). Qualitative research employs a multi-method, interpretive, and naturalistic perspective to understand its subject matter. This type of research is typically conducted in real-life settings, and common methods include interviews, observations, focus groups, and group interviews (Queirós, Faria, and Almeida, 2017). Although it does not require large sample sizes, qualitative research can be expensive and time-consuming, and data analysis requires expertise in the studied area (Bryman, 2003).

5.3.1 Quantitative research method

Research designs could be grouped into two: qualitative (e.g., face-to-face interview) and quantitative (e.g., survey and secondary data). Qualitative research employs a multi-method, interpretive, and naturalistic perspective to understand its subject matter. This type of research is typically conducted in real-life settings, and common methods include interviews, observations, focus groups, and group interviews (Queirós, Faria, and Almeida, 2017). Although it does not require large sample sizes, qualitative research can be expensive and time-consuming, and data analysis requires expertise in the studied area (Bryman, 2003).

Queirós, Faria, and Almeida (2017) suggest that, through quantitative research, it is possible to establish general patterns of behaviour and phenomena applicable across various contexts. This research approach is primarily associated with data collection methods such as questionnaires and analytical techniques like statistics and graphs. It focuses on generating or utilising numerical data, typically following a deductive viewpoint (Bell and Bryman, 2007). Hypothesis testing is a common approach in quantitative studies to assess the applicability of theories in specific situations, and statistical analysis is used to determine whether a theory is accepted or rejected. Statistical tests help to simplify the raw data and facilitate the testing of theoretical hypotheses, aligning with the deductive research logic presented in **Figure 18**. Therefore, quantitative research is preferable in the current study, which could overcome the shortcomings of qualitative listed above.

The quantitative part of this study emphasises on theory testing, where the hypotheses from the view of CAS and SNT are examined. Theories and data are vital for testing hypotheses, where high quality and large size of sample data could increase the possibility of finding exceptions to universal statements. This study is explanatory of nature, which provides additional insights into descriptive research by developing causal explanations. By using explanatory research, this study can verify the proposed direct influence of SSCM on financial and non-financial performances with expected moderation effects of SC resilience after controlling firm-level factors and industry types. Therefore, to explain the performance effects of the interaction between SSCM and SC resilience, this study draws from SC resilience and SSCM literature, as well as CAS and SNT, to develop, refine and expand existing knowledge of the interplay between SC resilience and sustainability. The main aim of the study is to generalise the interaction mechanism between SC resilience and SSCM on the performance outcomes. The following section of the research design illustrates the utilisation of quantitative methods employed in the deductive and objective approaches.

Quantitative empirical research using secondary data was chosen over first hand (e.g., case study or survey questionnaire) due to its ability to provide a comprehensive and holistic understanding of the phenomenon under investigation. First, Quantitative empirical research utilising secondary data was chosen due to its ability to offer a rich, comprehensive, and holistic understanding of the complex relationship between supply chain resilience and sustainability. One of the significant advantages of secondary data, especially when extracted from established databases, lies in its richness and extensiveness. Such data encompasses large, diverse samples spanning multiple industries and years, offering depth and breadth in analysis that would be otherwise time-consuming, costly, and logistically challenging to gather first hand.

In terms of data objectivity, secondary data is less prone to biases, particularly those that may occur due to human factors in primary data collection. For instance, interviewer bias, respondent bias, and recall bias are circumvented. As our data covers a significant timespan (2010-2018), it enables an objective longitudinal analysis, free from the constraints and variability of individual human recollection.

The comprehensive coverage of the database also aids in the study's representativeness. Our analysis encompasses a wide array of firms across different sectors, namely automobile, food, and heavy-polluting industries, facilitating a broad perspective on the phenomena being studied. This widespread coverage allows us to generalize the findings more confidently to other contexts, thus enhancing the external validity of the research.

Furthermore, using secondary data lifts the restrictions of time and place that often constrain primary data collection. The data has already been collected, which expedites the research process, and allows researchers to devote more time to data analysis rather than data collection. This convenience, paired with the longitudinal aspect of the data, provides us with a unique opportunity to study the evolution and impacts of supply chain resilience and sustainability practices over time.

Finally, the quantitative nature of this approach enables robust statistical analysis, allowing us to test hypotheses and measure the strength and direction of relationships between variables. This empirical, data-driven investigation facilitates rigorous and robust testing of theoretical assumptions and contributes to theory development and refinement in the field of supply chain management. It provides a means to quantify the impacts of supply chain resilience and sustainability on financial and innovation outcomes, lending credence to our findings.

5.3.2 Research context

China's distinct mix of economic, cultural, and regulatory elements makes it a great and intriguing research context for studying SC resilience and sustainability. China's status as the world's most populous country and a major player in the global economy ensures its critical role in the realm of SCM cannot be overlooked. The country's unique position as a key supplier and market for a range of goods and services provides an opportunity to investigate how SC resilience and sustainability are addressed in a complex, multi-layered environment. Moreover, China's economy has undergone significant structural transformations in recent years, resulting in rapid growth and making it an interesting case for exploring the impact of these changes on SC resilience and sustainability. The unique cultural and historical background also influences its business practices during the economic transformation, making it an even more valuable research context for studying SCM.

Furthermore, China's strict environmental regulations and policies have been a topic of global interest in recent years. In 2019, China's State Council issued guidelines for establishing a system to promote green manufacturing, including the requirement for industrial enterprises to implement green manufacturing standards. This reflects the country's commitment to addressing environmental concerns and promoting sustainable practices in the manufacturing sector. China has also set a target of reaching carbon neutrality by 2060, which is expected to significantly impact SC operations in the country. These policies present a unique opportunity to investigate how SC resilience and sustainability are affected by such regulatory changes and how firms adapt to meet these requirements.

The examination of SC resilience and sustainability within specific industries is of paramount importance, given the environmental implications and resilience concerns associated with them. The automobile, food, and heavy-polluting industries serve as pertinent contexts for studying the interplay between these two critical concepts. These sectors offer a unique combination of significant economic impact, sustainability challenges, and vulnerability to disruptions, making them ideal candidates for investigating the intersection between SC resilience and sustainability. By exploring these industries, valuable insights can contribute to the broader understanding of how businesses can navigate the complex intersections of economic, environmental, and societal aspects within their SC resilient operations.

The automobile industry, given the growing domestic demand and China's prominence as the largest automobile market globally. It plays a substantial role in bolstering China's foreign revenue through significant vehicle and component exports. Furthermore, as a major driver for technological innovation, particularly in areas such as electric vehicles and autonomous driving, the automobile industry plays an instrumental role in fostering China's technological competitiveness. Similarly, the food industry in China is a critical sector, characterised by its vast scale and diversity that extends from agriculture to distribution. Serving the needs of the world's largest population, the industry experiences consistent demand for food products, making it resilient to market volatility. Economically, it contributes significantly to the nation's foreign revenue and positive trade balance due to China's substantial export of processed food products. Even the heavy-polluting industries, including coal, steel, and chemicals, despite posing significant environmental challenges, are integral to China's industrial growth. They form the backbone of China's economic output, providing crucial raw materials and energy resources that underpin the industrial growth of the nation. However, their influence extends beyond economic value. The industries play a strategic role in national energy security and industrial development, directly impacting societal stability.

Moreover, as these industries are under mounting pressure to reduce their environmental footprint, they are progressively becoming crucial players in China's transition towards a low-carbon economy, shaping the nation's economic and environmental future. The automobile industry is a significant contributor to global GHG emissions, both directly through vehicle emissions and indirectly through manufacturing processes. Moreover, the industry has considerable impacts on natural resources, from the extraction of metals for vehicle production to the consumption of petroleum for vehicle operation. Furthermore, with increasing societal awareness and regulatory focus on environmental sustainability, the industry faces the challenge of transitioning towards more sustainable practices, such as electric vehicles and recycling initiatives.

The food industry's sustainability issues are multi-faceted, encompassing environmental, social, and economic dimensions. Environmental concerns arise from the industry's impacts on land use, water resources, and biodiversity. For instance, intensive farming practices can lead to soil degradation and water pollution, while overfishing threatens marine biodiversity. The industry also faces social sustainability issues, such as ensuring fair labour practices and animal welfare. Economically, the challenge lies in balancing these sustainability considerations with the need to feed a growing global population.

Heavy-polluting industries are often at the heart of discussions on industrial sustainability due to their significant environmental impacts. These industries contribute substantially to global GHG emissions and are associated with severe local pollution, including air and water pollution. Simultaneously, these industries are key to many economies and societal functions, providing essential materials and energy.

This duality necessitates a nuanced approach to sustainability, balancing environmental protection with economic needs.

Apart from sustainability issues, these industries also share the similar concern of SC risks. While the nature and source of SC disruptions may vary, the automobile, food, and heavy-polluting industries, due to their operational complexities and external dependencies, are particularly vulnerable to such disruptions, warranting a detailed examination of their SC resilience and sustainability practices.

The automobile industry is marked by its intricate, global network of suppliers, rendering it particularly susceptible to disruptions. Any disturbance at one point of the SC can have a ripple effect, significantly impacting the entire network. These disruptions can stem from a multitude of sources, ranging from natural disasters affecting production facilities to geopolitical tensions leading to trade restrictions or import-export challenges. Additionally, fluctuations in raw material prices and availability can lead to cost increases or production halts. Furthermore, rapid technological changes, such as the transition to electric vehicles or advancements in autonomous driving technology, can cause significant disruptions by requiring substantial overhauls in production processes and SC structures.

The food industry's SC faces unique challenges due to its dependence on natural and biological processes. Weather fluctuations, climate change impacts, or disease outbreaks among livestock or crops can substantially affect agricultural yields, leading to supply shortages and price volatility. Moreover, the global nature of food SCs exposes them to geopolitical risks and transport disruptions that could delay deliveries and cause spoilage. Additionally, food safety concerns can lead to significant disruptions. An incident of contamination or the breach of safety standards at any point in the SC can necessitate widespread product recalls, causing substantial financial losses and damage to reputation.

For heavy-polluting industries such as steel, cement, and coal, SC disruptions often arise from regulatory changes. Given their significant environmental footprint, these industries are subject to stringent emission standards and environmental regulations. Any new regulations or standards can necessitate major equipment upgrades or process changes, leading to potential production slowdowns or even shutdowns. Further, these industries often rely on the extraction of finite natural resources, making them vulnerable to disruptions due to resource depletion or fluctuations in commodity prices. Lastly, societal pressure and reputational risks associated with environmental damage or worker safety incidents can also lead to disruptions and necessitate significant remedial measures.

Examining resilience and sustainability issues within these sectors is critical, given the environmental implications and resilience concerns associated with them. Their exposure to various disruptions provides a wealth of insight into managing and structuring resilient supply chains. At the same time, their environmental footprints, whether in the form of GHG emissions from the automobile and heavy-polluting industries or impacts on land use, water resources, and biodiversity from the food industry, highlight the urgency of SSCM practices. As such, these sectors offer a rich context for investigating the balance and interplay between SC resilience and sustainability. In essence, these industries offer a potent setting where economic, environmental, and societal concerns intersect, making them an ideal choice for this study.

5.3.3 Sample and data

5.3.3.1 Data source

The study focuses on publicly listed Chinese firms in the automobile, manufacturing, and heavy-polluting industries. All public companies in China are required by the China Securities Regulatory Commission to disclose information about their financial status. It enables access to the financial data required for the regression analysis. In addition, public companies in annual reports also report the transactions with the key suppliers and customers, which helps to identify the linkages among different SC entities and figure out SC networks. Consistent with the literature (Yang et al., 2019), this empirical analysis focuses on China’s A-share market-listed companies on the Shanghai and Shenzhen Stock Exchanges. Firms with B-shares (foreign shares) are excluded since they are subject to separate legislation and currencies.

The data for this quantitative study comes from a variety of sources, including the China Stock Market and Accounting Research (CSMAR) database (http://www.gtarsc.com) and the Chinese Research Data Services Platform (CNRDS) database (http://www.cnrds.com). Both of these databases have been utilised in recent research, with the former largely recognised as China's most authoritative data source. CSMAR has been used to identify targeted companies and the financial performance data, while the SC data and SSCM practices datasets are obtained from CNRDS. CSMAR and CNRDS map firms with the stock code so that the datasets would be merged across the two databases. The industry classification codes follow the China Securities Regulatory Commission's Guidelines for the Industry Classification of Listed Companies (2012 Revision).

This empirical analysis focuses on three clusters of industries: food manufacturing, automobile manufacturing, and heavy-polluting industries. With the Guidelines for the Industry Classification of Listed Companies, the food manufacturing industry refers to C13, C14, C15, and C36 for automobile manufacturing. Based on the Guideline for Environmental Information Disclosure of Listed Companies set out by the Ministry of Ecology and Environment, sixteen sub-industries are identified as heavy-polluting ones like thermal power, steel, cement, etc. **Table 21** lists the industries included with the standard industry code and firm numbers.

Table 21 Industry Classification and Code in CSMAR

Industry Name	Code	No.
Coal mining and washing	B06	22
Oil and gas extraction	B07	6
Ferrous metal mining and dressing	B08	2
Non-ferrous metal mining and dressing	B09	13
Agricultural and side-line food processing	C13	52
Food manufacturing	C14	47
Liquor, beverage and refined tea manufacturing	C15	38
Textile	C17	64
Leather, fur, feathers and their products and footwear	C19	14
Paper and paper product	C22	41
Petroleum processing, coking and nuclear fuel processing	C25	24
Chemical raw materials and chemical products manufacturing	C26	274
Pharmaceutical manufacturing	C27	217
Chemical fibre manufacturing	C28	32
Non-metallic mineral products	C30	108
Ferrous metal smelting and rolling processing	C31	38
Non-ferrous metal smelting and rolling processing	C32	70
Metal products	C33	73
Automobile manufacturing	C36	112
Electricity and heat production and supply	D44	66
SUM	20	1313

Source: Author.

5.3.3.2 Data collection

This study employs quantitative methods (i.e., regression analysis) using the secondary data provided by the third party to obtain a large sample of publicly listed Chinese firms from 2010 to 2018. In order to measure the constructs for the regression analysis, the firm-level data should be collected on a yearly basis. The data collection process started with identifying the public firms.

The selected timespan for data collection in this study is critical in capturing the dynamic nature of the relationship between SC resilience and sustainability. By examining a span of eight years, from 2010 to 2018, this study can gain insights into the long-term trends and patterns that shape these constructs within the selected industries. This extended timeframe allows us to observe changes in SC practices, environmental regulations, and industry dynamics over time, providing a more comprehensive understanding of the interplay between resilience and sustainability.

Moreover, the chosen timespan aligns with significant events and developments that have occurred within the industry sectors of interest. Over this period, substantial shifts in environmental awareness, technological advancements, and regulatory frameworks have been witnessed that have influenced both SC practices and sustainability considerations. By encompassing these critical years, the sample can capture the effects of evolving industry contexts on the relationship between SC resilience and sustainability.

Furthermore, studying a multi-year timeframe allows this study to account for cyclical patterns, industry-specific fluctuations, and potential lag effects. SC disruptions and sustainability practices may exhibit temporal variations, impacted by factors such as economic cycles, policy changes, or technological advancements. By including a range of years, the sample can mitigate the risk of capturing a snapshot of the relationship that may not fully capture the nuances and complexities inherent in these phenomena.

The selection of 2010 as the starting year for data collection is justified due to its significance in capturing key economic and industrial developments. It aligns with the emergence of sustainability concerns and enables an examination of industry responses. Additionally, starting in 2010 ensures access to reliable and comprehensive data sources, enhancing the study's validity. Therefore, this chosen starting year provides a comprehensive view of the relationship between supply chain resilience and sustainability in the selected industries.

The original data was collected till 2019, while the choice to end data collection in 2018 is justified by several factors. Concluding data collection in 2018 enables an assessment of multiple economic cycles and industry trends and leverages available and reliable data sources through a substantial eight-year timeframe. Secondly, 2018 marks a critical point in recent history, capturing the immediate pre-pandemic period. More importantly, the availability and completeness of data for the chosen industries extend until 2018. After balancing the richness of the timespan and sample size, data in 2019 is excluded from the initial dataset as the innovation-related data is incomplete in 2019 and could cause a substantial loss of sample size if it is included.

In summary, the selected timespan of eight years provides a comprehensive view of the relationship between SC resilience and sustainability by capturing long-term trends, industry-specific dynamics, and the influence of critical events. Utilising comprehensive and reliable data sources ensures the accuracy and integrity of the analysis, contributing to the robustness of the findings. It allows for a more robust analysis of the interplay between these constructs within the chosen industries, accounting for temporal variations and providing a holistic understanding of their relationship over time.

The detailed data collection process could be summarised into five steps (see **Figure 19**). Four categories of data – SC resilience, SSCM practices, financial performance, and innovation performance- were obtained and merged through the data collection and construction processes for the next-step analysis. Detailed procedures are demonstrated, and the final sample is presented in **Figure 20** regarding the distribution of industry, province, and year.

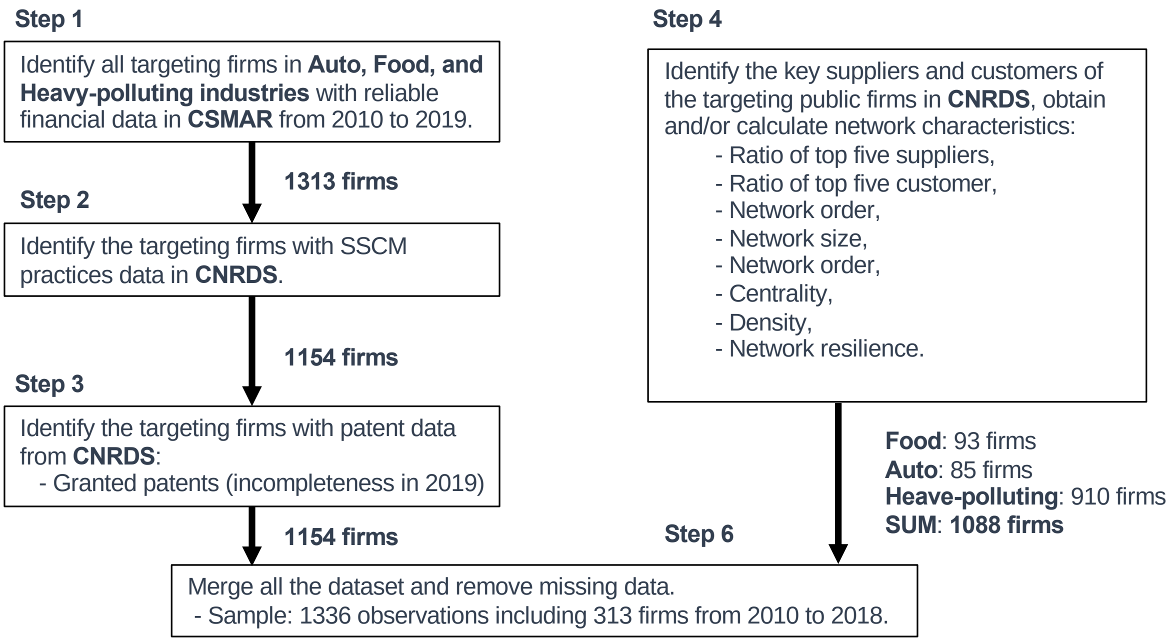

Figure 19 The diagram of the data collection process

Source: Author.

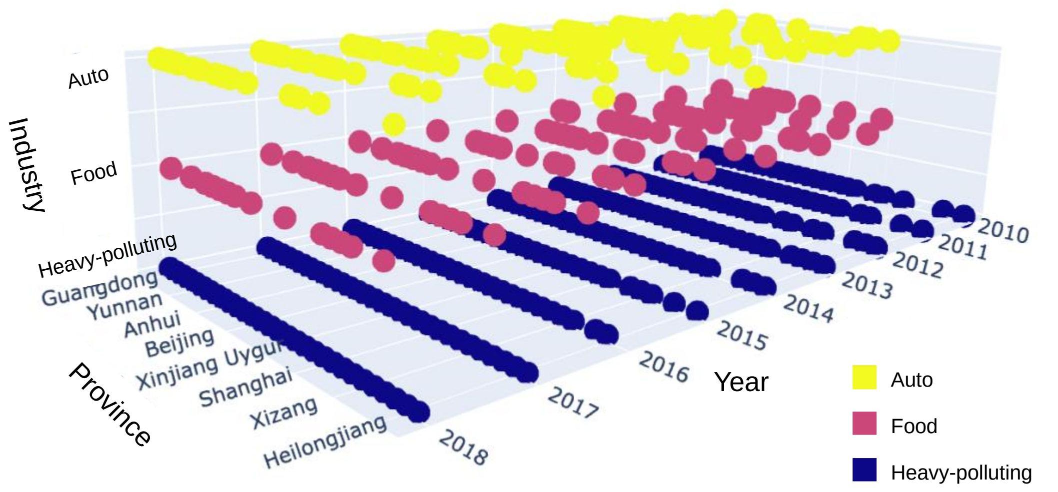

Figure 20 The industry distribution of the final sample

Source: Author.

Step 1: First, all the food, auto, and heavy-polluting public firms listed in CSMAR from 2010 to 2019 were identified. Based on the full list of public firms in CSMAR, our sample includes 1313 out of 3790 public firms across 20 sub-industries, of which 137 are in the food industry, 112 in the auto, and 1064 in the heavy-polluting industry. All the industry codes included are listed in **Table 21.** From CSMAR, registration information (e.g., registration address) of each public firm could be obtained along with the financial information.

Step 2: Second, CNRDS was used to gather SSCM practice data. From 2010 to 2019, 7464 firm-year observations were collected for 1154 public enterprises. Similar to Kinder, Lydenberg, and Domini (KLD), the CNRDS database includes annual data on a wide cross-section of Chinese enterprises, including several measures of strengths and concerns for each of the six SSCM dimensions (community, corporate governance, diversity, employee relations, environment, and product). According to CNRDS, the scores are calculated by third-party raters who have knowledge of SSCM activities and performance but have no direct stake in the businesses. In each of the six categories, there are 58 indications of strengths and concerns, the majority of which are qualitative, assessed as "1" (the business has exhibited this strength or worry) or "0" (otherwise).

Step 3: To measure innovation performance, the yearly granted patent data is retrieved from CNRDS. CNRDS provides the records of three different types of patents for each public firm. All three types of patents have been obtained in this research to calculate the sum of patents, which could provide a holistic view of the knowledge-creation process for each firm.

Step 4: the network-related SC resilience measurement deployed to the CNRDS database. The transactions of public firms with the top five suppliers and customers could disclose the SC network structure in the targeting industry. The information of suppliers and customers (i.e., firm code) should be recognisable. Otherwise, the firm-year observations should be removed if the SC companies cannot be identified. 26005 transactions and 16359 SC companies (923 in the auto, 1299 in the food, and 14137 in the heavy-polluting industry) are found from 2010-2019, among which 1088 firms are publicly listed (85 in auto, 93 in food, 910 in heavy-polluting industry). All these transaction data of SC networks are used to calculate the measures related to structural characteristics.

Step 5: Data consolidation. Financial data, SSCM practices data, innovation data, and SC resilience data could be merged with the registration location of public firms by the unique stock code of each firm. The sample size of datasets was lowered in this stage due to a lack of SSCM information, supplier and customer information, and financial data (e.g., missing data for constructing independent or control variables). This step completed all the computations of the control and (in) dependent variables. Due to the incompleteness of patent data in 2019 and the not-applicable data of network characteristics, the sample finally reduced 1336 firm-year observations for 313 firms from 2010 to 2018.

5.4 Variable measurements

In the current study, four variables are included: firm performance, sustainable practices, SC resilience, and SC risks. In the following sub-section, the measurement and calculation of each variable is given in detail. **Table 23** (at the end of this sub-section) summarises each variable's data source and measurement.

5.4.1 Measurement of SSCM practices

The environmental, social, and governance (ESG) criteria have emerged as a widely-accepted approach for assessing SSCM (Wang, Dou and Jia, 2016). While TBL focuses on broader dimensions of sustainability, ESG focuses on a company's performance in terms of environmental impact, social responsibility, and governance procedures. This distinction highlights the evolution of sustainability measurement from a general approach to a more targeted and actionable set of criteria. ESG has become a reliable and popular measurement for public firms. It allows investors, stakeholders, and other interested parties to evaluate a company's long-term sustainability and ethical conduct, thereby enabling more informed decision-making and promoting responsible business practices (Friede et al., 2015). Therefore, this study measures SSCM practices with ESG criteria.

Therefore, SSCM, as the independent variable, is considered as an aggregate variable with three dimensions in the empirical model: environmental (E) SSCM, (S) social SSCM, and (G) SSCM. The value of aggregate level SSCM is measured as the average of ESG SSCM dimensions, reflecting the equal weights of the three dimensions. The measurement of SSCM practices uses the data from the corporate social responsibility (CSR) sub-databases of CNRDS databases, where SSCM practices are evaluated from six domains with 57 indicators listed in **Table 22.** Both **strengths and concerns** are evaluated. Six numerical indicators (i.e., number of patents. R&D expense, the ratio of technical staff, R&D Staff, page of CSR report, and the donation amount) include missing values, which were accordingly removed from the index system in this study. The qualitative indicators are evaluated as either “1” (the firm has demonstrated this strength or concern) or “0” (otherwise). This study evaluates responsible practices with a penalty for irresponsible practices; therefore, the combination of both SSCM strengths and concerns are considered in the measurement. Following Rothenberg, Hull, and Tang (2017), Yang et al. (2019), this study uses derives each domain of SSCM practices by deducting the sum of concerns from the sum of strengths (Apaydin et al., 2020). After evaluating the indicators in each domain, the six domains are grouped into three ESG dimensions for the measurement of SSCM practices in this study, the loading factor of each dimension is also measured (see **Figure 21**).

Table 22 Industry Classification and Code in CSMAR

SSCM domains	**Strength(S) or Concern(C)**	**Qualitative indicators**
Product	Strength	Quality system
Product	Strength	After sale service
Product	Strength	Customer satisfaction survey
Product	Strength	Quality honour
Product	Strength	Anti-corruption measures
Product	Strength	Strategy sharing
Product	Strength	Integrity business philosophy
Product	Strength	Other product strength
Product	Concern	Product disputes
Environment	Strength	Green product
Environment	Strength	Three reductions
Environment	Strength	Circular economy
Environment	Strength	Energy saving
Environment	Strength	Green office
Environment	Strength	Environment certificate
Environment	Strength	Environment honour

SSCM domains	Strength(S) or Concern(C)	Qualitative indicators
Environment	Strength	Other environment strength
Environment	Concern	Environmental penalty
Environment	Concern	Emission of pollutants
Employee	Strength	Employee share
Employee	Strength	Employee benefits
Employee	Strength	Safety management system
Employee	Strength	Safety production training
Employee	Strength	Occupational safety certification
Employee	Strength	Vocational training
Employee	Strength	Employee communication channels
Employee	Strength	Other employee strength
Employee	Concern	Employee safety disputes
Employee	Concern	Layoffs
Diversity	Strength	Communist
Diversity	Strength	Female executives
Diversity	Strength	Female director seats
Diversity	Strength	Innovative human resource project
Diversity	Strength	Other diversity strength
Diversity	Concern	No female executives
Governance	Strength	Comprehensiveness CSR report
Governance	Strength	CSR web column
Governance	Strength	CSR leading mechanism
Governance	Strength	CSR vision
Governance	Strength	CSR training
Governance	Strength	Reliability guarantee CSR report
Governance	Strength	Other company governance strength

SSCM domains	Strength(S) or Concern(C)	Qualitative indicators
Governance	Concern	Accounting violation
Community	Strength	Education support
Community	Strength	Charity support
Community	Strength	Volunteer activity
Community	Strength	International assistance
Community	Strength	Employment drive
Community	Strength	Local economy
Community	Strength	Other community strength
Community	Concern	Financing disputes

Source: Author (based on CNRDS databases).

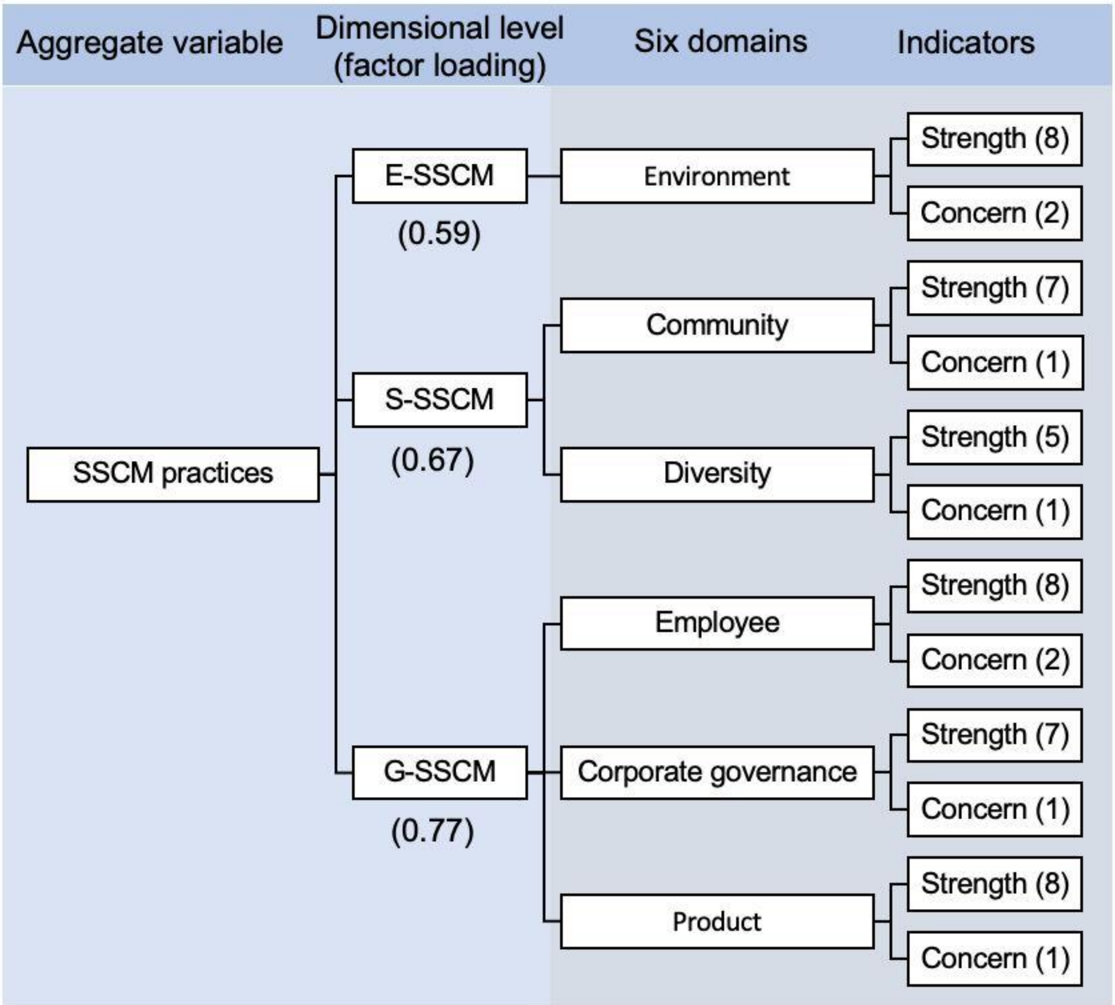

Figure 21 SSCM practices measurement

Source: Author (based on CNRDS databases).

5.4.2 Measurement of SC resilience

SC resilience is conceptualised as an adaptive capability from multiple perspectives. One approach classifies SC resilience according to disruption stages, consolidating capabilities into three phases: readiness, response, and recovery (Han et al., 2020; Hohenstein et al., 2015). These stages are also known as proactive, concurrent, and reactive resilience capabilities (Ali et al., 2017; Li et al., 2017). Another approach emphasises the formative capabilities of SC resilience (Ambulkar et al., 2015; Castillo, 2022; Christopher and Peck, 2004; Ponis and Koronis, 2012), including flexibility, redundancy, agility, visibility, and risk management culture (Iftikhar et al., 2021; Li et al., 2017).

However, in the first method, SC resilience components are not mutually exclusive, while the second approach fails to ensure comprehensiveness. (Shishodia et al., 2021). An alternative stream of literature focuses on the functionality of SC resilience in addressing uncertainties, conceptualising it as bridging or buffering resilience (Manhart, Summers, and Blackhurst, 2020) or bouncing-back or bouncing-forward resilience (Bondeli and Havenvid, 2022). This perspective integrates the classification attributes of SC resilience from the first two approaches but retains the disadvantages of the discrete measurement of SC resilience.

As a result, this study CAS and SNT explores SC resilience measurement dimensions, recognising that interconnectivity and collaboration are critical aspects of SC resilience (Sajko et al., 2021). In this study, the measurement of SC resilience is distinguished the previous approaches from two distinct perspectives. Firstly, SC resilience refers to the capacity of the SC system to address uncertainties and revert to a stable and normalised state (Castillo, 2022; Han et al., 2020). This notion of resilience differs from organisational resilience (Novak, Wu and Dooley, 2021), which transcends individual firms and is grounded in the interactions between SC members, highlighting the importance of inter-firm resources and relationships (Madhavaram et al., 2022; Pettit et al., 2019). Secondly, SC resilience is inherently intertwined with the structure of the SC network (Kim, Chen, and Linderman, 2015). Therefore, SC resilience should be assessed from a multi-scale perspective, encompassing the various structural levels of the SC network, including nodes, dyads, and the overall network structure. In alignment with the approach proposed by Jüttner and Maklan (2011), the current study adopts a capability-oriented perspective for the evaluation of SC resilience. Drawn upon CAS and SNT, SC resilience is conceptualised as a system adaptive capability stemming from the structural features of the SC network.

The resilience literature shows a need for more empirical knowledge of SC resilience (Castillo, 2022). Empirical studies in SC resilience have developed questionnaire scales and measure SC resilience from the strategic level (Ambulkar, Blackhurst and Grawe, 2015; Chowdhury and Quaddus, 2017). There are no consistent and common measurements of resilience at the scale of SC (Jiang et al., 2023; Juan and Li, 2023). By focusing on the network structure, this study acknowledges the complex interactions among SC partners, capturing a more holistic perspective of SC resilience in the scope of the SC network-structured system. This adopted approach provides a comprehensive understanding of how resilience is built and maintained through the relationships between different actors within the SC. It complements the existing SC resilience literature by addressing the limitations of other approaches, providing a more inclusive analysis of the dimensions of SC resilience.

SC resilience is an unobservable variable in the model. Drawn upon CAS and SNT, SC resilience as a meta capability built in firm-level resource resilience, dyad-level relationship resilience, and network-level structural resilience in the multiscale SC network-structured system (see **Figure 22)**. To measure SC resilience at an aggregate level, this study uses factor analysis to combine multiscale dimensions of SC resilience into a higher-level composite score. This approach provides greater clarity regarding the contribution of each dimension to the overall SC resilience score. **Figure 22** presents the hierarchy of SC resilience with the sub-constructs and measurement metrics with factor loading value.

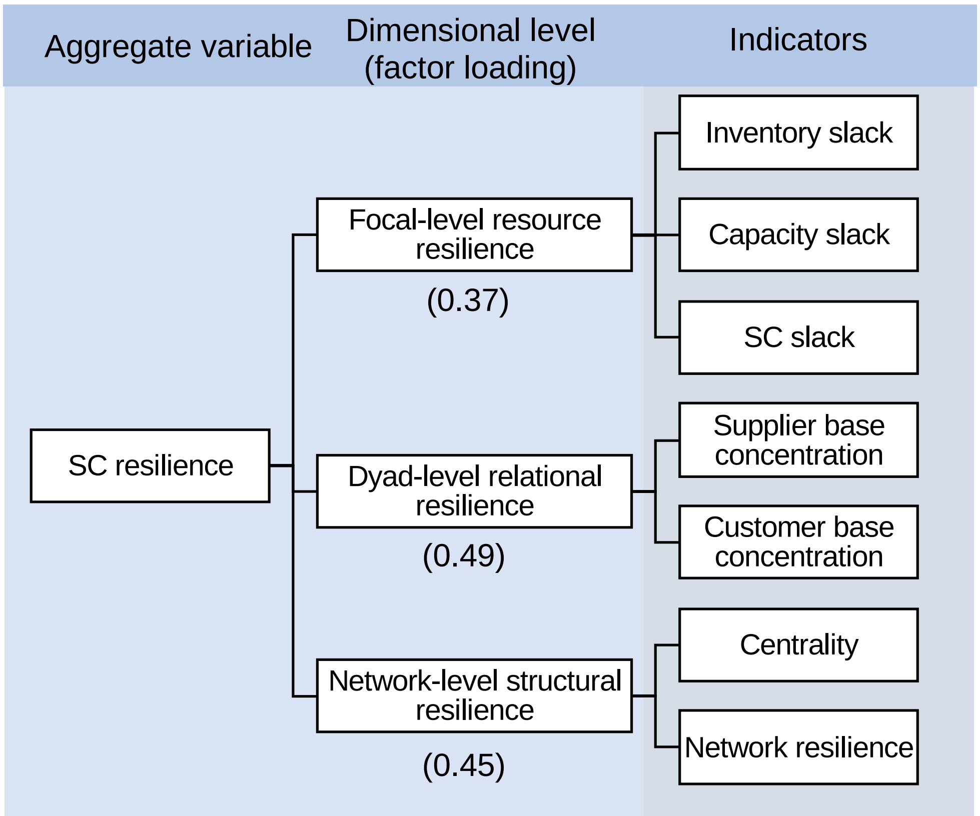

Figure 22 SC resilience measurement

Source: Author.

Firm-level resource resilience refers to the resource redundancy at the focal firm in order to enhance resilience in the face of unexpected events (Maghsoudi et al., 2018). Having excess resources on hand can improve the firm's flexibility and agility, the variety of its product or service offerings, and the quality of its connections with suppliers and other SC system partners. The resource-redundant firms can respond quickly to unexpected disruptions and maintain the continuity of their SC operations (Azadegan, Modi and Lucianetti, 2021). To measure firm-level resource resilience (i.e., redundancy), financial statistics could provide evidence of resource slacks on inventory, capability, and SC slacks (Kovach et al., 2015).

(1) *Inventory slack* refers to the amount of inventory a company has that exceeds its minimum requirements for production and sales. This consists of raw, task-in-process inventory, and finished goods inventory (Hendricks, Singhal and Zhang, 2009). Inventory slack is determined by calculating the inventory-to-sales ratio. The higher the ratio, the greater the company's inventory slack.

(2) *Capacity slack* refers to the unused or excess capacity of a firm's resources, including physical, human, and technological resources (Kovach et al., 2015). Capacity slack can be quantified in several ways, such as the difference between actual and potential output, the amount of unused production capacity, or the amount of idle time among employees. In this study, Capacity slack is calculated as the inventory-to-sales ratio. The higher the ratio, the more inventory slack a firm has.

(3) *SC slack is the cash cycle slack in a company's SC. This covers accounts payable to the firm's suppliers as well as receivables from the firm's customers (Hendricks, Singhal, and Zhang, 2009; Kovach et al., 2015; Chen, Yu, and Gong, 2022). In line with previous studies, this study employs the difference between account receivables and payables as a measure of SC slack, which indicates the availability of cash inside the firm's SC.* The higher the difference is, the more SC slack a firm has.

Dyad-level relational resilience is grounded in the interactions between firms and their SC partners, reflecting the intensity and strength of these partnerships (Chu et al., 2019). This dynamic is indicative of the information symmetry or asymmetry and power dynamics present in these relationships (Qiu, 2018). This study utilises two indicators to reflect the nature of interactions between the focus enterprises and their suppliers and customers: supplier base concentration and customer base concentration (Qiu, 2018). These measures were chosen because they reflect the degree of influence and power that focal firms have over their major and close partners.

This study focuses on the first-tier suppliers and customers who have direct linkages with focal firms, as they play a crucial role in shaping the purchase and production plans, especially during unfavourable situations like supply disruptions and panic buying. To provide an overall view of upstream and downstream relationships, SC concentration is composed of the average of supplier base concentration and customer base concentration (Han et al., 2022; Zhu, Yeung and Zhou, 2021). This metric is calculated as the average ratio of the top five suppliers and the top five customers (Zhu, Yeung and Zhou, 2021; Wen, Ke and Liu, 2021; Qiu, 2018).

Network-level structural resilience, or network resilience, is reflected in the physical SC network structure. Network resilience is defined as the capacity of the entire SC system to adjust to changing conditions and may be operationalised using network structural features (Kim, Chen and Linderman, 2015). Dixit, Verma and Tiwari (2020) provides a good reasoning in the relationships between structural characteristics and network resilience based on the extant findings in their mathematical models. Drawing from network structural characteristics (Kim, Chen, and Linderman, 2015) and the reasoning provided by Dixit, Verma, and Tiwari (2020), this study examines network-level structure resilience as a composite effect of four structural characteristics: (1) network centrality, (2) network connectivity, (3) network density, and (4) network size.

(1) *Network centrality* pertains to a focal firm's significance within the SC network. A firm with high centrality occupies a central position in the network, allowing it to exert influence and control over other members (Kim and Zhu, 2018). When a highly central firm experiences a disruption, the flow of items to numerous nodes is impacted, making centrality inversely proportional to network resilience.
(2) *Network connectivity* denotes the degree to which firms within the SC network are interconnected (Hearnshaw and Wilson, 2013). Greater connectivity implies enhanced collaboration and information flow among network members

(Hearnshaw and Wilson, 2013). Furthermore, high connectivity allows alternative pathways to meet demand during disruptions, making connectivity directly proportional to network resilience.

(3) *Network density* calculates the ratio of existing connections in the network compared to the total number of potential connections (Todo, Matous and Inoue, 2016). A denser network suggests that a larger number of firms are located within a smaller geographic area, meaning local disruptions have the potential to affect many connected firms. Therefore, density is inversely proportional to network resilience.

(4) *Network size* is the total number of firms in the network. More extensible networks provide greater diversity and redundancy, which can improve SC resilience by offering alternative supply sources and distribution channels during disruptions. An increased network size bolsters resilience, as the presence of extra sources of supply and connections can function as potential "buffers," subsequently raising the overall levels of network resilience (Craighead et al., 2007; Falasca et al., 2008). As a direct consequence, network size is related to resilience.

This approach offers a metric for measuring SC resilience at the network scale. The network structures in each industry are analysed using social network analysis techniques to derive network attributes. **Figure 23** presents network structures in auto, food, and heavy-polluting industries with the sample dataset from 2010 to 2018, and **Figure 24-26** presents network structures on a yearly basis for each industry category. The red nodes are the targeted public firms, and the yellow nodes are interconnected non-public firms (i.e., major suppliers or customers) in SC networks.

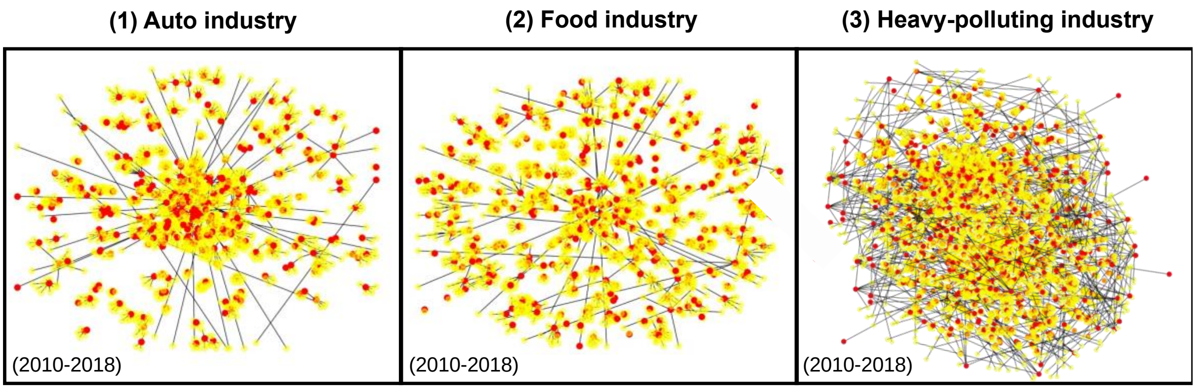

Figure 23 Network structures of targeted industries

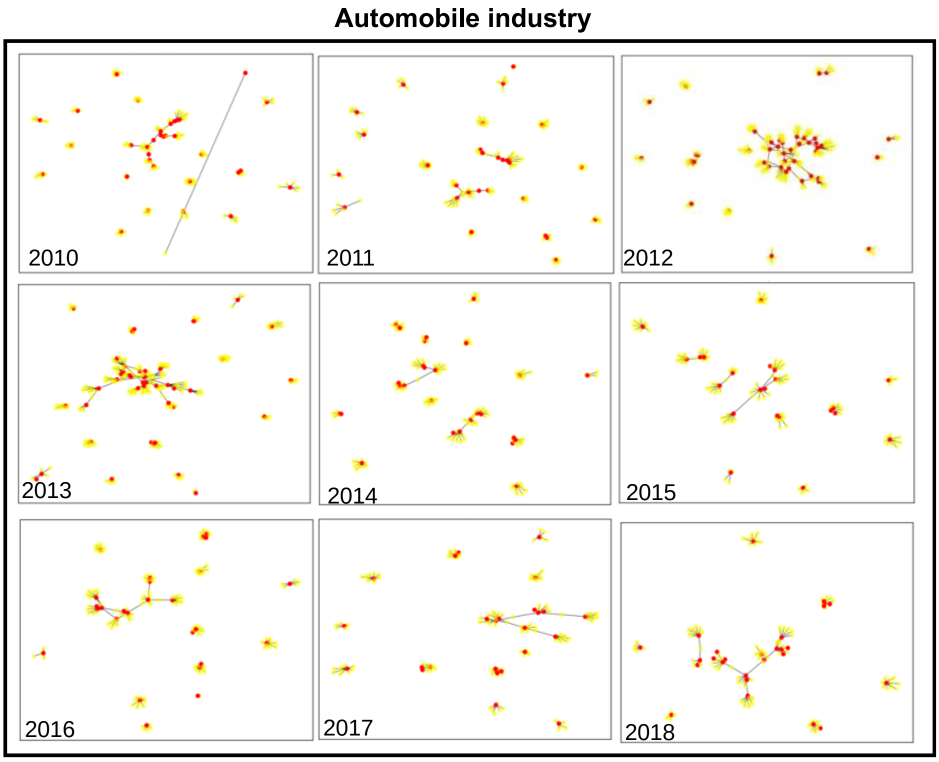

Figure 24 Network structures of the automobile industry in each year

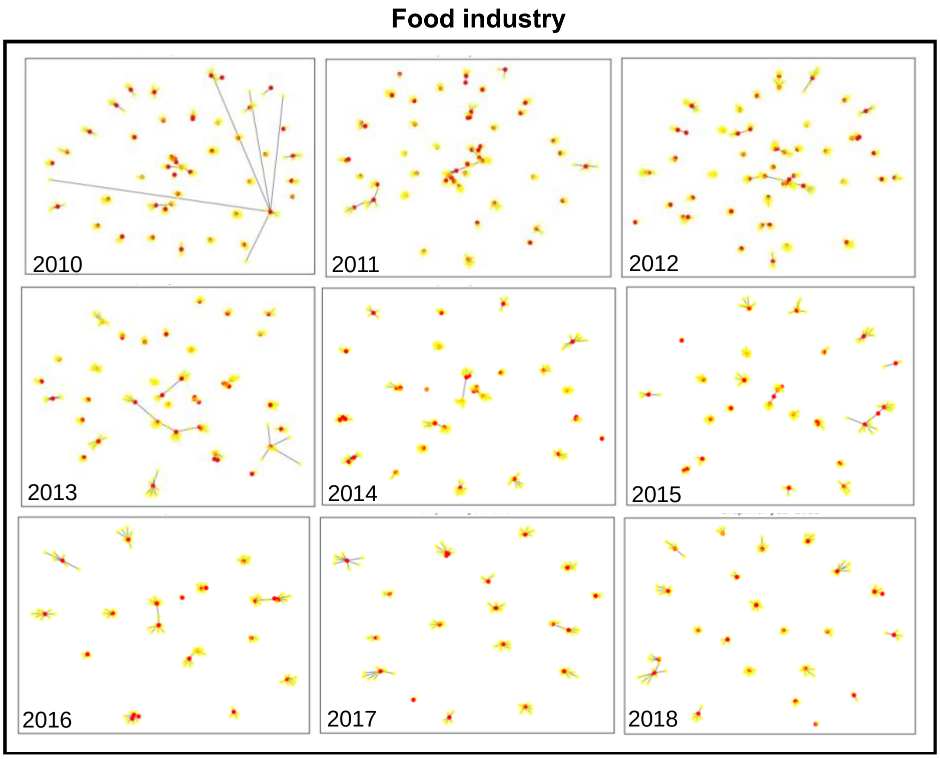

Figure 25 Network structures of the food industry in each year

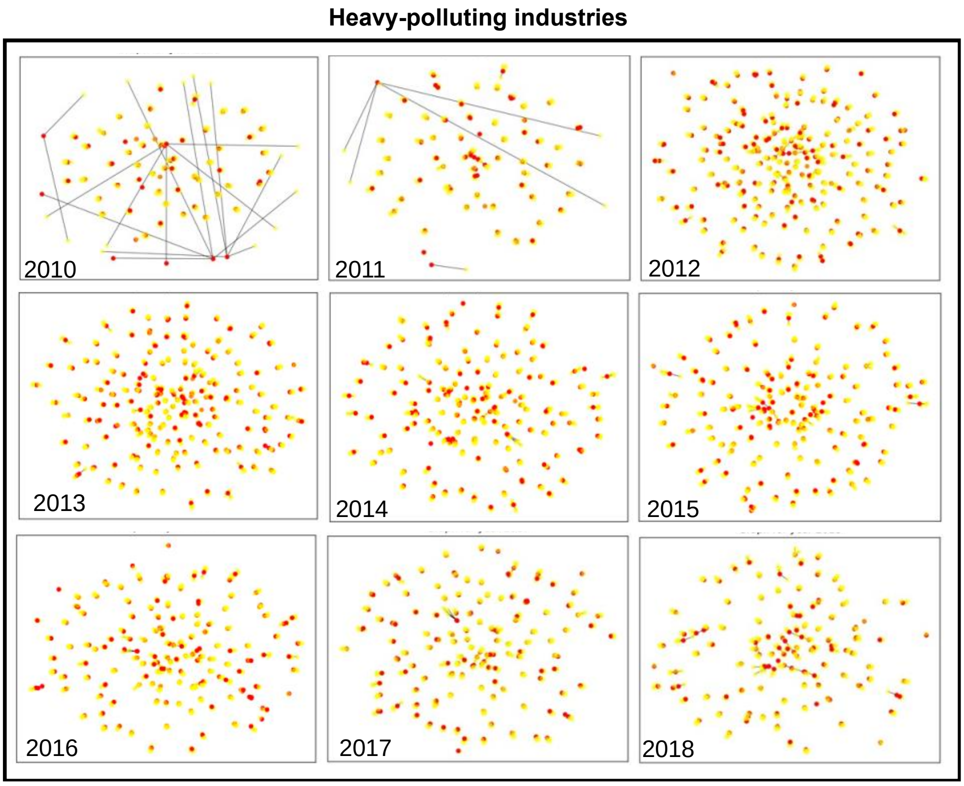

Figure 26 Network structures of heavy-polluting industries in each year

5.4.3 Measurement of firm performance: financial and innovation performance

In this study, firm performance is posited as the dependent variable (DV), with two types of performance being assessed: financial performance and innovation performance. Performance-driven SC adaptation highlights the importance of achieving positive outcomes for overall success, as profitability ensures business continuity and innovation promises future prosperity (Ageron, Gunasekaran, and Spalanzani, 2012). The direct incentives for adopting SSCM practices and fostering SC resilience are derived from these two aspects.

Financial performance is selected as one of the important characteristics of company performance to be assessed, primarily because it serves as an essential indicator of an organization's overall health and stability (Gupta and Gunasekaran, 2019). Financial performance reflects a firm's capability to generate revenues, control costs, and achieve profitability. Strong financial performance is crucial for business continuity, as it enables companies to invest in resources, innovations, and processes that can help them maintain a competitive edge in the market (Wong, Wong, and Boon-Itt, 2013).

Various measures, such as return on assets (ROA), return on equity (ROE), return on investment (ROI), net profit margin, and earnings per share (EPS), can be used to assess financial performance (Gupta and Gunasekaran, 2019). These indicators provide insights into a firm's financial health, including efficiency, profitability, and overall value creation. However, each indicator may capture distinct dimensions of financial performance and may have varying levels of relevance depending on the industry or company size.

Return on assets (ROA) is used as this study's major financial performance measuring metric (Wong et al., 2013). ROA is a popular financial statistic that assesses a company's profitability in proportion to its total assets. ROA clearly shows how successfully a company uses its assets to produce profits by dividing net income by total assets. This metric is particularly suitable for assessing financial performance in the context of SCM, as it accounts for both the operational and investment aspects of a business (Wagner, 2008). ROA is a widely-accepted and well-established financial metric, making it comparable across different firms and industries. This permits a more considerable investigation of the link between SC resilience, SSCM practices, and financial success. Furthermore, ROA is a suitable metric because it is less susceptible to financial manipulations or distortions than other financial performance indicators, such as ROE or EPS (Gupta and Gunasekaran, 2019). As a result, it provides a more reliable and consistent measure of financial performance.

This study aims to evaluate innovation performance as another crucial aspect of firm performance. The emphasis on innovation performance stems from the realization that a company's capacity to innovate and adapt to changing market conditions is critical to long-term success and competitiveness (Prajogo and Olhager, 2012). Innovations can result in the creation of new goods, processes, or business models, allowing a company to stay ahead of its rivals and fulfil the changing needs of its consumers. Firms may improve their SC resilience and SSCM practices and manage the difficulties posed by a more complex and uncertain business environment to equip the SC with innovativeness (e.g., new technologies) towards business continuity and competitiveness (Ageron et al., 2012).

Innovation performance can be assessed using various indicators, including research and development (R&D) expenditures, the amount of new product launches, the proportion of sales attributable to new products, and the number of granted patents (Prajogo and Olhager, 2012). Each of these metrics encapsulates distinct facets of a firm's innovative capacity, with their significance potentially varying across industries or based on the specific goals of the analysis.

In this study, the total number of granted patents is selected as the primary measurement indicator for innovation performance. Patents are widely recognized as a valuable proxy for a firm's innovative output, as they represent the formal protection of new inventions or discoveries resulting from research and development activities (Bellamy, Ghosh, and Hora, 2014). Granted patents can indicate a firm's commitment to R&D and its ability to transform research into commercially viable products or processes. By counting the number of granted patents, the study can objectively quantify the innovative output, making it easier to compare innovation performance across different firms and industries.

Moreover, the number of granted patents can signal the potential for future growth and market opportunities, as patented technologies may enable firms to create new revenue streams or achieve a competitive advantage in their industry (Prajogo and Olhager, 2012). By focusing on granted patents, the study can examine the relationship between SC resilience, SSCM practices, and a firm's capacity to innovate, shedding light on the potential long-term benefits of investing in SC resilience development and SSCM practices.

The research seeks to provide comprehensive knowledge of the possible advantages that come from the deployment of SSCM initiatives and the development of SC resilience by analysing both financial performance (as assessed by ROA) and innovation performance (as evaluated by granted patents) (Ageron et al., 2012).

5.4.4 Control variables

This study also controls six firm-level variables, including firm size, revenue growth, board size, Tobin's Q, stock value, and firm age, as they may be related to financial or innovation performance.

The firm's size is an essential control variable, as larger firms may have different resources and capabilities that could impact their SSCM and performance compared to smaller firms (Yang, Hong and Modi, 2011; Yang et al., 2022). In line with previous studies (Lam, 2018; Rehman, Khan and Rahman, 2020), this study measures firm size as the total assets.

Controlling sales growth is critical. It takes into account the impact of a company's performance and financial health and development prospects. (Jia, 2020). A higher sales growth rate can suggest a stronger and more competitive firm capable of managing disruptions and adjusting to market fluctuations.

The size of a company's board of directors can influence its strategic decision-making and governance, affecting its resilience, SSCM implementation, and performance. (Boone et al., 2007). Larger boards may offer diverse perspectives and expertise, while smaller boards may be more agile and responsive to change (Endrikat et al., 2021).

Tobin's Q is a financial indicator that compares the market worth of a company's assets to the replacement cost (Chung and Pruitt, 1994). It is selected as a control variable, accounting for the influence of a firm's investment and development potential on resilience, SSCM, and performance outcomes. Tobin's Q is the ratio of the firm's market value plus the book value of its debt to its total assets (Lewellen and Badrinath, 1997). A higher Tobin's Q may indicate that the firm has valuable assets or growth prospects that contribute to its resilience (Broadstock et al., 2020).

Stock value, or market capitalisation, represents the total value of a firm's outstanding shares of stock (Titman, Wei and Xie, 2004). This control variable helps to account for the influence of a firm's overall market value on its resilience and performance (You et al., 2020). Firms with higher stock values may have greater financial resources and flexibility to navigate disruptions and pursue innovative strategies.

Firm age is defined as the number of years from the company's inception. Compared to younger organisations, older firms may have greater expertise, establish contacts, and collected resources (Coad, Segarra and Teruel, 2016), which could affect their performance (Husted and Sousa-Filho, 2019).

Table 23 Summary of variable measurement

Variables	Description and Calculation	Data Source
Dependent Variables- Firm performance		
Financial performance	Return on assets (ROA), which is calculated as net operating profit divided by the average of last year's and current year's total assets.	CSMAR
Innovation performance	Total granted patents, which is calculated as the sum of all three types of patents.	CNRDS
SSCM practices		
Environment SSCM	Measured as the sum of "strengths" items minus the sum of "concerns" items in environment domain.	CNRDS-CSR
Social SSCM	Measured as the sum of "strengths" items minus the sum of "concerns" items in employee, diversity, and community domains.	CNRDS-CSR
Governance SSCM	Measured as the sum of "strengths" items minus the sum of "concerns" items in governance and product domains.	CNRDS-CSR
SC resilience		
Centrality	Measured as PageRank centrality, referring to the connections with the connection weight and the directions. The higher PageRank centrality, the more authority is the node.	CNRDS-SCM
Network connectivity	This indicator measures how well the node in a network is connected.	CNRDS-SCM
Network size	The number of the nodes in a network	CNRDS-SCM
Network density	Measured as the ratio of the number of edges and the number of possible edges	CNRDS-SCM
Network resilience	Network resilience= (network connectivity* network size)/ (network density*centrality)	CNRDS-SCM

Variables	Description and Calculation	Data Source
Customer base concentration	The percentage of listed company's operating income from the top five customers in total income	CNRDS-SCM
Supplier base concentration	The proportion of the total purchase amount of the listed company from the top five suppliers in the total purchase amount of the year	CNRDS-SCM
Capacity slack	Capacity slack is measured by the ratio of yearly gross property, plant, and equipment (PPE) to yearly sales	CSMAR, CNRDS
Inventory slack	Inventory slack is measured as the days of inventory for the firm in each year, which is calculated by dividing a firm's average inventory (INV) in the current year by its yearly cost of goods (COGS).	CSMAR, CNRDS
SC slack	SC slack is measured by the cash-to-cash cycle of the firm in the current year, which is the days of inventory plus days of accounts receivables minus days of accounts payables.	CSMAR, CNRDS
Control variables		
Firm size	Natural logarithm of firm's total assets.	CSMAR
Sales growth	One-year growth of a firm's net sales in percent.	CSMAR
Board size	The number of directors on the board of a company.	CSMAR
Tobin's Q	The ratio of net sales to total assets.	CSMAR
Stock value	The total gross domestic product in the specific province.	CSMAR
Firm age	The number of years since the establishment of the company.	CSMAR

Source: Author.

5.5 Summary

Chapter 5 justified positivism, with its objective and value-free approach, is the suitable philosophical stance of this study in Section 5.2. Based on the research questions, the deductive logic of the empirical study is demonstrated to guide the quantitative research design in Section 5.3. Section 5.3 also illustrates the research context (i.e., auto, food, and heavy-polluting industries in China) and sample process, including selecting and merging secondary data from reliable databases. After data cleaning processes, sample data are ready to be used for variable measurement in Section 5.4. Specifically, SSCM practices are measured from three dimensions based on ESG measurements. Drawn upon SNT, a measurement hierarchy is proposed for SC resilience, where SC resilience is operationalised as a composite variable, measured from focal-level resource resilience (i.e., resource redundancy in capacity, inventory, and SC cash cycle), the dyads-level relational resilience (i.e., supplier and customer base concentration), and the network-level structural resilience (i.e., network resilience, composited by network density, network size, network connectivity, centrality).

Chapter 6 Empirical Study

6.1 Introduction

This chapter addresses the ***RQ3*** **-** *what is the nature of the relationship between SC resilience and SSCM in terms of their impact on firm performance*- by examining how SC resilience and SSCM practices interact to affect firm performance. The empirical model in Section 6.2 is proposed to analyse the interaction mechanisms between SC resilience and SSCM practices, hypothesised in **Chapter 4**. Section 6.2 also illustrates the suitability of the fixed effect panel data analysis method for the model examination. Section 6.3 presents the empirical results, including description and correlation statistics, and regression results.

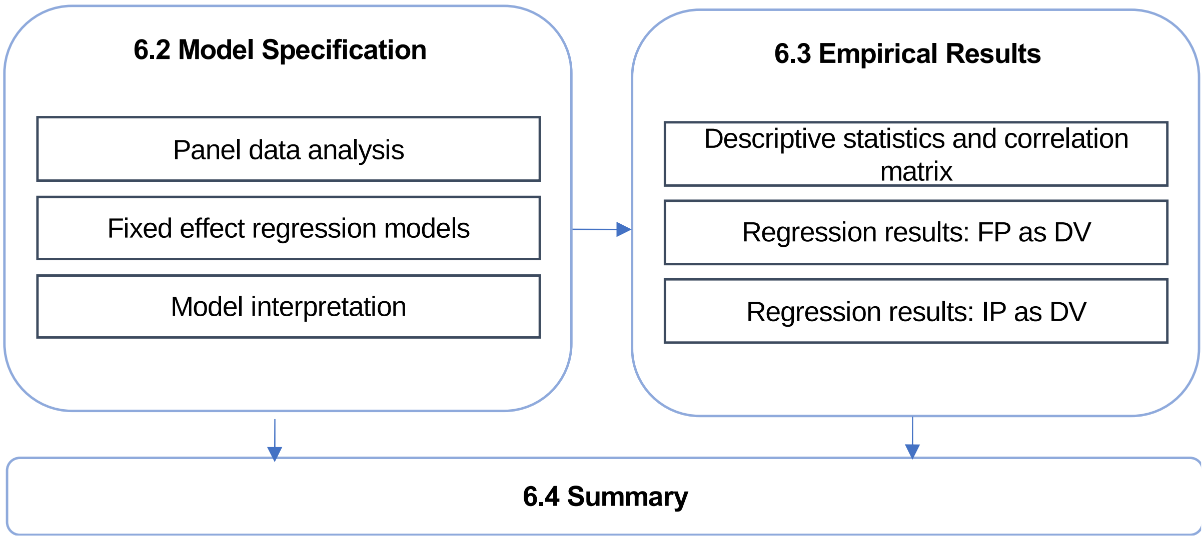

Figure 27 The structure of Chapter 6

6.2 Model specification

The panel data structure of the dataset in this study, comprising observations across both time (2010-2018) and individuals (313 firms), lends itself well to the utilisation of specific statistical methods designed for this kind of data. Panel data offer several advantages including increased variability, less collinearity among variables, greater degrees of freedom, and more efficiency. Furthermore, it allows for the control of individual heterogeneity, a critical aspect given the potential variability across firms in terms of their supply chain practices.

There are several classical statistical methods that are often applied to panel data. These include pooled ordinary least squares (OLS), random effects, and fixed effects models. Each of these models have their strengths and weaknesses, and the choice of the model depends largely on the specific nature of the data and the research questions. Pooled OLS, which ignores the panel structure of the data, could be used when there is no reason to assume individual heterogeneity or if the individual effect is uncorrelated with the explanatory variables. However, its application may lead to biased and inconsistent estimates in the presence of unobserved individual-specific effects that correlate with the regressors (Hutcheson, 2011). Random effects models allow for individual effects, but these effects are assumed to be uncorrelated with the explanatory variables, a condition that, if violated, could lead to biased and inconsistent estimates. Fixed effects models, on the other hand, control for any time-invariant characteristics of the individuals, and therefore, provide consistent estimates even if individual effects correlate with other variables. This model is preferred when dealing with variables that vary over time.

To determine the most appropriate model for panel data, several statistical tests are employed. One commonly used test is the Hausman test, which provides a systematic procedure to choose between the fixed effects and random effects model. The test essentially checks the difference in coefficients estimated by the random effects and fixed effects models. If there is a systematic difference, the test provides a p-value indicating that the fixed effects model is more appropriate. Another test used in this determination is the Breusch-Pagan Lagrange Multiplier (BP LM) test, which tests the null hypothesis that variances across entities are zero. If this null is rejected, it implies that the pooled OLS model is not the best fit, and a random effects or fixed effects model is more appropriate.

In this study, the Hausman and BP LM tests both indicate that the fixed-effects model is the best fit with p-values smaller than 0.05 and pool OLS and random effect models are not suitable to the nature of the sample in this study. These statistical tests, along with the inherent nature of the data and the research objectives, lend support to the use of a fixed effects model in the analysis. Therefore, a fixed-effects model is employed in this empirical study is to examine the direct impact of a firm's SSCM practices on financial performance (***H1***) and innovation performance (***H2***), SC resilience on financial performance (***H3***) and innovation performance (***H4***), and the moderating effects of SC resilience (***H5***), and the moderating effects of SSCM (***H6***).

Fixed effect models can efficiently account for the variations both across time (from 2010 to 2018) and individuals (313 firms), as it can control for individual characteristics that may differ across firms but remain constant over time. This aspect is especially crucial when considering SC resilience and SSCM practices, as these aspects may significantly differ from one firm to another due to factors such as corporate culture, leadership, and business strategy. Specifically, this study seeks to examine the direct impact of a firm's SSCM practices and SC resilience on financial and innovation performance, and the moderating effects of SC resilience and SSCM. In this context, the fixed-effects model can control for time-invariant unobservable factors at the firm level, which could potentially be linked to the firm's SC resilience, SSCM, or performance outcomes. By using firm-level fixed effects, the model can account for these unobserved variables, thereby mitigating potential endogeneity issues and providing consistent within-firm estimates. Additionally, the study also controls for time-fixed effects, thus accounting for unobservable time-specific variables that may potentially affect a firm's financial success over time. Significant economic events or trends that could influence the studied relationships are therefore accounted for.

However, the application of fixed-effects models does pose certain challenges, which have been carefully addressed in this study. One of the principal concerns relates to the possible endogeneity arising from unobservable firm-level characteristics related to SC resilience, SSCM, or performance outcomes (Lam, 2018). To mitigate this, the model includes several control variables such as firm size, revenue growth, board size, Tobin's Q, stock value, and firm age. Further, the study adopts firm-level fixed effects to control for these unobserved time-invariant factors. This approach is valid as all firms in the sample have observations relating to SSCM and SC resilience variables (Bockstedt, Druehl and Mishra, 2015; Li et al., 2022; Yang et al., 2022). Consequently, the fixed-effects model offers a reliable mechanism for removing these unobserved firm-specific factors, thereby alleviating endogeneity concerns and permitting consistent within-firm estimates. Another challenge posed by the application of fixed-effects models is the potential influence of unobservable time-specific variables on a firm's financial success. Given that the study spans nine years, from 2010 to 2018, it's essential to account for these time-specific effects that could result from significant economic events or trends during this period. To address this issue, the study incorporates year-level fixed effects into the model.

Therefore, this study used firm- and time-fixed effect regression analysis to address omitted variables issues and common trends in firm performance over time and control for unobservable firm-level heterogeneity. Two regression models are deployed to investigate the effects of SSCM practices and SC resilience on two different types of firm performance: financial performance (FP) and innovation performance (IP). The correlation matrix and the variance inflation factor (VIF) were used to evaluate the assumptions for multicollinearity. The variables will be eliminated from the regression model if the VIF value exceeds 10. The following are the regression models:

$FP_{itj} = \alpha_{itj} + \beta_{1itj} Sust_{itj} + \beta_{2itj} Resil_{itj} + \beta_{3itj} Sust_{itj} * Resil_{itj} + \beta_{4itj} Con_{itj} + \varepsilon_{itj}$ (Equation 1);

$IP_{itj} = \alpha_{itj} + \beta_{1itj} Sust_{itj} + \beta_{2itj} Resil_{itj} + \beta_{3itj} Sust_{itj} * Resil_{itj} + \beta_{4itj} Con_{itj} + \varepsilon_{itj}$ (Equation 2),

where,

FP_{itj} = Financial performance for firm i of industry j in year t;

IP_{itj} = Innovation performance for firm i of industry j in year t;

$Sust_{itj}$ = The measure of SSCM practices for firm i of industry j in year t;

$Resil_{itj}$= The measure of SC resilience for firm i of industry j in year t;

Con_{itj} = The set of control variables for firm i of industry j in year t.

In the first regression model, the dependent variable (DV) is the financial performance (FP) of firm i of industry j at year t, denoted by FP_{itj}. The model includes several independent variables and control variables. The term $Sust_{itj}$ represents the measurement of SSCM practices for firm i of industry j at year t. $Resil_{itj}$ stands for the measurement of SC resilience for firm i of industry j at year t. The interaction term

($Sust_{itj}$ * $Resil_{itj}$) captures the joint effect of SSCM and SC resilience. Furthermore, Con_{itj} represents a set of control variables for firm i of industry j at year t, which includes factors such as firm size, revenue growth, board size, Tobin's Q, stock value, and firm age. Finally, ε_{itj} is the error term.

The second regression model is identical to the first, except that the dependent variable is innovation performance (IP) instead of FP. It is represented by IP_{itj} for firm i of industry j at year t. In both models, the β coefficients are the parameters of interest, signifying the effect of the respective independent variables on the dependent variable. The α_{itj} represents the intercept of the regression equation.

6.3 Empirical results

6.3.1 Descriptive statistics and correlation matrix

Outliers are managed by winsorising the transformed dataset, a technique that mitigates the effects of extreme values that could potentially distort empirical results. The winsorising method trims the extreme values by assigning data points above the 99th percentile to the 99th percentile value and any data points below the 1st percentile to the 1st percentile value. By limiting the impact of extreme values, winsorising prevents these outliers from disproportionately affecting the results, leading to a more accurate representation of the relationships between variables.

Before running the main regressions, the normalisation transformation was applied to continuous variables. Normalisation enhances the linear relationship between variables, a fundamental assumption in regression analyses. A stronger linear relationship allows for more accurate and reliable estimates of the moderation effect. Skewed data can introduce bias and distort the interpretation of the results. Normalisation minimises skewness, thus reducing the likelihood of obtaining spurious results and increasing the validity of the moderation effect. Variables measured on different scales can lead to misleading results when assessing moderation effects. Normalisation brings variables onto a common scale, ensuring a fair comparison and a more accurate interpretation of the results. Therefore, this study uses normalised data to improve the performance of the regression model, leading to more precise estimates of the moderation effect and better overall model fit.

Table 24 provides descriptive statistics for variables. The first two variables are FP_ROA and IP_Patent, respectively, for financial performance and innovation performance. Variables 3-6 are SSCM variables, where SSCM, E-SSCM, S-SSCM, and G-SSCM stand for composite SSCM, environmental SSCM, social SSCM, and governance SSCM. Variables 7-10 are all related to SC resilience. Variable 7 (SCResi) is composite SC resilience. Variable 8 is FocalResi, which measures focal-level resource resilience. Variable 9 is DyadsResi, which measures dyadic-level relational resilience. Variable 10 is NetResi, which measures network-level structural resilience. In **Table 24**, all six SSCM and SC resilience variables are significantly correlated with small to moderate correlations. E-SSCM is positively correlated with S-SSCM (r = 0.389) and G-SSCM (r = 0.517), indicating that firms prioritising environmental SSCM practices are also more likely to prioritise social and governance aspects. SC resilience variables (FocalRes, DyadsRes, and NetResi) are all negatively correlated with each other, but the correlations are relatively small. This suggests that while these resilience measures may capture different aspects of SC resilience, they are also somewhat related to each other. Based on the correlation analysis, while there are some significant correlations among the variables, the correlations are generally weak to moderate in strength, and there is no evidence of strong multicollinearity among the independent variables (IVs). It is valuable to explore further the causation among SSCM practices, SC resilience and performance dimensions.

Table 24 Descriptive statistics and correlation matrix of variables

Variable	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) FP_ROA	0.0263	0.0501	1						
(2) IP_Patent	0.0183	0.0604	-0.1217***	1					
(3) SSCM	0.4230	0.1671	-0.2276***	0.1337***	1				
(4) E-SSCM	0.4328	0.1805	-0.2346***	0.1128***	0.6590***	1			
(5) S-SSCM	0.4506	0.1655	-0.1693***	0.0861***	0.8756***	0.3890***	1		
(6) G-SSCM	0.5007	0.1594	-0.1770***	0.1371***	0.8218***	0.5169***	0.4567***	1	
(7) SCResi	0.1927	0.0667	0.1144***	-0.1533***	0.0141	-0.0546**	0.0696**	-0.0276	1
(8) FocalResi	0.1122	0.0643	0.0681**	-0.1437***	0.0034	-0.0528*	0.0560**	-0.0360	0.9767***
(9) DyadsResi	0.2819	0.1541	0.3137***	-0.1449***	-0.1585***	-0.2135***	-0.1054***	-0.1099***	0.0961***
(10) NetResi	0.4330	0.3404	0.0961***	-0.2314***	-0.1532***	-0.0983***	-0.1727***	-0.0755***	0.0808***
(11) Firm size	0.5024	0.1532	-0.6190***	0.3271***	0.3369***	0.3299***	0.2363***	0.2915***	-0.2473***
(12) Sale growth	0.0845	0.0482	-0.0226	-0.0374	0.0350	0.0094	0.0327	0.0341	-0.0540**
(13) Board size	0.4754	0.1451	-0.1999***	0.1453***	0.1048***	0.1458***	0.0563**	0.0880***	-0.1233***
(14) Tobin's Q	0.7601	0.1810	-0.2945***	0.0253	0.1179***	0.1125***	0.0920***	0.0912***	-0.1171***
(15) Stock value	0.0502	0.0799	-0.2250***	0.2088***	0.3440***	0.2698***	0.2871***	0.2759***	0.0141
(16) Firm age	0.4546	0.1582	-0.0592**	-0.0326	-0.0613**	0.0004	-0.1004***	-0.0117	-0.1028***

Variable	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(8) FocalResi	1								
(9) DyadsResi	0.0634**	1							
(10) NetResi	0.0379	0.0903***	1						
(11) Firm size	-0.1901***	-0.3339***	-0.1837***	1					
(12) Sale growth	-0.0654**	-0.0183	-0.0037	0.0201	1				
(13) Board size	-0.0837***	-0.0656**	-0.0430	0.2556***	0.0153	1			
(14) Tobin's Q	-0.0625**	-0.0467*	-0.1201***	0.3946***	-0.0482*	0.0949***	1		
(15) Stock value	0.0429	-0.1552***	-0.1969***	0.5580***	0.0286	0.0421	0.1421***	1	
(16) Firm age	-0.0826***	0.0175	0.0117	0.1459***	-0.0572**	0.0631**	0.5128***	0.0197	1

Note: Number of Observations=1336; ***p<0.01; **p<0.05; *p<0.1. Variables are normalised. SD stands for standard deviation.

6.3.2 Regression results: financial performance (FP) as DV

Table 25 and **Table 26** provide an overview of the overall effects of SSCM and SC resilience on FP, as well as the overall moderation effect of SC resilience and SSCM. To better understand the breakdown effects of the three dimensions of SSCM practices and three SC resilience constructs, **Table 27** and **Table 28** can be examined, respectively. **Table 29** summarises the regression results of hypotheses testing regarding **H1**, **H3, H5a**, and **H6a**.

Table 25 Fixed effect regression analysis: SSCM, SC resilience, and FP.

	Model 1	**Model 2**	**Model 3**	**Model 4**
Dependent variable	FP_ROA	FP_ROA	FP_ROA	FP_ROA
Control variable	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value
Firm size	0.00932 (-23.89631) ***	0.00942 (-23.37878) ***	0.00976 (-23.38395) ***	0.00977 (-23.39415) ***
Sale growth	0.02191 (-0.60599)	0.02189 (-0.56498)	0.02186 (-0.74623)	0.02187 (-0.75881)
Board size	0.00758 (-1.33288)	0.00758 (-1.23563)	0.00756 (-1.36736)	0.00757 (-1.32937)
Tobin's Q	0.00735 (-3.41404) ***	0.00736 (-3.28219) ***	0.00733 (-3.22575) ***	0.00734 (-3.21966) ***
Stock value	0.0161 (6.54375) ***	0.01642 (6.79834) ***	0.0166 (7.22851) ***	0.01662 (7.25488) ***
Firm age	0.00779 (3.43746) ***	0.00784 (3.17692) ***	0.00783 (3.01243) ***	0.00783 (2.99337) ***
Independent variable				
SSCM		0.00956 (-1.89809) *	0.00955 (-1.69287) *	0.00959 (-1.61329)
SCResi			0.00112 (-3.04202) ***	0.00521 (-1.43496)
Interaction term				
SSCM x SCResi				0.01069 (0.79804)
Constant	0.00607 (24.00151) ***	0.00701 (21.73572) ***	0.0071 (21.99909) ***	0.00712 (21.91252) ***
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
R-squared	0.41199	0.41358	0.41764	0.41792
N	1336	1336	1336	1336

***p<0.01; **p<0.05; *p<0.1.

In **Table 25**, Model 1 only has control variables. SSCM is included in Model 2, and it has a statistically significant positive coefficient (coefficient = 0.00956, $p<0.1$). Model 2 reveals a positive association between SSCM and financial performance after controlling for other factors such as firm size, sales growth, board size, Tobin's Q, stock value, firm age, and firm and year fixed effects. Therefore, **H1 is supported**. Model 3 adds SC resilience as an independent variable, and its coefficient is statistically significant, indicating that SC resilience has a significant positive effect (coefficient = 0.00112, $p<0.01$) on financial performance after controlling for other factors such as SSCM, firm size, sales growth, board size, Tobin's Q, stock value, firm age, and firm and year fixed effects. Therefore, **H3 is supported**.

Model 4 in **Table 25** includes the interaction term of SSCM and SC resilience. However, the interaction term's coefficient is not statistically significant, and SSCM and SC resilience are not substantially linked with FP, showing that the relationship among SC resilience, SSCM, and FP may be more complicated than previously assumed and that alternative forms of the relationship may be required to completely represent the relationship. Therefore, additional test is conducted to uncover the complexity in **Table 26.**

Table 26 examines the quadratic relationships between SSCM and FP and SC resilience and FP, and the interaction term. Model 5 shows the results of SSCM, the quadratic term of SSCM and control variables. Model 6 adds SC resilience to Model 5. Model 7 also includes the interaction term of SC resilience and SSCM. And Model 8 adds the interaction term of SC resilience and the quadratic term of SSCM. Model 9 includes the quadratic term of SC resilience. Models 10-12 examined the interaction terms involving the quadratic term of SC resilience.

Recalling the conflict observation of the financial effects of SSCM in the literature, the regression results in **Table 26** suggest the relationship between SSCM and FP may not be linear but a curve, as SSCM practices are a costly investment, which means the financial rewards could be more obvious after economic scales. The quadratic component of SSCM (SSCM Squared) is included in the regression model to investigate the non-linear relationship between SSCM and FP.

Table 26 presents the results of our analysis, which shows that both SSCM and SC resilience have significant positive effects on firm performance (FP), **supporting**

H1 and H3. Specifically, the results of Model 5 indicate that the quadratic and linear coefficients of SSCM are both positive and significant (coefficient = 0.05241, $p<0.01$ and coefficient = 0.05328, $p<0.01$, respectively), suggesting that the relationship between SSCM and FP is not strictly linear and may follow a U-shaped curve. Additionally, Model 6 demonstrates that SC resilience also positively impacts FP (coefficient = 0.0011, $p<0.05$), which is consistent with the findings of Model 3, where **H3 was supported**.

When comparing the results of Models 6-8 in **Table 26**, it is found that the interaction term of SC resilience with SSCM was not significant in Model 7 but became substantial when combined with the interaction term of SC resilience and the quadratic term of SSCM in Model 8. This implies that SC resilience has a greater positive moderating effect on SSCM's quadratic term, **supporting H5a**. Surprisingly, Models 9-12 indicate that the relationship between SC resilience and FP is also not strictly linear, as the coefficient of the quadratic term of SC resilience is significantly positive (coefficient = 0.0003, $p<0.05$). However, the quadratic term of SC resilience did not moderate the linear or quadratic SSCM-FP relationship. Conversely, the interaction terms of SC resilience with SSCM (coefficient = 0.6381, $p<0.05$) and SSCM Squared (coefficient = 0.6399, $p<0.05$) are significantly positive, indicating the linear and quadratic terms of SSCM can moderate SC resilience-FP relationship. Thus, **H6a is supported**.

Model 9 in **Table 26** illustrates the curvilinear relationship between SSCM and FP, as well as the curvilinear connection between SC resilience and FP. These relationships are interdependent, suggesting that SC resilience can serve as a moderating factor in the association between SSCM and FP. Likewise, the bond between SC resilience and FP can be influenced by SSCM. **Figure 28** responding to Model 9 in **Table 26** visually presents the intertwined relationships among SSCM, SC resilience, and FP. **Figure 29** responding to Model 9 in **Table 26** reflects the margin effect of SSCM on FP is contingent upon the value of SC resilience, emphasising the interdependence between these variables.

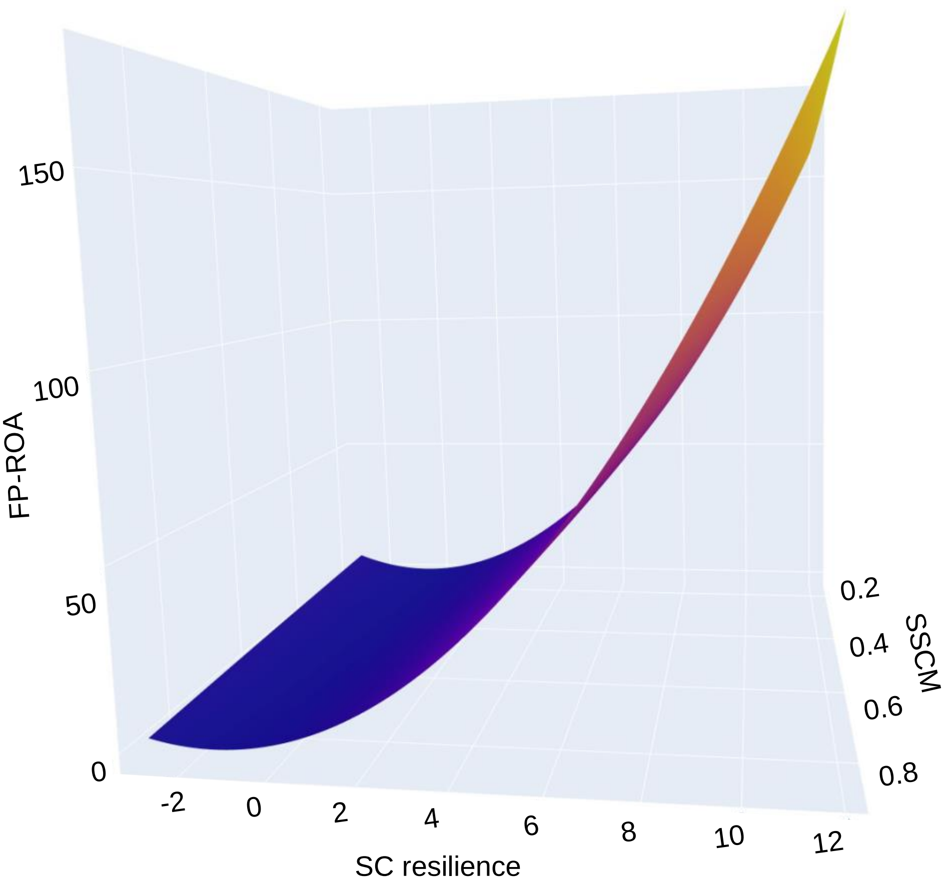

Figure 28 Model 9 in Table 26: SSCM, SC resilience, and FP

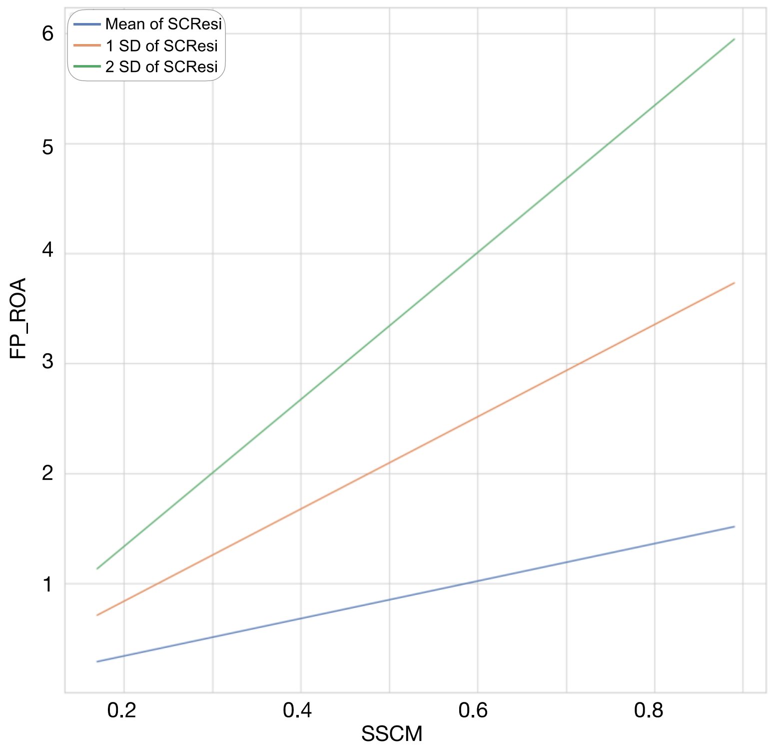

Figure 29 Model 9 in Table 26: margin effect of SSCM on FP

Table 26 Fixed effect regression: quadratic SSCM-FP relationship

	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Dependent variable	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA
Control variable	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value
Firm size	0.00916 (-23.6639) ***	0.00952 (-23.41792) ***	0.00953 (-23.42972) ***	0.00948 (-23.64866) ***	0.00975 (-23.51919) ***	0.00975 (-23.51069) ***	0.00975 (-23.5102) ***	0.00977 (-23.44143) ***
Sale growth	0.0213 (-0.17094)	0.02131 (-0.32017)	0.02131 (-0.33337)	0.0212 (-0.37526)	0.02117 (-0.39562)	0.02118 (-0.39865)	0.02118 (-0.40057)	0.02119 (-0.38791)
Board size	0.00737 (-1.15533)	0.00736 (-1.25885)	0.00737 (-1.21931)	0.00733 (-1.17417)	0.00732 (-1.16842)	0.00732 (-1.16786)	0.00732 (-1.16756)	0.00733 (-1.16098)
Tobin's Q	0.00717 (-4.04461) ***	0.00716 (-3.98305) ***	0.00716 (-3.9768) ***	0.00713 (-3.77571) ***	0.00712 (-3.79982) ***	0.00713 (-3.79783) ***	0.00713 (-3.79754) ***	0.00713 (-3.7981) ***
Stock value	0.01646 (4.61035) ***	0.01671 (4.96811) ***	0.01673 (4.99736) ***	0.01668 (4.73599) ***	0.01675 (4.94997) ***	0.01677 (4.94176) ***	0.01679 (4.92874) ***	0.01715 (4.68662) ***
Firm age	0.00762 (3.25597) ***	0.00762 (3.12546) ***	0.00762 (3.1056) ***	0.0076 (2.88581) ***	0.00761 (2.71775) ***	0.00761 (2.71792) ***	0.00761 (2.71916) ***	0.00761 (2.72712) ***
Independent variable								
SSCM	0.05328 (-9.07694) ***	0.05345 (-8.8154) ***	0.05346 (-8.80175) ***	0.0534 (-8.44328) ***	0.05333 (-8.47461) ***	0.05397 (-8.39154) ***	0.05368 (-8.44066) ***	0.05692 (-7.73915) ***
SSCM Squared	0.05241 (8.87233) ***	0.05253 (8.64465) ***	0.05254 (8.64513) ***	0.05248 (8.28685) ***	0.05242 (8.34526) ***	0.05267 (8.31632) ***	0.05249 (8.34225) ***	0.05661 (7.48635) ***
SCResi		0.0011 (-2.34778) **	0.00507 (-1.32348)	0.01546 (-4.16469) ***	0.01553 (-3.91381) ***	0.01784 (-3.3496) ***	0.01738 (-3.40887) ***	0.01946 (-3.34353) ***
SCResi Squared					0.0003 (2.18603) **	0.0019 (0.22628)	0.0011 (0.39797)	0.00704 (0.71915)
Interaction term								
SSCM x SCResi			0.01041 (0.8353)	0.06288 (4.03088) ***	0.06381 (3.58194) ***	0.06998 (3.21849) ***	0.06825 (3.27973) ***	0.07907 (3.16652) ***
SSCM Squared x SCResi				0.06304 (-3.94647) ***	0.06399 (-3.49559) ***	0.06732 (-3.28641) ***	0.06594 (-3.34502) ***	0.07902 (-3.15747) ***
SSCM x SCResi Squared						0.0039 (0.11608)		0.03306 (-0.66501)
SSCM Squared x SCResi Squared							0.00448 (0.19586)	0.03804 (0.68346)
Constant	0.01436 (18.4271) ***	0.01433 (18.47326) ***	0.01434 (18.44252) ***	0.01432 (18.13814) ***	0.01433 (18.27617) ***	0.01461 (17.95589) ***	0.01452 (18.07004) ***	0.01514 (17.14476) ***
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.44642	0.44871	0.449	0.4554	0.45736	0.45737	0.45738	0.45756
N	1336	1336	1336	1336	1336	1336	1336	1336

***p<0.01; **p<0.05; *p<0.1.

To examine **H1(a-c)** and **H3(a-c)**, the breakdown effects of SSCM are evaluated in **Table 27** and **Table 28**, respectively.

There are six regression models in **Table 27**: Model 13 has the linear effect of E-SSCM, S-SSCM, and G-SSCM, after all, control variables as well as the firm- and year-level fixed effects; Model 14 examines the linear term of SSCM (ESG) and quadratic terms of SSCM (ESG); Model 15 adds SC resilience; Model 16-18 Model add the moderating roles of SC resilience on SSCM (ESG) dimensions and the quadratic terms of SSCM (ESG).

Table 28 includes six new regression models in addition to Model 5. Model 19 incorporates focal-level resilience (FocalResi) following SSCM, squared SSCM, all control variables, and fixed effects at the firm and year levels. Model 20 incorporates FocalResi as well as the SSCM-FocalResi interaction term. Model 21 includes dyads-level resilience (DyadsResi) following SSCM, Squared SSCM, all control variables, and firm- and year-level fixed effects. DyadsResi and the interaction term of SSCM and DyadsResi are included in Model 22. Model 23 has network-level resilience (NetResi) following SSCM, squared SSCM, all control variables, and firm- and year-level fixed effects. Model 24 incorporates NetResi as well as the SSCM/NetResi interaction term. These models investigate the influence of multiple dimensions of SC resilience on the association between SSCM and performance.

Table 27 Fixed effect regression: quadratic SSCM (ESG)-FP relationship

	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20	Model 21
Dependent variable	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA
Control variable	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value
Firm size	0.0095 (-23.12586) ***	0.00929 (-23.31006) ***	0.00963 (-23.06633) ***	0.00967 (-23.0849) ***	0.00965 (-23.11529) ***	0.00963 (-23.06679) ***	0.00962 (-23.30743) ***	0.00963 (-23.06679) ***	0.00962 (-23.30743) ***
Sale growth	0.02189 (-0.59698)	0.02135 (-0.23511)	0.02136 (-0.37625)	0.02136 (-0.40295)	0.02133 (-0.42966)	0.02136 (-0.40392)	0.02129 (-0.38777)	0.02136 (-0.40392)	0.02129 (-0.38777)
Board size	0.00759 (-1.161)	0.00743 (-1.06172)	0.00742 (-1.15112)	0.00743 (-1.08888)	0.00742 (-1.02216)	0.00743 (-1.07253)	0.00741 (-1.06321)	0.00743 (-1.07253)	0.00741 (-1.06321)
Tobin's Q	0.00738 (-3.21387) ***	0.00721 (-3.95923) ***	0.0072 (-3.9111) ***	0.0072 (-3.91258) ***	0.00719 (-3.87157) ***	0.00721 (-3.82082) ***	0.00721 (-3.58725) ***	0.00721 (-3.82082) ***	0.00721 (-3.58725) ***
Stock value	0.01643 (6.83159) ***	0.01646 (4.84291) ***	0.01672 (5.16624) ***	0.01674 (5.23071) ***	0.01673 (5.13955) ***	0.01672 (5.19919) ***	0.01667 (5.1946) ***	0.01672 (5.19919) ***	0.01667 (5.1946) ***
Firm age	0.00788 (3.0779) ***	0.00768 (3.15416) ***	0.00768 (3.05096) ***	0.00768 (3.02145) ***	0.00769 (2.83639) ***	0.00771 (2.93475) ***	0.00769 (2.78781) ***	0.00771 (2.93475) ***	0.00769 (2.78781) ***
Independent variable									
E-SSCM	0.00688 (-1.68484) *	0.02284 (-3.78488) ***	0.02282 (-3.72719) ***	0.02281 (-3.73618) ***	0.02277 (-3.69546) ***	0.02282 (-3.68426) ***	0.02275 (-3.70298) ***	0.02282 (-3.68426) ***	0.02275 (-3.70298) ***
S-SSCM	0.00947 (-1.50002)	0.04116 (-3.40746) ***	0.04116 (-3.29974) ***	0.04125 (-3.20481) ***	0.04236 (-2.54717) **	0.04115 (-3.28143) ***	0.04106 (-3.43538) ***	0.04115 (-3.28143) ***	0.04106 (-3.43538) ***
G-SSCM	0.00872 (0.76136)	0.03833 (-5.28234) ***	0.03839 (-5.10824) ***	0.0384 (-5.14962) ***	0.0384 (-5.29809) ***	0.03838 (-5.11366) ***	0.0388 (-4.52813) ***	0.03838 (-5.11366) ***	0.0388 (-4.52813) ***
E-SSCM Squared		0.02459 (3.32177) ***	0.02457 (3.25185) ***	0.02457 (3.25681) ***	0.02453 (3.2108) ***	0.02458 (3.21405) ***	0.0245 (3.28168) ***	0.02458 (3.21405) ***	0.0245 (3.28168) ***
S-SSCM Squared		0.04424 (2.90387) ***	0.0442 (2.85313) ***	0.04426 (2.77751) ***	0.04532 (2.16702) **	0.0442 (2.82311) ***	0.04409 (2.96775) ***	0.0442 (2.82311) ***	0.04409 (2.96775) ***
G-SSCM Squared		0.03464 (5.45081) ***	0.0347 (5.26274) ***	0.03473 (5.31378) ***	0.03472 (5.45984) ***	0.03471 (5.29957) ***	0.03513 (4.68973) ***	0.03471 (5.29957) ***	0.03513 (4.68973) ***
SCResil			0.0011 (-2.17889) **	0.00436 (-1.76382) *	0.01299 (-2.89314) ***	0.00473 (-1.74868) *	0.01453 (-3.54676) ***	0.00473 (-1.74868) *	0.01453 (-3.54676) ***
Interaction term									
E-SSCM x SCResil				0.0065 (-1.22147)	0.02393 (1.29659)				
E-SSCM Squared x SCResil					0.02654 (-1.69216) *				
S-SSCM x SCResil						0.00886 (1.2529)	0.05717 (2.60667) ***		
S-SSCM Squared x SCResil							0.06096 (-2.44194) **		
G-SSCM x SCResil								0.00891 (1.27539)	0.05253 (3.3186) ***
G-SSCM Squared x SCResil									0.0464 (-3.14765) ***
Constant	0.00706 (21.44193) ***	0.01374 (18.2023) ***	0.01373 (18.22379) ***	0.01372 (18.21136) ***	0.0138 (17.80083) ***	0.01374 (18.14036) ***	0.01375 (17.82873) ***	0.01374 (18.14036) ***	0.01375 (17.82873) ***
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.41487	0.44594	0.44793	0.44855	0.44974	0.44858	0.45106	0.44861	0.45271
N	1336	1336	1336	1336	1336	1336	1336	1336	1336

***p<0.01; **p<0.05; *p<0.1.

In **Table 27**, the coefficient estimation of G-SSCM and S-SSCM are not statistically significant at the 10% significance level in Model 13; only the effect of E-SSCM on FP is significantly positive at the 10% level of significance. Compared with Model 13, Model 14 adds the quadratic terms of SSCM (ESG), and all six SSCM(ESG) and quadratic terms of SSCM (ESG) variables remain significantly positive ($p<0.05$). **Thus, H1(a-c) are supported.** Model 14 is consistent with the conclusion of quadratic relationships between SSCM and FP from Model 5. The coefficient of SC resilience remains significantly positive ($p<0.1$) across Models 15 to 18, showing that a firm's SC resilience increases its FP. This conclusion is consistent with Model 3 and Model 6. That, **H3 is supported**.

Regarding the moderating effects, the interaction between SC resilience and E-SSCM in Model 16 is insignificant the interaction between SC resilience and the quadratic term of E-SSCM is statistically significant and positive (coefficient=0.2654, $p<0.1$). It suggests that the relationship between E-SSCM and FP is not significantly moderated by SC resilience. Still, the relationship between E-SSCM Squared and FP is moderated by SC resilience. This implies that a firm's E-SSCM enhances its FP to a larger extent if its SC resilience is stronger. In Model 17, the interaction terms between S-SSCM and SC resilience and squared S-SSCM and SC resilience are significant, indicating that the linear and quadratic relationship between S-SSCM and FP are both moderated by SC resilience. In Model 18, the interaction terms between G-SSCM and SC resilience and squared G-SSCM and SC resilience are significant, indicating that the linear and quadratic relationship between G-SSCM and FP are both moderated by SC resilience. Thus, **H5a is supported**.

Based on the results of Model 15 in **Table 27,** additional tests are conducted to verify the quadratic relationships between SC resilience and FP. The quadratic term of SC resilience has a significantly positive effect on FP (coefficient = 0.0003, $p<0.01$), which is much smaller than the coefficient of SC resilience (coefficient =0.0015, $p<0.01$). And all six linear terms of SSCM (ESG) and quadratic terms of SSCM (ESG) have significantly positive coefficients ($p<0.01$): 0.02277 (E-SSCM), 0.04106 (S-SSCM), 0.03829 (G-SSCM), 0.02451 (E-SSCM Squared), 0.04409 (S-SSCM Squared), and 0.03462 (G-SSCM Squared). This result is consistent with Model 15, that SSCM (ESG) dimensions have non-linear relationships with FP, and the effects of SSCM (ESG) dimensions vary. This result implies the non-linear relationship between SC resilience and FP, which aligns with Model 9 in **Table 26**.

Table 28 Fixed effect regression: SC resilience dimensions-FP relationships.

	Model 5	Model 19	Model 20	Model 21	Model 22	Model 23	Model 24
Dependent variable	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA	FP_ROA
Control variable	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value
Firm size	0.00916 (-23.6639) ***	0.00943 (-23.66545) ***	0.00942 (-23.7055) ***	0.00951 (-21.218) ***	0.00929 (-21.24517) ***	0.00917 (-23.66026) ***	0.00918 (-23.66878) ***
Sale growth	0.0213 (-0.17094)	0.0213 (-0.37354)	0.02128 (-0.40099)	0.02109 (-0.14847)	0.02056 (-0.29999)	0.02131 (-0.16958)	0.02131 (-0.17554)
Board size	0.00737 (-1.15533)	0.00735 (-1.19539)	0.00735 (-1.12657)	0.0073 (-1.33316)	0.00713 (-1.85946) *	0.00737 (-1.16081)	0.00738 (-1.2031)
Tobin's Q	0.00717 (-4.04461) ***	0.00717 (-3.8648) ***	0.00716 (-3.85576) ***	0.00712 (-4.4916) ***	0.00694 (-4.76459) ***	0.0072 (-4.0753) ***	0.0072 (-4.07333) ***
Stock value	0.01646 (4.61035) ***	0.01673 (5.06121) ***	0.01671 (5.04784) ***	0.01633 (4.33343) ***	0.01593 (4.68854) ***	0.01655 (4.53163) ***	0.01674 (4.3631) ***
Firm age	0.00762 (3.25597) ***	0.00762 (3.07123) ***	0.00761 (3.03442) ***	0.00755 (3.19364) ***	0.00736 (2.96846) ***	0.00764 (3.28326) ***	0.00764 (3.29148) ***
Independent variable							
SSCM	0.05328 (-9.07694) ***	0.05339 (-8.79751) ***	0.05333 (-8.79663) ***	0.05277 (-9.03192) ***	0.05962 (-3.76078) ***	0.05329 (-9.07727) ***	0.05923 (-7.8279) ***
SSCM Squared	0.05241 (8.87233) ***	0.0525 (8.608) ***	0.05245 (8.63864) ***	0.0519 (8.88143) ***	0.05308 (6.14989) ***	0.05243 (8.86612) ***	0.05435 (8.34746) ***
FocalResi		0.00111 (-2.75988) ***	0.00511 (-2.49811) **				
DyadsResi				0.0072 (5.27125) ***	0.02582 (9.52935) ***		
NetResi						0.0031 (-0.53895)	0.01327 (0.63153)
Interaction term							
FocalResi x SSCM			0.01046 (1.94621) *				
DyadsResi x SSCM					0.05471 (-8.37546) ***		
NetResi x SSCM							0.02829 (-0.77907)
Constant	0.01436 (18.4271) ***	0.01432 (18.43554) ***	0.01431 (18.4107) ***	0.01458 (16.98791) ***	0.01746 (9.31746) ***	0.01452 (18.30336) ***	0.01673 (15.50159) ***
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.44642	0.44958	0.45115	0.45778	0.48504	0.44654	0.44679
N	1336	1336	1336	1336	1336	1336	1336

***p<0.01; **p<0.05; *p<0.1.

In **Table 28**, Model 19, Model 21, and Model 23 add FocalResi, DyadsResi, and NetResi, respectively, after controlling SSCM, SSCM Squared, control variables, and firm- and time-fixed effects. The significant positive coefficients suggest focal-level resilience (coefficient=0.0011, p<0.01) and dyads-level resilience (coefficient = 0.0072, p<0.01) have positive impacts on FP. However, the results of Model 23 cannot support the FP effects of the network-level resilience (p>0.1). Thus, **H3(a) and H3(b) are supported, H3(c) is rejected.**

Regarding the moderating effects, Model 20, Model 22, and Model 24 add the interaction terms between SSCM and SC resilience dimensions, respectively. In Model 20, the interaction term between SSCM and FocalResi (coefficient=0.0104, p<0.1), can be interpreted as the moderating effect of SSCM on the relationship between FocalResi and FP. This means that the effect of focal-level resilience on FP depends on the level of SSCM. In other words, the relationship between FocalResi and FP is stronger or weaker depending on the level of SSCM. If SSCM is high, the relationship between FocalResi and FP is expected to be stronger, while if SSCM is low, the relationship is expected to be weaker. In Model 22, the interaction term between SSCM and DyadsResi is significantly positive (coefficient=0.05471, p<0.01). This means that the effect of dyads-level resilience on FP depends on the level of SSCM. The relationship between DyadsResi and FP is stronger or weaker depending on the level of SSCM. If SSCM is high, the relationship between FocalResil and FP is expected to be stronger, while if SSCM is low, the relationship is expected to be weaker. In Model 24, the interaction term between SSCM and NetResi is insignificant (p>0.1). This means that the effect of network-level resilience on FP does not depend on the level of SSCM. **Thus, H6a is supported.**

The results in **Table 28** show that the moderating effects of SSCM on the FP effects of SC resilience dimensions are varied. SSCM moderates the focal- and dyads-level resilience-FP relationships but not the network-level resilience-FP relationship. **Figure 30** and **Figure 31** present the margin effects of SSCM in the associations between focal- and dyads-level resilience and FP, respectively.

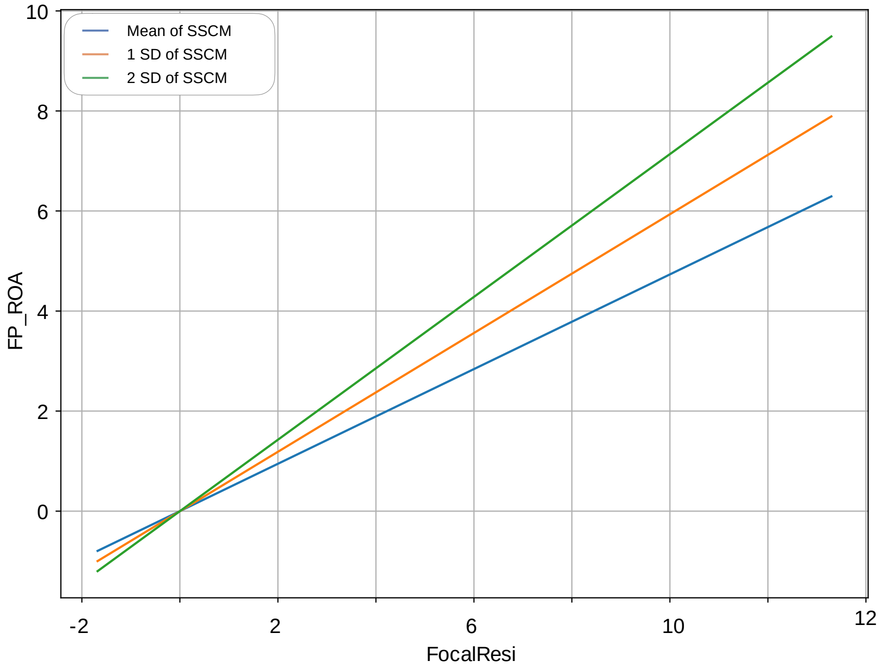

Figure 30 Model 20 in Table 28: moderation effects of SSCM on the association between focal-level resilience and FP

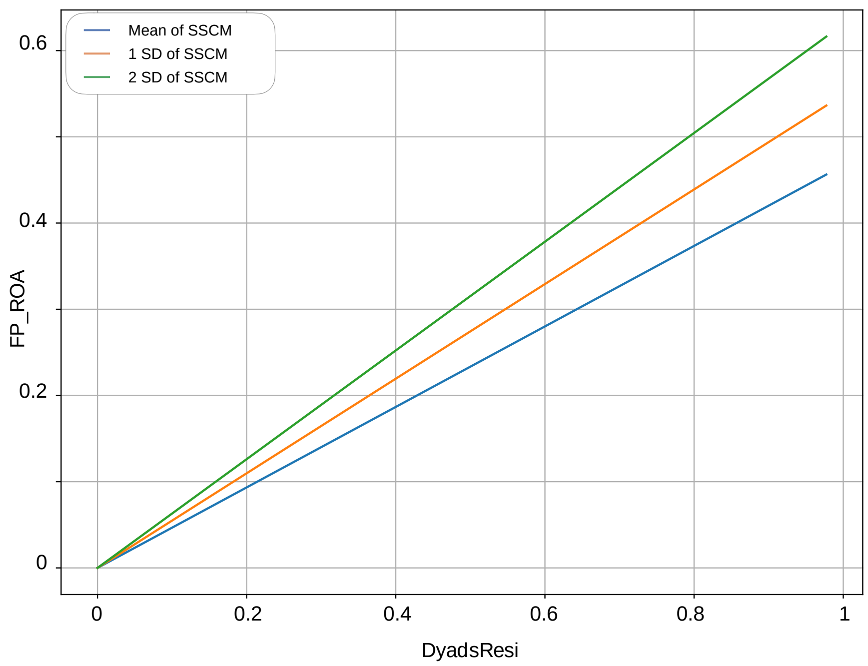

Figure 31 Model 20 in Table 28: moderation effects of SSCM on the association between dyads-level resilience and FP

Table 29 summarises the regression results with the proposed hypotheses with FP as dependent variables.

Table 29 Results of hypotheses testing (FP as DV)

Hypotheses	IVs	Moderators	DVs	Results
H1	**SSCM**		**FP**	**Supported**
H1a	E-SSCM		FP	Supported
H1b	S-SSCM		FP	Supported
H1c	G-SSCM		FP	Supported
H3	**SC resilience**		**FP**	**Supported**
H3a	Focal-level resilience		FP	Supported
H3b	Dyads-level resilience		FP	Supported
H3c	Network-level resilience		FP	Rejected
H5a	**SSCM**	**SC resilience**	**FP**	**Supported**
H5a	E-SSCM	SC resilience	FP	Supported
H5a	S-SSCM	SC resilience	FP	Supported
H5a	G-SSCM	SC resilience	FP	Supported
H6a	**SC resilience**	**SSCM**	**FP**	**Supported**
H6a	Focal-level resilience	SSCM	FP	Supported
H6a	Dyads-level resilience	SSCM	FP	Supported
H6a	Network-level resilience	SSCM	FP	Supported

Source: Author.

6.3.3 Regression results: innovation performance (IP) as DV

Table 30 provides an overview of the overall effects of SSCM and SC resilience on IP, as well as the overall moderation effect of SC resilience and SSCM. **Table 31** investigates the relationships among SSCM, three dimensions of SC resilience, and IP and **Table 32** examines the breakdown effects of SSCM. **Table 33** summarises the regression results regarding hypotheses testing of **H2**, **H4**, **H5b**, and **H6b**.

Table 30 Fixed effect regression analysis: SSCM, SC resilience, and IP.

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
Dependent variable	PP_Patent	PP_Patent	PP_Patent	PP_Patent	PP_Patent	PP_Patent	PP_Patent	PP_Patent
Control variable	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value
Firm size	0.01369 (9.69103) ***	0.01385 (9.50301) ***	0.01416 (8.47761) ***	0.01434 (8.24366) ***	0.01434 (8.2905) ***	0.01454 (7.83944) ***	0.01476 (7.5632) ***	0.01476 (7.60683) ***
Sale growth	0.03217 (-2.07444) **	0.03218 (-2.08519) **	0.0321 (-2.27136) **	0.03212 (-2.29014) **	0.0321 (-2.26627) **	0.03207 (-2.28963) **	0.03209 (-2.31282) **	0.03207 (-2.28889) **
Board size	0.01113 (2.64574) ***	0.01114 (2.61403) ***	0.01109 (2.52406) **	0.01111 (2.47861) **	0.01112 (2.40675) **	0.01108 (2.54402) **	0.0111 (2.49194) **	0.01111 (2.41945) **
Tobin's Q	0.01079 (-3.176) ***	0.01081 (-3.20428) ***	0.01075 (-3.09956) ***	0.01077 (-3.14293) ***	0.01077 (-3.15533) ***	0.01074 (-3.08987) ***	0.01076 (-3.1424) ***	0.01076 (-3.15495) ***
Stock value	0.02364 (1.11259)	0.02415 (0.98047)	0.02395 (1.70399) *	0.02439 (1.52933)	0.0244 (1.46299)	0.02409 (1.89864) *	0.02448 (1.70592) *	0.02449 (1.64048)
Firm age	0.01144 (-1.24468)	0.01153 (-1.16713)	0.01142 (-1.46189)	0.0115 (-1.35804)	0.0115 (-1.3237)	0.01146 (-1.6252)	0.01153 (-1.51144)	0.01153 (-1.47802)
Independent variable								
SSCM		0.01406 (0.54046)		0.01403 (0.7709)	0.01408 (0.62767)		0.01406 (0.90962)	0.01411 (0.76583)
SCResi			0.00165 (-3.33449) ***	0.00165 (-3.37866) ***	0.00765 (0.78361)	0.00226 (-3.65701) ***	0.00227 (-3.73003) ***	0.00779 (0.40833)
SCResi Squared						0.00044 (1.79241) *	0.00044 (1.8559) *	0.00044 (1.86943) *
Interaction term								
SSCM x SCResi					0.0157 (-1.54875)			0.01568 (-1.56518)
Constant	0.00892 (-2.86436) ***	0.01031 (-2.74835) ***	0.00915 (-2.00156) **	0.01043 (-2.12539) **	0.01045 (-2.03291) **	0.00927 (-1.68017) *	0.01049 (-1.91043) *	0.0105 (-1.81639) *
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.12826	0.12845	0.1355	0.13589	0.13745	0.13759	0.13812	0.13971
N	1336	1336	1336	1336	1336	1336	1336	1336

***p<0.01; **p<0.05; *p<0.1.

In **Table 30**, Model 1 includes only control variables. Model 2 includes SSCM. The coefficient of SSCM is not statistically significant (p>0.1), indicating that there is a positive relationship between SSCM and financial performance after controlling for other factors such as firm size, sales growth, board size, Tobin's Q, stock value, firm age, and firm and year fixed effects. Therefore, **H2 is rejected**. Model 3 adds SC resilience as an independent variable. Its coefficient is statistically significant, indicating that SC resilience has a significant positive effect (coefficient = 0.00165, p<0.01) on IP after controlling for other factors such as firm size, sales growth, board size, Tobin's Q, stock value, firm age, and firm and year fixed effects. Therefore, **H4 is supported**. Models 4 include both SSCM and SC resilience as independent variables. The results hold the same. Model 5 adds the interaction term of SSCM and SC resilience. The coefficient for the interaction term is not statistically significant (p>0.1), and SSCM does not have moderating effects on SC resilience-IP relationship. Thus**, H6b is rejected**. However, the results of Model 4 imply it is possible that the relationship between SC resilience and IP is more complex than initially thought and that other forms of the relationship may be necessary to fully capture the relationship.

Table 30 also examines the quadratic relationships between SC resilience and IP in Model 6. Model 7 adds SSCM to Model 6, and Model 8 also includes the interaction term of SC resilience and SSCM. The results of Model 6 indicate that the linear and quadratic coefficients of SC resilience are both positive and significant (coefficient = 0.00226, p<0.01 and coefficient = 0.00044, p<0.1, respectively), suggesting that the relationship between SC resilience and IP is not strictly linear and may follow a slightly U-shaped curve. **Figure 32,** responding to Model 6 in **Table 30,** visually presents the curvilinear relationship between SC resilience and IP.

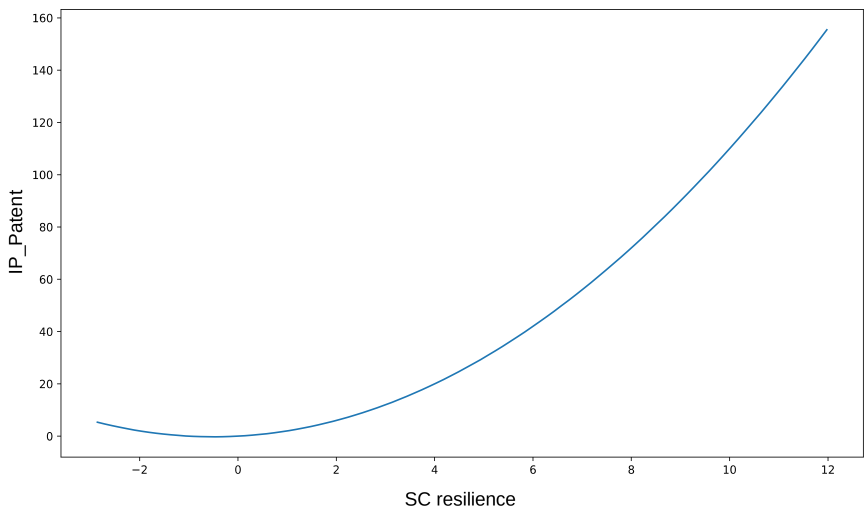

Figure 32 Model 6 in Table 30: a curvilinear impact of SC resilience on IP

Given that the coefficient for SCResi Squared is considerably smaller than that of SCResi (0.00044 compared to 0.00226). As such, the quadratic effect of SC resilience on IP has minimal impact on the model and can be removed to simplify it. The coefficient of SSCM in model 7 is not significant (p>0.1), **rejecting H2**. This result is consistent with Model 2. The coefficient of SSCM in model 8 remains insignificant (p>0.1), and the coefficient of SSCM x SCResi is insignificant (p>0.1), **rejecting H6b and H5b**.

In sum, **Table 30** suggests that SSCM has no significant impact on IP, while SC resilience has a not strictly linear relationship with IP. And SSCM has no moderating effects on the SC resilience-IP relationship. Therefore, **H2, H5b and H6b are rejected, while H4 is supported.**

Table 31 Fixed effect regression: SC resilience dimensions- IP relationships

	Model 2	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
Dependent variable	IP_Patent	IP_Patent	IP_Patent	IP_Patent	IP_Patent	IP_Patent	IP_Patent	IP_Patent	IP_Patent
Control variable	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value
Firm size	0.01385 (9.50301) ***	0.01421 (8.37302) ***	0.01421 (8.38961) ***	0.01452 (8.72667) ***	0.01455 (8.77219) ***	0.01361 (9.38861) ***	0.0136 (9.33517) ***	0.01397 (8.30827) ***	0.01462 (7.6757) ***
Sale growth	0.03218 (-2.08519) **	0.03211 (-2.34003) **	0.0321 (-2.31936) **	0.03218 (-2.09128) **	0.03218 (-2.09407) **	0.03162 (-2.10325) **	0.03157 (-2.09587) **	0.03156 (-2.34529) **	0.03157 (-2.35055) **
Board size	0.01114 (2.61403) ***	0.01109 (2.58126) ***	0.0111 (2.52845) **	0.01115 (2.64821) ***	0.01116 (2.59329) ***	0.01095 (2.5853) ***	0.01095 (2.4729) **	0.0109 (2.55465) **	0.01091 (2.58211) ***
Tobin's Q	0.01081 (-3.20428) ***	0.01078 (-3.00069) ***	0.01078 (-3.01322) ***	0.01085 (-3.10346) ***	0.01086 (-3.14087) ***	0.01067 (-3.87195) ***	0.01065 (-3.9167) ***	0.01064 (-3.66833) ***	0.01068 (-3.57824) ***
Stock value	0.02415 (0.98047)	0.0244 (1.59665)	0.02439 (1.60735)	0.0242 (1.05168)	0.02422 (1.0043)	0.02385 (0.25511)	0.02437 (-0.21345)	0.02413 (0.85708)	0.02419 (0.91817)
Firm age	0.01153 (-1.16713)	0.0115 (-1.41292)	0.0115 (-1.3833)	0.01153 (-1.14696)	0.01154 (-1.1807)	0.01135 (-0.73016)	0.01134 (-0.70803)	0.01133 (-0.96992)	0.01133 (-0.95626)
Independent variable									
SSCM	0.01406 (0.54046)	0.014 (0.6573)	0.01405 (0.51638)	0.01408 (0.47205)	0.02528 (1.07879)	0.01384 (0.06832)	0.02151 (1.72047) *	0.01379 (0.18557)	0.01382 (0.13315)
FocalResi		0.00167 (-3.62545) ***	0.00772 (0.65949)					0.00164 (-3.44741) ***	0.00164 (-3.45505) ***
DyadsResi				0.01099 (-1.12008)	0.03866 (0.6234)				0.01076 (-0.9102)
NetResi						0.00461 (-7.00398) ***	0.01903 (0.42811)	0.00459 (-6.90913) ***	0.00459 (-6.86907) ***
Interaction term									
SSCM x FocalResi			0.01579 (-1.47613)						
SSCM x DyadsResi					0.08171 (-0.98235)				
SSCM x NetResi							0.04048 (-2.18819) **		
Constant	0.01031 (-2.74835) ***	0.01037 (-2.22944) **	0.01038 (-2.13162) **	0.0113 (-2.04837) **	0.01467 (-2.20463) **	0.01065 (-0.50689) 0	0.0127 (-1.62199) 0	0.01068 (-0.08378) 0	0.01157 (0.27079) 0
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared **N**	0.12845 1336	0.137 1336	0.13842 1336	0.12928 1336	0.12991 1336	0.15952 1336	0.16255 1336	0.16699 1336	0.16751 1336

***p<0.01; **p<0.05; *p<0.1.

In **Table 31**, Model 2 is the basic model, which controls SSCM, control variables, yea- and firm- fixed effects. Models 9 to 14 investigate the impacts of SC resilience dimensions (i.e., focal-, dyads-, and network-level resilience) on IP, respectively, along with the test of the moderation effect of SSCM. Models 15 and 16 examine the joint effects SC resilience dimensions on IP.

The comparison of Model 9, 11, 13 verifies the different impacts of a single dimension of SC resilience on IP. The coefficients of FocalResi (coefficient=0.00167, p<0.01) in Model 9 and NetResi in Model 13 (coefficient=0.00461, p<0.01) are positive at 1% level of significance, while the coefficient of DyadsResi is not statistically significant at the 10% level of significance in Model 11. Thus**, H4a and H4c are supported, but H4b is rejected.** This conclusion remains robust in Models 15 and 16. In Model 15, the coefficients of FocalResi (coefficient=0.00164, p<0.01) and NetResi (coefficient=0.00459, p<0.01) are significantly positive. The difference between the values of the two coefficients implies NetResi has a stronger impact on IP over FocalResi (0.00459 compared to 0.00164). Model 16 added DyadsResi, where the coefficients of FocalResi (coefficient=0.00164, p<0.01) and NetResi (coefficient=0.00459, p<0.01) remain the same, but DyadsResi has no significant impact on IP. The results of Model 16 verify the robustness of the previous regression results.

In terms of moderating effects, the interaction between SSCM and focal-level resilience is not statistically significant in Model 10, and so is the interaction between SSCM and dyads-level resilience in Model 12. However, the coefficient of the interaction term SSCM x NetResi (coefficient=0.04048, p<0.05) is significantly positive at 5% significance level in Model 14, indicating a positive moderating effect of SSCM on the network-level resilience-IP relationship.

Model 14 in **Table 31** suggests that SSCM and NetResi are two compounding variables in the regression model. The interaction between SSCM and network-level resilience uncovers the positive and direct impact of SSCM on IP, suggested by the significant coefficient of SSCM (coefficient=0.02151, p<0.1) in the model. Thus, **H6b is supported.** With the presence of network-level resilience, SSCM has a positive impact on IP, **partially supporting H2.** The moderation effect of SSCM on network-level resilience-IP relationship is visualised in **Figure 33** for Model 14 in **Table 31.**

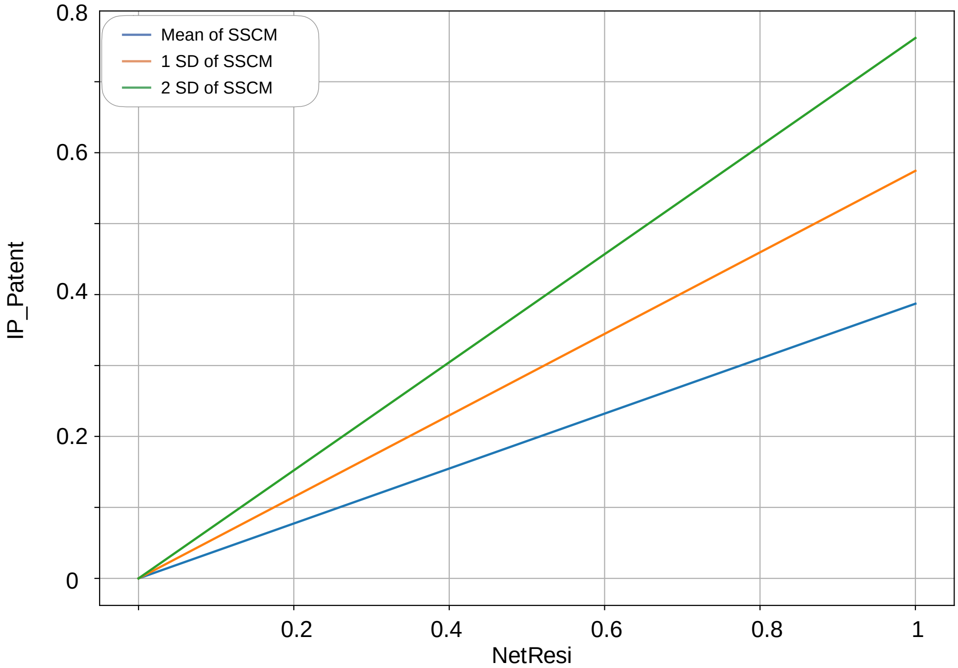

Figure 33 Model 14 in Table 31: moderation of SSCM on the association between network resilience and IP

In sum, **Table 31** suggests that SSCM has no significant direct effect on IP without the presence of network-level resilience, and SSCM has a positive moderating effect on the network-resilience-IP relationship. The impacts of SC resilience dimensions are varied. Focal- and network-level resilience positively impacts IP, where the impact from network-level resilience is considerably larger than focal-level resilience. However, no evidence suggests significant impacts of dyad-level resilience on IP. Therefore, **H2 and H6b are supported with the presence of network-level resilience, while H4 is supported.**

Table 32 Fixed effect regressions: SSCM dimensions, SC resilience dimensions, IP.

	Model 17	Model 18	Model 19	Model 20	Model 21	Model 22	Model 23
Dependent variable	IP_Patent	IP_Patent	IP_Patent	IP_Patent	IP_Patent	IP_Patent	IP_Patent
Control variable	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value	Coef. [SE] P-value
Firm size	0.01397 (9.38833) ***	0.01431 (8.33229) ***	0.01456 (8.1216) ***	0.0146 (8.62176) ***	0.01462 (8.68154) ***	0.01373 (9.2044) ***	0.01378 (9.44947) ***
Sale growth	0.03218 (-2.11043) **	0.03212 (-2.36295) **	0.03214 (-2.33211) **	0.03218 (-2.12044) **	0.03213 (-2.11693) **	0.03159 (-2.13185) **	0.03148 (-2.18065) **
Board size	0.01117 (2.65306) ***	0.01112 (2.63068) ***	0.01117 (2.51681) **	0.01117 (2.70003) ***	0.01126 (2.92404) ***	0.01096 (2.61327) ***	0.01094 (2.38561) **
Tobin's Q	0.01085 (-3.10731) ***	0.01081 (-2.92791) ***	0.01087 (-3.00437) ***	0.01088 (-2.99822) ***	0.01088 (-3.13431) ***	0.01068 (-3.74101) ***	0.01067 (-3.97417) ***
Stock value	0.02416 (1.02792)	0.02441 (1.62636)	0.02445 (1.67051) *	0.0242 (1.10796)	0.0242 (1.11162)	0.02384 (0.30981)	0.02439 (-0.35698)
Firm age	0.01159 (-1.28039)	0.01156 (-1.49584)	0.01164 (-1.36963)	0.01159 (-1.25642)	0.01159 (-1.21262)	0.01139 (-0.90663)	0.01138 (-0.72266)
Independent variable							
E-SSCM	0.01011 (-0.73887)	0.01007 (-0.82633)	0.01007 (-0.81452)	0.01018 (-0.88594)	0.02061 (-1.03984)	0.00992 (-0.7885)	0.016 (-1.03619)
S-SSCM	0.01392 (-0.59839)	0.0139 (-0.31642)	0.01399 (-0.25801)	0.01392 (-0.61072)	0.02871 (-1.38703)	0.01375 (-1.42038)	0.02268 (-1.39398)
G-SSCM	0.01282 (1.72771) *	0.01277 (1.61668)	0.01289 (1.36374)	0.01282 (1.76879) *	0.02689 (3.13844) ***	0.0126 (2.11941) **	0.02034 (4.04363) ***
FocalResi		0.00167 (-3.57039) ***	0.00801 (0.81357)				
DyadsResi				0.01106 (-1.24906)	0.0396 (0.93362)		
NetResi						0.00462 (-7.16775) ***	0.01914 (0.71761)
Interaction term							
E-SSCM x FocalResi			0.01088 (-0.0498)				
S-SSCM x FocalResi			0.01613 (0.11043)				
G-SSCM x FocalResi			0.01671 (-1.51959)				
E-SSCM x DyadsResi					0.06496 (0.66419)		
S-SSCM x DyadsResi					0.09312 (1.13213)		
G-SSCM x DyadsResi					0.08262 (-2.61183) ***		
E-SSCM x NetResi							0.02942 (0.51599)
S-SSCM x NetResi							0.03999 (0.63062)
G-SSCM x NetResi							0.03622 (-3.48981) ***
Constant	0.0107 (-0.56079)	0.01212 (-0.90646)	0.01229 (-2.24243) **	0.01158 (-0.81905)	0.01273 (-1.97099) **	0.0124 (-0.99401)	0.01248 (-2.09569) **
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.16273	0.16321	0.17049	0.16312	0.17085	0.16338	0.17077
N	1336	1336	1336	1336	1336	1336	1336

***p<0.01; **p<0.05; *p<0.1.

In **Table 32**, Model 17 includes SSCM (ESG) dimensions as IVs, where G-SSCM variable has a positive coefficient (0.01282, p<0.1) at 1% level of statistical significance, indicating that governance SSCM has a positive relationship with IP. However, in Model 17, the E-SSCM and S-SSCM variable is not statistically significant (p > 0.1), suggesting that environmental and social SSCM practices may not have a meaningful relationship with IP. Thus, **H2a and H2b are rejected, and H2c is supported**.

Models 18 to 23 investigate the impacts of SC resilience dimensions on IP and the moderating effects, respectively. Model 18, Model 20, and Model 22 add FocalResi, DyadsResi, and NetResi, respectively, after controlling SSCM (ESG), control variables, and firm- and time-fixed effects. The significant positive coefficients suggest focal-level resilience (coefficient=0.00167, p<0.01) in Model 18 and network-level resilience (coefficient = 0.00462, p<0.01) in Model 22 have positive impacts on IP. However, the results of Model 20 cannot support the IP effects of the Dyads-level resilience (p>0.1). Thus, **H4a and H4b are supported, and H4c is rejected.** This conclusion is robust and consistent with Model 9, Model 11, and Model 13.

Regarding the moderating effects, Model 19, Model 21, and Model 23 add the interaction terms between SSCM (ESG) dimensions and SC resilience dimensions, respectively. In Model 19 adds the interaction terms between FocalResi and SSCM (ESG) dimensions. The interaction terms are not statistically significant (p>0.1), which suggests the impact of SSCM (ESG) on IP is independent of a firms's focal-level SC resilience, **rejecting H5b**. It is also found that focal-level resilience may have a stronger impact on IP compared to governance SSCM, as the coefficient of G-SSCM turned insignificant after adding FocalResi in Model 18. However, the interactions between Focal Resi and SSCM (ESG) did not yield better performance on IP.

Model 21 adds the interactions term between DyadsResi and SSCM (ESG) dimensions. The interaction terms between DyadsResi and E-SSCM (S-SSCM) are not statistically significant (p>0.1), which suggests the impacts of E-SSCM and S-SSCM on IP are independent of a firm's dyads-level SC resilience. However, the interaction term between DyadsResi and G-SSCM is statistically significant (coefficient=0.08262, p<0.01), which suggests the impacts of G-SSCM on IP depend on a firm's dyads-level SC resilience, though dyads-level resilience has no direct impact on IP. Thus, **H5b is partially supported** with the presence of dyads-level resilience. The margin effect of G-SSCM on IP is dependent on dyads-level resilience, as visualised in **Figure 34**.

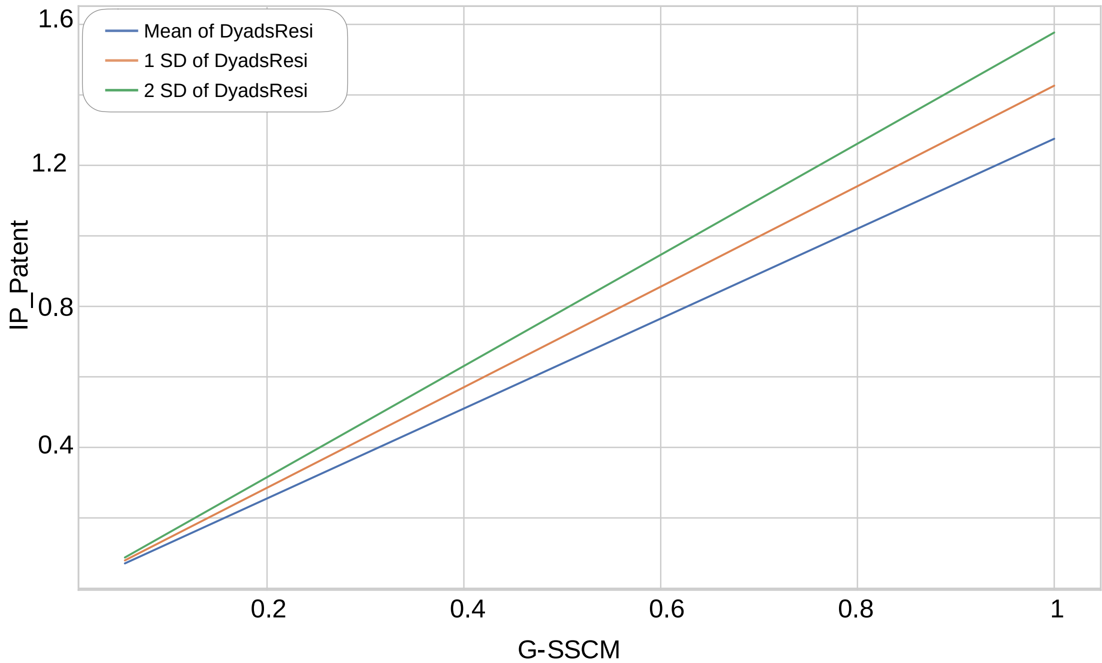

Figure 34 Model 21 in Table 32: moderation effect of dyads-level resilience on the association between G-SSCM and IP

Similar to Model 21, Model 23 adds the interactions term between NetResi and SSCM (ESG) dimensions. The interaction terms between NetResi and E-SSCM (S-SSCM) are not statistically significant (p>0.1), which suggests the impacts of E-SSCM and S-SSCM on IP are independent of a firms's network-level SC resilience. However, The interaction term between NetResi and G-SSCM is statistically significant (coefficient=0.08262, p<0.01), which suggests the impacts of G-SSCM on IP are dependent of firms' network-level SC resilience. Thus, **H5b is partially supported** with the presence of network-level resilience. The margin effect of G-SSCM on IP can be contingent upon network-level resilience, seen in **Figure 35**.

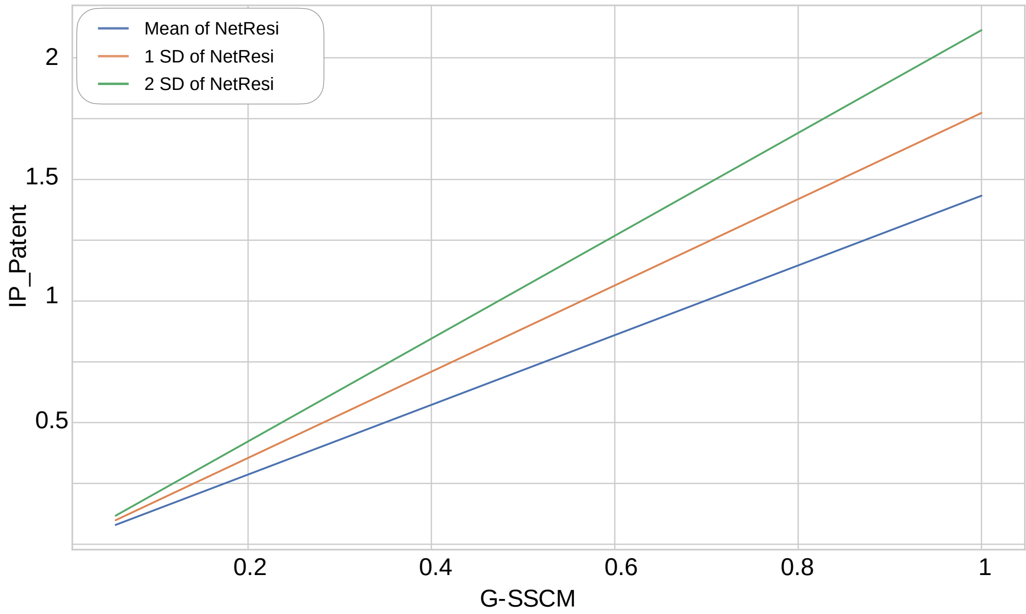

Figure 35 Model 23 in Table 32: moderation effect of network-resilience on the association between G-SSCM and IP

In sum, **Table 32** suggests that governance SSCM has a positive relationship with IP, but environmental and social SSCM practices may not have a meaningful relationship with IP. Focal and network-level resilience have direct and positive impacts on IP, while Dyads-level resilience doesn't. The moderating effects of dyads-level resilience on the governance SSCM-IP relationship is significantly positive, as well as network-level resilience on the relationship of governance and IP. Thus, **H2a and H2b are rejected, and H2c is supported**. **H4a and H4b are supported, and H4c is rejected. H5b is partially supported with the presence of network-level or dyads-level resilience.**

Table 33 summarises the regression results with the proposed hypotheses with IP as dependent variables.

Table 33 Results of hypotheses testing (IP as DV)

Hypotheses	IVs	Moderators	DVs	Results
H2	**SSCM**		**IP**	Partially supported
H2a	E-SSCM		IP	Rejected
H2b	S-SSCM		IP	Rejected
H2c	G-SSCM		IP	Supported
H4	**SC resilience**		**IP**	Supported
H4a	Focal-level resilience		IP	Supported
H4b	Dyads-level resilience		IP	Rejected
H4c	Network-level resilience		IP	Supported
H5b	**SSCM**	**SC resilience**	**IP**	Partially supported
H5b	G-SSCM	Focal-level resilience	IP	Rejected
H5b	G-SSCM	Dyads-level resilience	IP	Supported
H5b	G-SSCM	Network-level resilience	IP	Supported
H6b	**SC resilience**	**SSCM**	**IP**	Partially supported
H6b	Focal-level resilience	SSCM	IP	Rejected
H6b	Dyads-level resilience	SSCM	IP	Rejected
H6b	Network-level resilience	SSCM	IP	Supported

6.4 Summary

Chapter 6 examines the proposed conceptual framework of the interplay between SSCM and SC resilience in **Chapter 4** and uncovers the interaction mechanisms of SC resilience and SSCM, and their effects on financial and innovation performance, responding to **RQ3**.

The empirical results confirm the beneficial effects of SC resilience and SSCM on financial and innovation performance. The findings suggest the positive effects of SSCM practices on financial performance are consistent across all three dimensions. But only governance SSCM is beneficial for innovation performance. The magnificence of the positive impacts of SC resilience on performance outcomes differs depending on the level of analysis. Focal-level and dyads-level resilience positively impact financial performance, whereas network-level resilience has a more significant impact on innovation performance than focal-level resilience.

The empirical results also reveal the synergies of SC resilience and SSCM practises on performance outcomes. SC resilience positively moderates all main SSCM-financial performance relationships (i.e., SSCM as an aggregate variable, environmental, social, and governance SSCM). The impacts of SSCM on financial performance is stronger when SC resilience is higher. SSCM as an aggregate variable does not contribute to innovation performance without the presence of network-level resilience. Dyads-level resilience positively moderates the governance SSCM-innovation relationship. The study suggests that the interaction mechanism between resilience and sustainability is complex when the analysis is conducted at different levels.

Chapter 7 Discussions of Empirical Findings

7.1 Introduction

Chapter 7 summarises the main findings of the empirical studies and discusses the results in light of the literature. As argued in **Chapter 2**, the undergoing turbulence in the environment has posed severe challenges to resilience and sustainability in SCM. The world had to face the menace of the abrupt outbreak of uncertainties, including sustainability-related risks. In this background and in response to a recent call for a more in-depth study into the interplay between sustainability and resilience in SCM (Negri et al., 2021), this study has made a holistic attempt to comprehend how SC resilience interacts with SSCM to sustain firm performance. The main RQ in this study is **RQ3**:

What is the nature of the relationship between SC resilience and SSCM in terms of their impacts on firm performance?

This empirical study responds to this question from CAS and SNT perspectives by unveiling the moderating effects of SC resilience (SSCM) on the linkages between SSCM (SC resilience) and firm performance (i.e., financial and innovation performance), where synergies between SC resilience and SSCM are examined at different levels with consideration of the sub-constructs of SSCM and SC resilience variables. Specifically, SSCM is measured from environmental, social, and governance SSCM dimensions. Drawn upon CAS and SNT, SC resilience is measured at the node, dyads, and network levels, emphasising the focal-level resource redundancy, dyads-level supplier and customer relationships, and network-level structural resilience. The empirical results advocate that firms can do well by doing good and being resilient by examining the effects of SSCM-resilience interaction on financial and innovation performance, respectively, as financial and innovation performances are critical for business continuity and competitiveness short-term and long-term—the analysis utilised panel data from two common databases for publicly listed Chinese companies. The sample focuses on the automobile, food, and heavy-polluting industries.

This study is the first study empirically examining the synergies of SC resilience and SSCM practices on financial and innovation performance. This study also develops the novel measurement hierarchy of SC resilience from the CAS and SNT perspective, which measures resilience as the scale of the SC network-structured system (Novak, Wu and Dooley, 2021), enabling further empirical examinations of SC resilience with firm-level financial and SC data. The empirical findings echo previous studies (Negri et al., 2021; Negri, Cagno and Colicchia, 2022) and first get a generalised observation of the complex interaction mechanisms of SC resilience and SSCM at different levels, where SC resilience and SSCM are treated as composite variables with sub-level dimensions.

In this chapter, the summary of the empirical findings is provided in Section 6.2. The discussion of each hypothesis is in Section 6.3. Section 6.4 provides a summary of the empirical findings.

7.2 Summary of empirical findings

Before starting the main discussion, it is crucial to link the research findings to the hypotheses and determine how ***RQ3*** could be answered with the conclusions from the empirical statistics. In Chapter 5, *the empirical studies examined* hypotheses on *the direct impact of a firm's SSCM practices on financial performance (**H1**) and innovation performance (**H2**), SC resilience on financial performance (**H3**) and innovation performance (**H4**), and the moderating effects of SC resilience (**H5**), and the moderating effects of SSCM (**H6**).* **Figure 36** provides an overall summary of the research findings responding to examined empirical relationships.

This empirical analysis responded to the main associations between SSCM practices and firm performance, the impacts of SC resilience on performance, and the roles that SC resilience or SSCM could play in the main relationships. The overall relationships were examined, where SC resilience and SSCM are composed as second-order meta-variables. After this, the sub-level SC resilience and SSCM dimensions were examined to explore the intertwines among the first-order constructs of SC resilience and SSCM on performance outcomes. Therefore, the empirical results could bring a generalised conclusion as well as enrich the details of the interaction mechanisms of the two concepts. The empirical results confirmed the complexity of the interplay of SC resilience and SSCM, which can be synergised for financial and innovation performance. **Table 34** summarises the main findings responding to the hypotheses.

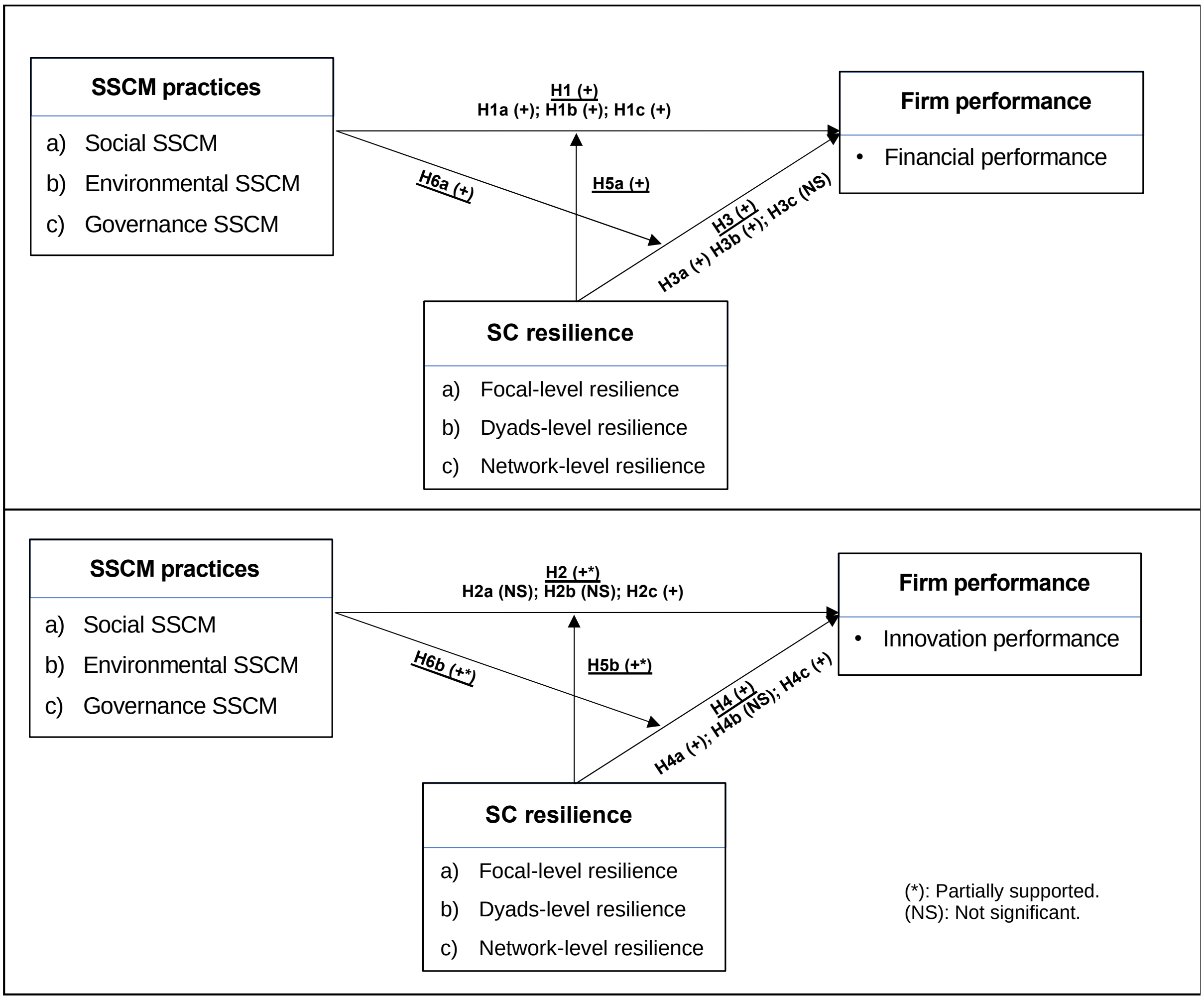

Figure 36 Summary of main findings in models

Table 34 Summary of empirical results of hypotheses

Types of effects		Hypotheses	Results	No. Section	Empirical models
Direct effects of SSCM on FP	**H1**	**SSCM → (+) FP**	**Supported**	**5.5.2**	2, 5-12, 19-24
	H1a	*E-SSCM → (+) FP*	Supported		14-18
	H1b	*S-SSCM → (+) FP*	Supported		14-19
	H1c	*G-SSCM → (+) FP*	Supported		14-20
Direct effects of SSCM on IP	**H2**	**SSCM → (+) IP**	Partially supported	**5.5.3**	Rejected by 2, Supported by 14
	H2a	*E-SSCM → (+) IP*	Rejected		17-23
	H2b	*S-SSCM → (+) IP*	Rejected		17-23
	H2c	*G-SSCM → (+) IP*	Supported		17, 20-23
Direct effects of SCRes on FP	**H3**	**SCRes → (+) FP**	**Supported**	**5.5.2**	3, 6, 8-12, 15-18
	H3a	*FocalRes → (+) FP*	Supported		19
	H3b	*DyadsRes → (+) FP*	Supported		21
	H3c	*NetRes → (+) FP*	Rejected		23
Direct effects of SCRes on IP	**H4**	**SCRes → (+) IP**	**Supported**	**5.5.3**	3-4, 6-8,
	H4a	*FocalRes → (+) IP*	Supported		9, 18
	H4b	*DyadsRes → (+) IP*	Rejected		11, 20
	H4c	*NetRes → (+) IP*	Supported		13, 22
Moderation effects of SSCM	H5	SCRes → (+) SSCM-Firm performance	Partially supported		
	H5a	SCRes→ (+) SSCM-FP	Supported	**5.5.2**	8-12, 16-18, 20, 22
	H5b	SCRes → (+) SSCM-IP	Partially supported	**5.5.3**	Rejected by 19, Supported by 21 and 23.
Moderation effects of SCRes	H6	SSCM → (+) SCRes-Firm performance	Partially supported		
	H6a	SSCM → (+) SCRes-FP	Supported	**5.5.2**	8-12, 16-18, 16-18, 20, 22
	H6b	SSCM → (+) SCRes-IP	Partially supported	**5.5.3**	14, 21, 23

Note: FP = Financial performance, IP = Innovation performance, SCRe = SC resilience, FocalRes= Focal-level resource resilience, DyadsRes = Dyads-level relational resilience, NetRes = Network-level resilience, E-SSCM = Environmental SSCM; S-SSCM= Social SSCM, G-SSCM= Governance SSCM.

Therefore, the following discussions will start with financial performance and innovation performance as DV (dependent variable), respectively. In each section, the direct impacts of SC resilience and SSCM on DV will be discussed, respectively, followed by the interaction mechanisms of SC resilience and SSCM.

7.2.1 Financial performance as DV

In **Section 6.3.2**, regression results of the direct and moderation effects of SSCM and SC resilience on FP, responding to **H1**, **H3, H5a**, and **H6a**. Model 2 in **Table 25** confirms the positive effects of overall SSCM on FP, supporting **H1**, and Model 3 in **Table 25** confirms the positive effects of overall SC resilience on FP, supporting **H3**.

Model 4 in **Table 25** suggests the complexity of the relationships among SSCM, SC resilience, and FP. Therefore, additional tests in **Table 26** reveal the non-linear SSCM-FP relationships in Model 5 and the not strictly linear SC resilience-FP relationship in Model 9. The conclusions of the positive effects of SC resilience and SSCM on FP still hold, implying the support of **H1** and **H3**.

Model 7 and Model 8 in **Table 26** suggest the positive moderation effects of SC resilience on the linear and quadratic SSCM-FP relationships, supporting **H5a**. Models 10-12, as the robustness check, confirm that no interaction exists between the quadratic term of SC resilience and SSCM terms. In sum, Model 9 reveals the overall direct effects of SSCM and SC resilience on FP as well as the moderation effects.

Tables 27 and **28** investigate the breakdown effects across SSCM and SC resilience dimensions, respectively. **Table 27** confirms the quadratic relationships between SSCM (ESG) dimensions on FP in the comparison of Model 13 and Model 14, echoing Model 9. All ESG dimensions of SSCM positively impact FP in Model 14, supporting **H1a**, **H1b**, and **H1c**. In Model 15, SC resilience, at the aggregate level, has a positive effect on FP. -Models 16 to 18 examine the moderation effects, confirming that the interactions between SC resilience and SSCM (ESG) dimensions have positive impacts on FP, supporting **H5a**. Models 19, 21, and 23 in **Table 28** imply that the focal-level and dyads-level resilience positively influence FP, but the network-level resilience does not, supporting **H3a** and **H3b** and rejecting **H3c**. Models 20, 22, and 24 in **Table 28** suggest that the focal-level and dyads-level resilience interact with SSCM on FP. Still, there is no evidence of the moderation effects of the network-level resilience in SSCM-FP relationship, supporting **H5a** with the condition.

7.2.2 Innovation performance as DV

In **Section 6.3.3**, regression results of the direct and moderation effects of SSCM and SC resilience on IP, responding to **H2**, **H4, H5b**, and **H6b**.

Model 2 in **Table 29** suggests that the overall SSCM does not directly impact IP, rejecting **H2**. Model 3 in **Table 29** suggests that SC resilience has a positive effect on IP, supporting **H4**. Robustness checks in Models 5 to 8 confirm the results of Model 2 and Model 3 and suggest that the relationship between SC resilience and IP is not strictly linear.

Table 29 investigates the breakdown effects of SC resilience dimensions. Model 9 and Model 13 in **Table 29** suggest the positive effects of focal-level and network-level resilience on IP, respectively, supporting **H4a** and **H4c**. However, Model 11 reveals no significant effect of dyads-level resilience on IP, rejecting **H4b**. As the robustness check, model 15 and Model 16 confirm this conclusion. Models 10, 12, and 14 investigate the moderation effects of SSCM on the associations between SC resilience dimensions and IP, suggesting SSCM only interact with network-level resilience for IP. The moderating effect of SSCM on the network-level resilience-IP relationships is significant and positive in Model 14, where SSCM has a direct and positive effect on IP with the presence of network-level resilience. It supports **H2** and **H6b**.

Table 30 investigates the breakdown effects of SSCM (ESG) dimensions. Model 17 suggests only governance SSCM have direct and positive impacts on IP but not environmental and social SSCM, rejecting **H2a** and **H2b** but supporting **H2c**. Models 18 and 22 suggest that focal- and network-level resilience have positive impacts on IP, supporting **H4a** and **H4c**. However, Model 20 implies that dyads-level resilience has no significant effect on IP, rejecting **H4b**. This conclusion echoes Models 9, 11, and 13 in **Table 29.** Models 19, 21, and 23 in **Table 30** imply that only governance SSCM interact with SC resilience dimensions. Governance SSCM interacts with both dyads-level and network-level resilience for IP. Model 21 suggests that dyads-level resilience does not directly affect IP but through the moderation effects on governance SSCM. Model 23 suggests that network-level resilience directly and positively affects IP as well as positively moderates the governance SSCM-IP relationship.

7.3 Discussions of hypotheses

7.3.1 Discussion of H1 and H2: direct effects of SSCM on firm performance

H1 and H2 proposed that SSCM practices can have a favourable influence on firm performance, encompassing both financial and innovation aspects. These hypotheses investigate the relationship between SSCM practices and firm performance, which serves the research question RQ3. The findings of the empirical analysis revealed that there is significant statistical evidence to support the positive impacts of SSCM on firm performance. Overall, SSCM has a positive influence on financial performance. However, when it comes to innovation performance, it requires the backing of network-level resilience. Among the environmental, social, and governance (ESG) dimensions of SSCM, each paves the way for gaining financial benefits. Interestingly, it's the governance aspect of SSCM that plays a role in improved innovation outcomes.

It's commonly thought that safeguarding our natural surroundings and society, as well as adopting SSCM practices, comes at a price. Good SSCM practices require firms to channel their resource toward less profitable SSCM activities and engage in new activities to build and maintain a sustainable image. The trade-off could be intangible benefits and potentially diminished financial returns. More recent literature explains the advantages of SSCM practices that investing in SSCM practices could enable firms to cut back inventory investment, increase recovery of assets and contain costs, and therefore lead to direct or indirect economic performance improvement through intra-organisational, upstream-and-downstream collaboration, reverse logistics and circular economy strategies, and so on (Geng, Mansouri and Aktas, 2017; Sardana et al., 2020; Vishwanathan et al., 2020; Fatima and Elbanna, 2022; Velte, 2021).

Evidence of the interaction between non-financial and financial performance can be observed that the non-financial performance (i.e., environmental performance) of SSCM can contribute to financial improvement (Feng et al., 2018), suggesting an indirect association between SSCM and financial performance. For instance, Endrikat, Guenther and Hoppe (2014) comprehensively discussed the positive and partially bidirectional linkages between environmental and financial performance, which offers further research on whether corporate environmental performance could bring indirect tangible benefits to certain types of SSCM practices. Feng et al. (2018) suggest that financial enhancement of environmental SSCM can be obtained through the transmission of operational excellence and environmental performance. Trumpp and Guenther (2017) provide evidence of a U-shaped relationship between corporate environmental and financial performance, considering carbon performance, waste density, profitability, and stock market performance.

However, the non-linear regression results shed light on the complex relationship between SSCM practices and FP, which may arise from the tension between the direct costs and intangible benefits of SSCM investments. Xie et al. (2019) confirmed an inverted U-shaped association between CSR disclosure and corporate efficiency in the global context while suggesting that activities regarding environmental, social, and governance SSCM may have nonnegative effects on financial performance but need to be further explored. In response to this call, Zhou, Liu and Luo (2022) uncovered that the performance of listed companies regarding ESG aspects is beneficial to the improvement of the company's operating capacity but has no significant effect on the company's profitability and growth capacity.

This study uncovers the mystery of the non-negative effects of SSCM practices, suggested by Xie et al. (2019) and complements (Zhou, Liu and Luo, 2022) with new evidence for the quadratic impacts of SSCM on profitability. This study further confirms a U-shaped relationship between SSCM and FP, indicating that SSCM practices have common features that positively relate to FP. It extends the empirical evidence on the overall performance of SSCM on FP beyond focusing on a specific aspect, such as SSCM related to environmental issues (Trumpp and Guenther, 2017) or corporate governance issues (Nollet, Filis and Mitrokostas, 2016). The finding of this study suggests that in the context of Chinese automobile, food, and heavily-polluting industries, SSCM is beneficial for financial rewards and is “too good to be too little” (Trumpp and Guenther, 2017).

Finding 1*: this study echoes existing studies on the positive effects of SSCM initiatives on firm performance (Sardana et al., 2020; Ahmad, Mobarek and Roni, 2021; Sarkis, 2020; Foo et al., 2021; Geng, Mansouri and Aktas, 2017; Vishwanathan et al., 2020), confirming a direct and non-linear (i.e., U-shaped) relationship between SSCM and financial performance*.

The finding of H1 suggests that SSCM practices positively impact financial performance. Firms can also “do well by doing good” by implementing SSCM practices that tackle social deficiencies within focal firms and partner companies. SSCM practices are often read as a signal of trustworthiness, the capacity to meet financial obligations, of lower risk associated with the diffusion of adverse shocks through SC networks (Chouaibi, Chouaibi and Rossi, 2022; Pham and Tran, 2020), which could increase the perceived usefulness of SSCM practices for society, customers, suppliers, and employees. The perception of SSCM efforts, therefore, benefits the focal firm from relationship quality with specific stakeholders (Pfajfar et al., 2022), accumulated reputation from targeted customer groups, market share from enlarged customer circle, and legitimacy by the society, which eventually could lead to financial success from a long-term perspective (Velte, 2021). Considering the advantage of risk mitigation (Gouda and Saranga, 2018; Chaudhuri et al., 2021), the implementation of social SSCM initiatives benefits firms from less operational disruption risk (Li, Choi and Chow, 2015) and reputation risk (K. Roehrich, Grosvold and U. Hoejmose, 2014; Nobanee et al., 2021) and therefore contribute to financial outcomes. For instance, ensuring a healthy and conducive work environment drives employees to perform better and reduces workforce instability, reducing the impacts and possibility of operational disruption (Shafiq and Soratana, 2020). Social certifications such as OHSAS 18001 and SA 8000 can help firms reduce the cost of regulatory fines and disruptions due to social liabilities (Nobanee et al., 2021b; K. Roehrich, Grosvold and U. Hoejmose, 2014).

Finding 2*: SSCM practices can have a direct and positive influence on innovation performance, but their impact depends critically on the existence of resilience at the network level.*

H2 posits that SSCM practices positively impact innovation performance. Or in other words, SSCM practices can facilitate the generation and transfer of knowledge. Given the positive direct effects of SSCM practices on innovation performance only with the presence of network-level resilience. This finding underscores the importance of network-level resilience as a necessary condition for enhancing the innovation effects of SSCM. Therefore, it is essential to align SSCM with network resilience regarding knowledge creation. This novel finding agrees with recent studies claiming that committing resources to SSCM practices related to environment, social, and governance favours innovation performance (Ardito et al., 2021; Ren et al., 2022; García-Piqueres and García-Ramos, 2022) and more importantly, advocates the importance of network-level resilience for yielding innovation performance of SSCM, echoing to CAS and SNT theoretical propositions and extant studies (Liu et al., 2021; Liao and Marsillac, 2015; Wang et al., 2021). SSCM should be integrated into the network-structured adaptive SC systems (Alinaghian, Qiu and Razmdoost, 2021; Braz and Marotti de Mello, 2022). A resilient network enables the transmission of knowledge across the SC network, which serves as the foundation of innovation.

Research has shown that SSCM practices, such as CSR, can act as antecedents of firm innovation. For instance, Wang et al. (2022) proposed that SSCM can promote the development of disruptive innovation, especially under severe technological turbulence. Broadstock et al. (2020) found evidence of a positive effect of adopting SSCM (i.e., ESG policy) on innovation capability based on a longitudinal observation of Japanese companies. By adopting SSCM practices, firms can create new knowledge and relational resources that stimulate them to meet stakeholders' needs in product offerings (Ardito et al., 2021). Empirical evidence from North American SMEs reveals that environmental orientation has a positive direct effect on product and process innovation performance, echoing the findings from Bhardwaj et al. (2018) on the first-mover advantage of CSR adoption. CAS and SNT suggest that firms that are well-connected and adaptive and pursue SSCM activities as an investment and opportunity can gain a competitive advantage over their peers (Cheng, 2020). By prioritising SSCM practices, firms can proactively transform them into process and product innovation sources. Research has shown that firms prioritising SSCM practices are better positioned to develop environmentally friendly products, improve product quality and differentiation (Surroca, Tribó and Waddock, 2010), and avoid technological and market turbulence (Wang et al., 2022).

However, the novel finding of **H2** emphasises that SSCM practices may fail to yield firm innovation directly without network resilience. The resources and capabilities that firms gather through SSCM orientation, charity and donation, and employee education schemes possess proactive competencies (Dibrell et al., 2015) that help provide a competitive advantage to firms by avoiding disruptions due to environmental, operational, and reputational (Nobanee et al., 2021), and financial risks (Lam, 2018). For SSCM practices to be successfully implemented, a firm has to gather network resources and involve internal and external coordination within its SC network. Commitment to the embedded SC network, such as sustainable supplier development, can align SC resources, reinforce partnerships, and reduce the information asymmetry (Giannoccaro and Iftikhar, 2022; Lins, Servaes and Tamayo, 2017). This can create opportunities for firms to innovate and differentiate themselves from competitors.

Aligning network resilience with SSCM practices is critical for enhancing innovation (Delbufalo, 2015; Bellamy, Ghosh and Hora, 2014). CAS and SNT suggest that by building a resilient network, firms can better manage risks and disruptions, increasing innovativeness(Choi and Krause, 2006; Kwak, Seo and Mason, 2018). By enhancing resilience at the network level, SCs can dynamically respond to turbulence and provide a stable environment for firms to innovate and experiment with new ideas and technologies across the cooperation network. Therefore, leveraging the network's resources and capabilities to develop new products and services (Liao and Marsillac, 2015), improve operational efficiency, and create value for customers (Danese and Romano, 2013) are necessary to yield innovativeness out of SSCM. The enhancement of network resilience means proactively promoting network collaboration (Arora et al., 2020), transparency

(Zhang, Hu and Liang, 2021), shared values, and mutual benefits with SC partners and stakeholders (Kabra and Ramesh, 2016), which is critical in managing uncertainties and disruptions brought about by various environmental, operational, reputational, and financial risks (Li et al., 2020). Given the significance of network resilience in sensing and addressing potential risks, it is vital to consider its impact on fostering innovation, which is a vital component of effective risk management. By aligning with network resilience, SCs can foster the emergence of innovative outcomes of SSCM practices.

7.3.2 Discussion of H1a-c and H2a-c: performance effects of SSCM dimensions

Hypotheses **H1a-c** and **H2a-c** suggest that the three dimensions of SSCM practices - environmental, social, and governance - exert distinct influences on firm performance concerning financial and innovation outcomes. These hypotheses aim to investigate if any specific SSCM practice offers a greater advantage for strategic decision-making concerning financial gains and knowledge generation. Empirical evidence supports these hypotheses by examining the effects of individual ESG dimensions of SSCM practices on financial and innovation performance, yielding the following insights.

SSCM literature has accumulated fragmented empirical evidence on the financial performance of SSCM at the aggregate level (Luo and Du, 2015; Wagner, 2010; García-Piqueres and García-Ramos, 2020), where the financial benefits of SSCM could be gained through reputation, risk mitigation, stakeholder reciprocation, and innovation enhancement (Vishwanathan et al., 2020). In line with the extant literature (Boakye et al., 2020; Geng, Mansouri and Aktas, 2017; Govindan et al., 2020; Wang, Dou and Jia, 2016; Velte, 2021; Fatima and Elbanna, 2022; Arora et al., 2020), this finding implies that *the implementation of all dimensions of SSCM initiatives can be beneficial to financial success, and that increasing governance SSCM can imply the enhancement of innovativeness* (Broadstock et al., 2020; Ardito et al., 2021). This finding enriches the current understanding of the performance outcomes of SSCM, suggesting the fit between SSCM practices on performance priorities.

7.3.2.1 Discussion of H1a-c: direct relationships between SSCM dimensions and financial performance

Hypotheses **H1a-c** propose that each dimension of SSCM practices (i.e., environmental, social, and governance) has various effects on financial performance. The results reveal that while the magnitudes of these impacts differ, all three dimensions of SSCM practices display U-shaped relationships with financial performance. In conjunction with Finding 1, it is evident that the effects of individual SSCM dimensions collectively contribute to promoting financial performance.

Finding 3*: All dimensions of SSCM practices – environmental, social, and governance SSCM - exhibit positive influences on financial performance, characterised by non-linear, U-shaped relationships. there is a noticeable congruence among SSCM dimensions on financial performance.*

CAS and SNT argue that SSCM, as an internal mechanism within SC network-structured systems, links internal and external stakeholders, such as society, employees, and other stakeholders (e.g., suppliers and customers). The relationships between firms and these stakeholders influence the dynamism of exchanges between the SC system and its environment, as well as the SC system's adaptability to potential turbulence. SSCM involves incorporating business sustainability into the management of the SC network (Arora et al., 2020; Haus-Reve, Fitjar and Rodríguez-Pose, 2019; Carter et al., 2019; Lu et al., 2018).

These network relationships are valuable, advantageous, and informal, potentially allowing firms greater access to resources, larger workforces, and improved corporate reputations. Shared values, information transparency, and trust can further enhance these benefits. Environmental and social SSCM practices (i.e., green collaboration and donation) foster connections between SC systems and stakeholders, including the ecological environment, employees, and society, by developing mutual benefits and trust (Liu et al., 2021). Firms' mutual benefits with stakeholders (i.e., social SSCM practices) encourage system adaptation, including adjusting the network structure to attain resilience against SC risks (Alinaghian, Qiu and Razmdoost, 2021). Governance SSCM practices, such as CSR information disclosure, can enhance the transparency of firms' SSCM activities, facilitate communication between the SC and external stakeholders, smooth the flow of information, and increase the customer perception of brand reputation (Pham and Tran, 2020).

Sustaining high-quality network relationships and capabilities demands specific investment, which can, in turn, impact firms' financial performance. This investment is valuable for enabling firms to access network resources, develop social connections, bolster their corporate reputations, and meet stakeholders' expectations. By fostering mutual benefits between firms and their stakeholders through environmental, social, and governance SSCM practices, SC systems can reinforce sustainable cooperation via network connections, becoming more adaptable to changing circumstances (Nair and Reed-Tsochas, 2019). A resilient SC network supports the implementation of SSCM practices by adjusting the network structure to achieve a resilient status against miscommunication, information asymmetry, and regulatory and social risks (Alinaghian, Qiu and Razmdoost, 2021). This, in turn, can streamline the flow of information and resources for business excellence, ultimately leading to financial benefits within the system.

Empirical evidence suggests the benefits of environmental SSCM practices, such as environmental collaboration (Arora et al., 2020; Boakye et al., 2020), eco-design (Dangelico, Pujari and Pontrandolfo, 2017a), green sourcing (Arora et al., 2020). Specifically, it has been pointed out that energy efficiency practices, greenhouse gases, material, and resource efficiency may have a non-linear relationship (e.g., an inverted U-shaped relationship) with financial relationship (Kusi-Sarpong, Sarkis and Wang, 2016), which should have the attention of SCM scholars and practitioners for allocating resources to **environmental SSCM practices** investment under the net-zero mission. For instance, green and lean practices, when implemented concurrently, proved to yield a multitude of synergistic competitive advantages and affect performance improvement (Jakhar, Rathore and Mangla, 2018).

It specifies that an increase in **governance SSCM** efforts focusing on product quality and corporate governance will increase financial benefits, consistent with the literature (Zhao, Wang and Pal, 2021; Randall and Ulrich, 2001). SSCM governance schemes' effects on CSR disclosure on financial performance may be less straightforward (Pham and Tran, 2020). However, a direct relationship is widely assumed in the previous literature (Fatima and Elbanna, 2022). Similarly, empirical evidence in recent studies confirms the benefit of SSCM governance practices (e.g., CSR disclosure or reporting) on financial performance, but with the transmission of corporate reputation (Pham and Tran, 2020; Liu and Lu, 2021) and corporate transparency (Zhang, Hu and Liang, 2021).

By investing in **governance SSCM practices** related to products and services, firms can mitigate the likelihood and consequences of reputation-damaging events. Such practices encompass the implementation of product quality management systems, enhancement of after-sales service, execution of customer satisfaction surveys, acquisition of certifications and honours for product quality, development of strategic partnerships and shared mechanisms, and avoidance of product or service disputes. Intuitively, it can be argued that companies that invest in product quality and service levels experience greater customer satisfaction and regulatory compliance, leading to improved reputation or corporate image and reduced reputation risks. This rationale is supported by a body of research exploring the interplay between reputation (risks) and firm performance in the context of SSCM (Liu and Lu, 2021; Karwowski and Raulinajtys-Grzybek, 2021; Dhingra and Krishnan, 2021; Pham and Tran, 2020; Azadegan et al., 2020; Saeidi et al., 2015; K. Roehrich, Grosvold and U. Hoejmose, 2014).

The same rationale applies to **social SSCM practices** that promote diversity, contribute to the community, and enhance employee welfare, supporting the assertion that "subsequent financial performance is positively associated with prior social responsibility" (Wang, Dou and Jia, 2016, p.1106) The conclusion is consistent with the literature with reference to Wiengarten, Lo and Lam (2017), Ma, Hao and Aloysius (2020), Hoogendoorn and Oosterbeek (2013), Brahma, Nwafor and Boateng (2020) and others. This argument can be further analysed from the perspectives of CAS and SNT. When a firm exhibits socially responsible behaviour, it is perceived as legitimate by the public, which in turn positively influences their judgments of the firm. The firm can establish informal social connections with the public by engaging in direct communication about CSR activities (e.g., donations and charity). This increases awareness of the firm's involvement in SSCM initiatives and directly contributes to the corporate image as a highly valuable intangible asset (Lai et al., 2010). Voluntary self-regulation through SSCM practices is an adaptive and proactive behaviour that reduces the need for government intervention (Karwowski and Raulinajtys-Grzybek, 2021), thus easing pressures on the already weak formal institutions. But it provides a further implication that by combining the SSCM scheme with product eco-adaption, internal governance with CSR compliance, and socially found activities, firms could offset the SSCM implementation's investment and enhance financial outcomes.

From an internal perspective, **social SSCM practices** investing in employee welfare can foster a reciprocal commitment between employees and the firm, leading to increased job satisfaction and organisational trust (Pfajfar et al., 2022) and, therefore, long-term financial returns. Several studies have shown that social SSCM practices for greater gender diversity on corporate boards or executive committees are associated with better financial performance (Brahma, Nwafor and Boateng; Ouni, Ben Mansour and Arfaoui, 2020; Endrikat et al., 2021). This is thought to be due to women's advantages to SC collaboration and efficiency in business teams (Ma, Hao and Aloysius, 2020). Maintaining good gender diversity on boards can also help to monitor managerial decision-making, reduce conflicts, lower agency costs (Rao and Tilt, 2016), and promote an ESG orientation (Ouni, Ben Mansour and Arfaoui, 2020) and corresponding CSR performance (Nerantzidis et al., 2022).

In summary, all three dimensions of SSCM practices contribute to financial improvement, and the effects of individual SSCM dimensions are synergistically aligned in promoting financial performance. From the perspectives of CAS and SNT, each dimension of SSCM practices can enhance network connections with internal and external stakeholders, strengthening the flow of information and resources across the network-structured system (Alinaghian, Qiu and Razmdoost, 2021; Braz and Marotti de Mello, 2022; Lu et al., 2018). By proactively adapting to stakeholders' expectations, these practices can reduce risks and costs, ultimately leading to improved financial performance. The findings support the U-shaped impact of all three dimensions of SSCM practices, indicating that their benefits are substantial rather than marginal. Future research could delve deeper into the alignment mechanisms among SSCM practice dimensions and investigate the individual-level, firm-level, and system-level factors within formal and informal connected networks.

7.3.2.2 Discussion of H2a-c: direct relationships between SSCM practices and innovation performance

The empirical findings support H2b, suggesting differentiated innovation performance of each dimension of SSCM practices (i.e., environment, social, and corporate governance). This study confirms that implementing environmental and social SSCM practices has non-trivial positive effects on innovation performance, echoing the extant research (Ardito et al., 2021; Broadstock et al., 2020; Dangelico, Pujari and Pontrandolfo, 2017a; Wang et al., 2022). While governance SSCM efforts could contribute to the enhancement of innovation capacity. It is consistent with previous studies (Ghobakhloo et al., 2021; Cheng, 2020; Schiessl, Korelo and Mussi Szabo Cherobim, 2022; Ren et al., 2022).

Finding 4*: only governance SSCM practices directly contribute to the improvement of innovation performance, while environmental and social SSCM practices do not, indicating a stronger alignment between governance SSCM and innovation outcomes.*

From the perspectives of CAS and SNT, SSCM practices can foster a non-linear knowledge-creation process that adapts and co-evolves in response to sustainability challenges. Addressing social and environmental sustainability issues may necessitate the development of new sustainability knowledge, competencies, and the reconfiguration of firm resources (Dangelico, Pujari and Pontrandolfo, 2017). The self-governed networking process also brings knowledge sharing and generation among the SC network, which puts the SC network in a better position to emerge sustainability needs from its stakeholders into innovation capabilities (Liao and Marsillac, 2015; Zhou, Govindan and Xie, 2020).

A body of research suggests that firms with a greater focus on environmental causes (i.e., environment-related SSCM practices) can innovate their products and services to reduce their environmental impact, thereby contributing to enhanced innovation capabilities (Schiessl, Korelo and Mussi Szabo Cherobim, 2022; Liao, 2018; Santos-Jaén, Madrid-Guijarro and García-Pérez-de-Lema, 2021; Pan, Sinha and Chen, 2021). SSCM activities serve to bolster firms' innovation capacity, which in turn increases their ability to differentiate themselves and gain competitive advantages. This notion is further supported by Bocquet et al. (2013), who found that firms engaged in proactive SSCM activities are more likely to exhibit innovation in their processes and product generation. The innovation could be driven by environmental regulations with higher environmental standards, which makes a win-win situation for SC members while producing new and innovative products for competitiveness (Carmine and De Marchi, 2022; Mühlbacher and Böbel, 2019).

It is empirically confirmed that the positive and direct influence of governance-related SSCM practices (e.g., CSR disclosure) on innovation performance, corroborating previous studies, which aligns with previous studies (Ren et al., 2022; Li, Lian and Xu, 2023; García-Piqueres and García-Ramos, 2022). Ren et al. (2022) found that mandatory CSR disclosure is strongly and consistently associated with increased legitimacy pressure, prompting firms to pursue substantive green innovations within the Chinese business context. Governance-related SSCM practices foster information transparency among SC partners, serving as a signal of collaborative attitudes among peer companies. This facilitates the dissemination of innovation knowledge throughout the network chain and plays a crucial role in representing the beliefs and expectations (Li, Lian and Xu, 2023). The conclusion of this study is in line with García-Piqueres and García-Ramos (2022), who propose that achieving different types of innovation performance (i.e., radical or incremental innovation) necessitates distinct types of SSCM practices.

However, this finding does not support a direct connection between environmental SSCM practices and innovation performance, which can be explained in three ways. Firstly, environmental SSCM practices may not be inherently proactive or easily convertible to innovation outcomes such as patents, as they may focus on activities such as green branding and pollution prevention innovation. Pollution prevention innovation refers to firms adopting innovative approaches to eliminate their current environmental impacts and avoid non-compliance costs

(Ning, Pan and Xu, 2017), which may be a reactive response to regulatory risks rather than disruptive innovation efforts. Hull and Rothenberg (2008) propose that firms' involvement in sustainable activities positively affects their performance by adopting innovation-related processes, which may not necessarily result in innovative outputs. Secondly, environmental SSCM practices may be strongly linked to green innovation (Achi, Adeola and Achi, 2022), which may not account for the entire spectrum of innovation capabilities. This study emphasises the overall innovation performance rather than solely green innovation. Thirdly, the relationship between environmental SSCM practices and innovation performance may be complex and not straightforward. While recent studies have highlighted the positive impacts of environmental SSCM practices on innovation performance (Wu, Liang and Zhang, 2020; Pan, Sinha and Chen, 2021; Ardito et al., 2021), this finding suggests that the relationship between environmental SSCM practices and innovation performance may be complicated, rather than a linear and direct one (Broadstock et al., 2020).

Finding 4 indicates no direct link between social SSCM practices and innovation performance. First, social SSCM practices concerning diversity and community engagement may enable firms to better comprehend emerging customer needs and capitalise on external stakeholder benefits (Wang et al., 2022). This can result in new market segments, government subsidies, public reputation, and firm value (Hawn and Ioannou, 2016). However, these practices do not directly lead to resources and capabilities for knowledge creation, as they primarily focus on providing benefits to external stakeholders rather than concentrating on workforce development and talent. Pan, Sinha and Chen (2021) indirectly support this explanation, concluding that social SSCM practices can moderate environmental SSCM-innovation relationships but not directly enhance innovation.

Second, although emphasising stewardship towards employees (i.e., internal stakeholders) may boost employee retention, loyalty, and creativity—essential prerequisites for knowledge sharing and generation—the interaction mechanism could be more intricate than a simple, direct connection. This finding conflicts with a recent study by Wang et al. (2022), which argues that employee-related SSCM practices (i.e., internal CSR) present unique opportunities for employee development and creativity, resulting in positive effects on knowledge creation processes and disruptive innovation. The divergent conclusions may imply that sectoral differences (such as high-tech, automotive, food, and heavily polluting industries), operationalisation of innovation performance (disruptive innovation versus general innovation capabilities), and sampling methods (questionnaires and secondary data) could be contingent factors in the relationship between internal social SSCM practices and innovation performance. Santos-Jaén, Madrid-Guijarro and García-Pérez-de-Lema (2021) suggest an indirect relationship between social SSCM practices and innovation, laying the groundwork for future research into how social SSCM practices might indirectly influence innovation performance.

Finding 4 highlights a lack of consensus regarding the impact of SSCM dimensions on innovation performance. Given the critical role of innovation within the SSCM literature (McDougall, Wagner and MacBryde, 2022; Achi, Adeola and Achi, 2022; Ren et al., 2022; García-Piqueres and García-Ramos, 2022), this study recommends that future research explore the relationship between the complementary nature of SSCM dimensions and their effect on desired performance outcomes. Additionally, future studies should assess these relationships using various innovation metrics in diverse research contexts, such as different industries, and adopt multiple perspectives and measurement approaches. In particular, further investigation into the role of governance within SSCM and its influence on the innovative outcomes of environmental and social SSCM practices is warranted.

This finding may provide a rationale for the discovery by Nollet, Filis, and Mitrokostas (2016) that a U-shaped relationship is only present between governance disclosure and financial performance rather than environmental and social disclosure. As innovation serves as a precursor to long-term financial performance, governance-focused SSCM practices, such as information disclosure, contribute to the accumulation of knowledge that fosters innovation and, consequently, enhances financial performance. Nonetheless, further empirical evidence is required to substantiate this assertion.

7.3.2.3 Summary of H1a-c and H2a-c

The rationale of H1a-c and H2a-c focuses on the multidimensionality of the nature of SSCM by investigating the direct SSCM-performance relationship. H1a-c and H2a-c imply the performance differences among each pair of SSCM practices-performance relationships. In line with previous studies on SSCM (Carmine and De Marchi, 2022; Carter et al., 2019), the findings of H1a-c have identified the financial benefits of SSCM. H2a-c also responds to the call for a more thorough understanding of SSCM effects on innovation performance (Cheng, 2020; Pan, Sinha and Chen, 2021). The results of H2a-c imply no direct interaction between environmental and social SSCM practices (i.e., environment-, employee-, community-, diversity-related SSCM practices) and innovation while focusing on governance-related SSCM practices, including CSR information disclosure and product quality control enable firms to benefit from knowledge creation.

It is instinctive that governance SSCM practices function well to tackle the stakeholder pressures and legitimacy changes. Driven by the external stakeholder's expectations, governance SSCM practices advocate green innovation (Cheng, 2020; Dangelico, Pujari and Pontrandolfo, 2017a; Ren et al., 2022); green process innovation and green innovation reporting (Khan, Johl and Johl, 2021) for market turbulence. So far, the findings of H1a-c and H2a-c address the question that all dimensions of SSCM practices could directly contribute to financial performance, but only governance SSCM brings direct enhancement of innovativeness. It is concluded that the effects of each pair of SSCM-performance relationships are various. Therefore, achieving the desired performance outcomes requires different formulations of SSCM practices.

Recent studies have explored the interplay among sustainable supply chain management (SSCM) practices, given the multidimensional nature of sustainability. For example, García-Piqueres and García-Ramos (2022) propose that the triple-bottom-line SSCM practices are interrelated and have super-additive effects on innovation, which could be incorporated into future research. Hossan Chowdhury and Quaddus (2021) examine sustainability governance within SC networks and contextually dependent SC sustainability, with the former acting as a moderator for the primary relationships between the latter, sustainability risks, and market performance.

Pan, Sinha and Chen (2021) categorise SSCM into economic, social, and environmental dimensions, assessing the impact of these three practices on multiple innovation outcomes, such as pollution prevention and sustainable environmental innovation. Their research confirms the moderating effects of social SSCM on the environmental SSCM-innovation relationship. Another set of studies focuses on the interactions between the indirect performance outcomes of SSCM practices (Dangelico, Pujari and Pontrandolfo, 2017a; Schiessl, Korelo and Mussi Szabo Cherobim, 2022; Broadstock et al., 2020). For example, Broadstock et al. (2020) demonstrates a non-linear relationship between ESG policy adoption and firms' innovation capacity, supporting an "indirect value-creation" process in which ESG contributes to financial outcomes through the pursuit of innovation activities. This study offers a potential explanation for the findings of H2a-c and encourages future research on the synergies among SSCM practices on performance outcomes. In a similar vein, Schiessl, Korelo and Mussi Szabo Cherobim (2022) argue that adopting CSR directly decreases firms' economic value while indirectly contributing to enhancing economic benefits through environmental innovation. Based on these studies and the findings of **H1a-c** and **H2a-c**, this research suggests that future studies could explore novel classifications of SSCM, the interplay among SSCM practices, the relationship between various SSCM practices and performance outcomes, and the dynamics of the SSCM-innovation nexus.

Current findings in this study cannot support further investigation of the interplay among SSCM practices with other performance outcomes (e.g., environmental and financial performance, innovation and financial performance) (Dong et al., 2020; Chouaibi, Chouaibi and Rossi, 2022; Nguyen et al., 2021; Shen et al., 2019; Endrikat, Guenther and Hoppe, 2014; Feng et al., 2018). Similarly, the interactions among the SSCM practices could be further examined based on the current study to figure out the holistic mechanism of SSCM. Based on the abundant empirical evidence on SSCM, a meta-analytic literature review could be conducted to synthesise the extant findings and draw the antecedents-SSCM-performance network. It is also important to identify the fit between desirable performance outcomes and the implementation of SSCM (i.e., environmental, social, and governance activities), where the synergies among different SSCM practices would be also considered. As distinguished in this study, network-level resilience is critical in the associations between SSCM and innovation performance, which could be extended to examining other performance outcomes. It is also valuable to verify the generalisation of the synergy between network resilience and SSCM in other research contexts (e.g., different countries or industries).

7.3.3 Discussion of H3 and H4: direct effects of SC resilience on firm performance

Recent reviews in the SC resilience domain have shown a burgeoning interest in exploring the antecedents and performance of SC resilience (Parast, 2022; Iftikhar, Purvis and Giannoccaro, 2021), where points out that the focus of SC resilience studies is on its antecedents (Cotta and Salvador, 2020; Belhadi et al., 2022; Münch and Hartmann, 2023) rather than performance (Juan and Li, 2023). It is because of the inconsistency of resilience measurement either as capabilities (Shin and Park, 2021; Silva and Ruel, 2022) or as consequences (Buyl, Boone and Wade, 2019; Sajko, Boone and Buyl, 2021; Li, Pournader and Fahimnia, 2022). The conceptualisation of SC resilience is not consistent, and the performance effects of SC resilience have yet been abundantly investigated though conceptually proposed (Castillo, 2022; Cohen et al., 2022). With the limited empirical knowledge observed in the extant literature (Abeysekara, Wang and Kuruppuarachchi, 2019; Yu et al., 2019; Li et al., 2017; Negri, Cagno and Colicchia, 2022), the empirical results of H3 and H4 expand the performance effects of SC resilience regarding financial and innovation performance.

The study is consistent with contemporary empirical research investigating SC resilience's performance outcomes. Recent studies have considered SC resilience as a predictor or antecedent of financial performance (Yu et al., 2019; Abeysekara, Wang and Kuruppuarachchi, 2019; Li et al., 2017); operational performance (Birkie, Trucco and Fernandez Campos, 2017), SC performance (Belhadi et al., 2021; Chowdhury, Quaddus and Agarwal, 2019), and reputational containment (Azadegan et al., 2020). Given the varying impact resilience can have on performance outcomes, Hypotheses **H3** and **H4** investigate the effects of resilience on both financial and innovation performance, and obtained the findings below.

Finding 5*: the aggregate SC resilience has a positive relationship with financial performance, which is not strictly linear but a U shape.*

The discovery of a U-shaped relationship between aggregate SC resilience and financial performance not only confirms the financial benefits of SC resilience but the changing nature of magnificence of the effect. The results suggest that when organisations invest in SC resilience, they are essentially enhancing their ability (i.e., resource, relationship, structure) to adapt and respond to disruptions (Tukamuhabwa et al., 2015), which can lead to improved financial performance (Chopra and Sodhi, 2014). However, the non-linear nature of this relationship suggests that the adaptive capabilities of SC systems may reach a point of diminishing returns, after which further investments in resilience will yield greater financial benefits (Christopher and Peck, 2004).

Developing SC resilience can be costly, as it involves investments in extra resource buffers, maintenance of reliable and flexible connections with partners, and participation in the coordination process of the entire SC system (Brandon-Jones et al., 2014). These expenditures may initially reduce financial rewards, but over time, the investments can accumulate, leading to improved SC resilience and substantial financial enhancements as the resilience level increases (Ivanov and Dolgui, 2020). By transferring scarce resources into resource redundancy and relationship management, SC resilience may initially divert investments away from business profitability and efficiency, potentially weakening financial performance. The overinvestment in SC resilience during the early stages may not yield straightforward financial rewards, causing a negative association between SC resilience and financial performance when resilience is at a lower level (Ponomarov and Holcomb, 2009). At this stage, activities in building SC resilience lead to additional costs for a firm, as they require investments in capacity, inventory, and cash buffer enhancement, and building high-quality relationships with partners and integrating into the network to meet the requirements of SC resilience (Christopher and Peck, 2004). However, as organisations continue to invest in and refine their resilience strategies, the financial performance improvements become more significant. The interconnectedness between SC partners enables the system to adapt more effectively to disruptions and changes, ultimately leading to improved financial performance (Blackhurst, Dunn, and Craighead, 2011). This U-shaped relationship underscores the importance of understanding the trade-offs involved in allocating resources to SC resilience and the need to balance initial costs with the long-term benefits of increased SC resilience (Craighead et al., 2007).

The U-shaped relationship between SC resilience and financial performance can be interpreted from the perspectives of CAS and SNT. These theories emphasise SC systems' dynamic and adaptive nature (CAS) and the importance of high-quality, flexible relationships between SC partners (SNT) (Pathak, Day, Nair, Sawaya, and Kristal, 2014). The development of SC resilience within a network-structured adaptive system can be both resource-intensive and costly, which may initially lead to a reduction in financial performance. Investments in SC resilience may involve allocating extra resources as a buffer, maintaining reliable and flexible connections with partners, and participating in the coordination process of the entire SC system (Choi and Krause, 2006). These investments can be costly, and the initial financial rewards may be minimal. However, over time, these investments can accumulate and contribute to increased SC resilience, ultimately yielding substantial financial enhancements as the resilience level increases (Kamalahmadi and Parast, 2016).

From a CAS perspective, the U-shaped relationship suggests that, as SCs adapt to the complexities of their SC environment, they must balance the costs and benefits of resilience investment (Pathak et al., 2014). Initially, the costs may outweigh the benefits, but as the organisation continues to adapt and refine its resilience strategies, the financial performance improvements become more significant. From an SNT perspective, the U-shaped relationship highlights the importance of fostering strong, flexible relationships with SC partners (Choi and Krause, 2006). These relationships may require a significant initial investment to establish trust, communication, and collaboration mechanisms. However, as the network matures and partners become more interconnected (Carnovale, Yeniyurt and Rogers, 2017; Kim and Zhu, 2018), the financial benefits of these relationships begin to outweigh the costs, leading to improved financial performance. The U-shaped relationship indicates that organisations should focus on building and maintaining robust relationships with their SC partners, recognising that the financial rewards may not be immediate but will grow over time as the network becomes more resilient.

The interplay between CAS and SNT perspectives demonstrates that SC resilience in a network-structured adaptive system, is not solely about investing in resources and capabilities but also about fostering a dynamic and interconnected network of SC partners (Cruz and

Wakolbinger, 2008). This interconnectedness enables the system to adapt more effectively to disruptions and changes, ultimately improving financial performance (Arora et al., 2021). However, organisations should be aware of the curvilinear relationship between investments in SC resilience and financial performance and consider the trade-offs involved in allocating resources to the development of resilience capabilities.

In addition to the financial benefits, organisations should consider the non-financial advantages of SC resilience, such as improved customer satisfaction, enhanced reputation, and increased stakeholder trust (Amiraslani et al., 2022). These non-financial benefits can further contribute to the overall value of investing in SC resilience and help organisations maintain a competitive edge in the market. Future research could extend **Finding 5** by exploring the underlying mechanisms driving the U-shaped relationship between SC resilience and financial performance. This would involve examining the specific resilience capabilities that contribute to this non-linear relationship and identifying the factors that influence the optimal level of investment in SC resilience. Moreover, researchers could investigate the interaction between financial and non-financial benefits of SC resilience and how these benefits collectively contribute to organisational performance.

Finding 6: *the aggregate SC resilience has a U-shaped relationship with innovation performance, similar to financial performance*.

In addition to evaluating financial performance, this study serves as a pilot study to investigate the innovation performance linked to SC resilience at an aggregate level. Though innovativeness can be viewed as organisational capabilities contributing to SC resilience (Iftikhar, Purvis and Giannoccaro, 2021; Malacina and Teplov, 2022). This study adopted measurable innovation outcomes – granted patent – to evaluate innovation as a performance. SC resilience could yield risk, innovation, benefits, challenges and responsiveness (Gunasekaran, Subramanian and Rahman, 2015). The empirical results show that the curvilinear relationship between SC resilience and innovation performance is substantiated by the dynamic interplay of competing forces that shape this association. These forces entail the need to balance fostering autonomous, self-driven innovation initiatives within an organisation and directing collaborative investments towards interfirm innovation activities in the SC network. This finding indicates that SCs can foster innovation by enhancing their resilience, thereby enabling organisations to adapt and thrive in a dynamic business environment.

In order to gain a comprehensive understanding of the complex relationship between SC resilience and innovation performance, it is crucial to examine the role of SC resilience in facilitating knowledge creation and dissemination, a critical factor in strengthening an organisation's innovation capabilities (Mazzucchelli et al., 2021; Carter, Leuschner and Rogers, 2007). SC resilience enhances knowledge creation and diffusion across the entire SC network by increasing information transparency, building trusted communication (i.e., relational capital), and strengthening the connectivity and interaction of collaboration network (i.e., structural capital). Such factors are particularly significant when SC members are geographically dispersed, as is often the case in a global business context (Mazzucchelli et al., 2021).

From CAS and SNT perspectives, SC resilience enables innovation through two key mechanisms: firstly, by facilitating knowledge diffusion and spillover across the network (Ahmed et al., 2022), and secondly, by fostering innovation capabilities within the firm (Hult, Ketchen and Arrfelt, 2007). First, SC resilience emphasises shared value across the network, providing a solid foundation for the diffusion of innovation. This enables a higher likelihood of cultivating knowledge spillover from other SC members (Sáenz, Revilla and Knoppen, 2014), as effective communication and collaboration within the network allow for the efficient transfer of ideas, best practices, and lessons learned (Torgaloz, Acar and Kuzey, 2023). SC resilience promotes the establishment of closely aligned supplier-customer partnerships, which not only reflects the trust inherent in such collaborations, but the extent of control also exercised within the relationship (Borgatti and Li, 2009), as well as the partners' readiness (Grötsch, Blome and Schleper, 2013) and capacity to facilitate knowledge exchange and development (Wang, Xue and Yang, 2022). By harnessing the benefits of knowledge spillover, organisations can accelerate the development and implementation of innovative solutions, thereby enhancing their overall innovation performance.

Secondly, SC resilience serves as an adaptive capability that enables organisations to navigate the constantly shifting business landscape (Borgatti and Li, 2009). This adaptability is inherently aligned with the core objective of innovation, which seeks to develop new and enhanced solutions in response to evolving market demands and challenges. By fostering SC resilience capabilities, firms can encourage the growth of internal capacities that contribute to the generation of novel knowledge and ideas (Chowdhury and Quaddus, 2017), ultimately cultivating a culture of continuous improvement and innovation within the organisation. This can be supported by maintaining resource redundancy (Brandon-Jones et al., 2014). Possessing surplus and unused resources in terms of capacity, inventory, and cash in hand enables firms to maintain flexibility, allowing for investment in innovation activities as needed.

Although SC resilience can be advantageous for an organisation's innovativeness, its impact on innovation performance, similar to financial performance, exhibits a curvilinear relationship. This suggests that during the initial stages of investing in SC resilience, innovation performance may experience a decline. This phenomenon can be attributed to the competition of resources between internal innovation initiatives and the development of resilience. As the SC becomes increasingly resilient, the competitive nature of resource allocation gradually transforms into the convergence of resources towards fostering innovation and bolstering SC resilience simultaneously (Al-Hakimi, Borade and Saleh, 2021). Consequently, organisations can benefit from enhanced innovation capabilities while maintaining a robust and adaptive SC.

Finding 6 highlights the critical role of SC resilience in driving innovation performance by nurturing intrafirm innovation capabilities and promoting knowledge diffusion and spillover across the network. Future research could delve deeper into the complexities of these relationships, addressing pertinent questions regarding the types of SC resilience capabilities that contribute most significantly to innovation performance and the mechanisms that facilitate knowledge flow across the network.

7.3.4 Discussion of H3a-c and H4a-c: performance effects of SC resilience dimensions

Responding to the call from Finding 5 and Finding 6, hypotheses **H3a-c** and **H4a-c** suggest that the three dimensions of SC resilience - focal-level resource resilience, dyads-level relational resilience, and network-level structural resilience - exert distinct influences on financial and innovation outcomes. The objective of these hypotheses is to investigate and compare the breakdown effects of SC resilience dimensions (i.e., focal-level resource resilience, dyads-level relational resilience, and network-level structural resilience) on financial and innovation performance, respectively. The comparisons bring insights into the synergies and trade-offs among SC resilience dimensions on desired performance outcomes.

7.3.4.1 Discussion of H3a-c: direct relationships between resilience and financial performance

***Finding 7**: Focal- and dyads-level SC resilience have positive impacts on financial performance, and the magnificence of dyads-level impacts is stronger than focal-level. Network-level resilience has no significant impact on financial performance.*

Finding 7 responds to Hypotheses H3a-c, suggesting that SC resilience dimensions (i.e., focal-level resource resilience and dyads-level relational resilience) can positively impact financial performance, while network-level structural resilience has no significant impact on financial performance. This finding provides empirical evidence of direct relationships between SC resilience dimensions and financial performance, suggesting that two SC resilience dimensions at focal- and dyads-level, in isolation, could be a significant booster of a firm's financial output. This network thinking of SC resilience has received support from other studies (Chatterjee and Chaudhuri, 2021; Kim, Chen and Linderman, 2015).

CAS and SNT suggest that focal-level resource resilience underpins not only proactive SC design strategies but also empowers focal firms to cultivate trust and embark on new collaborative endeavours. In a network-structured adaptive SC system, redundant resources serve as signals or information transmitted across the SC network to other stakeholders (Azadegan, Modi and Lucianetti, 2021). These signals indicate that focal firms possess the capability to manage change effectively, thereby fostering a conducive environment for the organisation and its stakeholders (Christopher and Peck, 2004).

Resource resilience at the focal level represents a fundamental tenet of resilience thinking, namely, the risk management culture within an organisation. This culture embodies an organisation's capacity for flexibility, demonstrated by its ability to mitigate vulnerabilities through a combination of reactive and proactive measures (Ivanov, 2020). By maintaining resource reserves in anticipation of potential disruptions (Ivanov, 2020), focal firms can augment business continuity even when faced with unforeseen events that impact the entire SC. This comprehensive understanding of resource resilience highlights its significance in shaping an organisation's adaptive capacity, competitive advantage, and long-term success in an increasingly complex and volatile global market. This finding echoes Hendricks, Singhal and Zhang (2009), which shows that firms with operational slack in their SCs experience a less adverse stock market reaction during SC disruptions.

Resource resilience not only underpins proactive SC design strategies but empowers focal firms to cultivate trust and embark on new collaborative endeavours. While it may be intuitive to perceive resource readiness as a financial burden—given that slack resources do not directly contribute to everyday value-creation processes —partners within the SC might view this preparedness as a strength (Du et al., 2022). The availability of such resources facilitates rapid collaboration, bolsters social connections, and enables an efficient response to urgent stakeholder demands. For instance, with readily available cash reserves, the focal firm becomes more responsive to stakeholder pressures (Chen, Liu and Tang, 2022), market fluctuations, and strategy reinforcement. A pool of unallocated funds can be deployed to mitigate risks and seize opportunities for long-term continuity, thereby yielding financial benefits (Yang, Jiang and Chen, 2021). Moreover, sufficient cash reserves also signal well-managed SC relationships with suppliers and customers, as well as strong internal governance over business operations.

SC resilience at dyads level, referring SC concentration, explain the average dependency focal firm have on the major suppliers and customers. Finding 7 suggests that if the sales are more concentrated among major buyers (i.e., supplier dependence) or the procurement is more concentrated among major suppliers (i.e., suppliers' customer dependence), the focal firms can have a better financial return. In a non-static environment marked by a higher degree of volatility and complexity, firms are required to manage their SC in a well-organised way to enhance their responsiveness and flexibility (Ho et al., 2015). Firms with strong ties with major suppliers and customers were considerably less affected by the outbreak (Liu et al., 2023). Especially, stronger customer concentration contributes to business performance by promoting customer integration (Chen et al., 2023), while maintaining supplier base concentration improve the focal firms' efficiency (Han et al., 2022) and business stability against disruption (Jiang et al., 2023), as it can reduce the complexity and reduce the transaction cost. There are findings that further support the view that variety increases complexity but also fosters sales growth (Eckstein et al., 2015). However, having a diverse set of suppliers and customers operating in a dynamic environment does not appear to be associated with an increase in financial performance (Akın Ateş et al., 2022). This conclusion is supported by H3b that reducing dyads-level relational resilience (supplier/customer portfolio concentration) hinders financial benefits.

This finding contradicts a dominant belief that the focal firm's dependence on a supplier may encourage the supplier to capture a share of profits from the focal firm, negatively impacting the focal firm's financial performance (Prajogo et al., 2020). Gu et al. (2022) claim that SC concentration does not mean relationship stability, and it makes the focal firm lost bargaining power (Oliveira, Kadapakkam and Beyhaghi, 2017). It could be explained by theories and the sample deployed in this study. From the CAS and SNT perspective, SC players in the system are formally or informally connected with shared knowledge and values, aiming to pursue a long-term relationship (Chen, Li and Linderman, 2022). It means there will be less motivation of supplier or customer companies to take advantage of focal firms, but motivation of mutual benefits and collaborative exchanges, which could mitigate or convert the assumed negative effect of dependence. In the sample of this study focuses on large and public companies, which means focal firms, as dominant SC members in the interconnected network, can obtain more substantial power than close partners and have better financial performance (Wang et al., 2021). Instead, this condition may also enable the focal firms to benefit from the asymmetrical dependency (Qiu, 2018) and avoid the partners' opportunism, but it could be further examined.

Surprisingly, SC resilience embedded in the SC network (i.e., network-level structural resilience) has no significant impact on financial performance, which is against the theoretical reasoning (Kim, Chen and Linderman, 2015; Dixit, Verma and Tiwari, 2020). The rationale for this finding can be explained in two ways. Firstly, from the perspectives of CAS and SNT, the topology of the entire network ensures adaptability to environmental changes by promoting buffering network connections to mitigate adverse effects (Kim, Chen and Linderman, 2015; Dixit, Verma and Tiwari, 2020; Dolgui and Ivanov, 2020). However, under normal business conditions, maintaining network resilience may entail certain disadvantages, such as information redundancy, inefficiency, network complexity (Birkie, Trucco and Fernandez Campos, 2017), and adverse ripple effects. (Giannoccaro and Iftikhar, 2022), which can hinder overall business performance.

The study's investigation of network resilience does not consider disruption risks as contingency factors, which may not accurately capture the advantages of network resilience amidst dynamic environments. By expanding the analysis of contingency factors (disruption risks or environmental uncertainties), future work can obtain a more nuanced understanding of the relationship between network resilience and financial performance.

7.3.4.2 Discussion of H4a-c: direct relationships between resilience and innovation performance

Finding 8*: Focal- and network-level SC resilience has positive impacts on innovation performance, and the magnificence of network-level impacts is stronger than focal-level.*

Finding 8, responding to H4a-c, confirms that SC resilience dimensions (i.e., focal- and network-level) could directly impact innovation performance. This study simultaneously examined and compared the direct relationships between SC resilience dimensions (i.e., focal-, dyads-, and network-level resilience) and innovation performance. The results of H4a-c suggest that focal- and network-level resilience can contribute the enhancement of innovation performance, while dyadic-level resilience appears to have no discernible effect on this metric.

The performance effects of focal-level resource resilience remain robust, as demonstrated by the similarity between hypotheses H3a and H4a. The results of H4a confirm that focal-level resource resilience is also advantageous for innovation performance. This conclusion highlights consistency in the direction of the effects of focal-level resource resilience, encompassing capacity slack, inventory slack, and SC slack. From the CAS and SNT perspectives, resilience at focal firms facilitates knowledge exchange and fosters flexibility in adapting to changing circumstances (Pathak et al., 2014; Scholten and Schilder, 2015). Consequently, focal-level resource resilience holds promise for both financial benefits and knowledge creation.

Finding 8 suggests that resource slacks can be transformed into value creation, as the availability of financial resources, materials, and capacity can stimulate the development of flexible knowledge management schemes (Pettit, Fiksel, and Croxton, 2010). This, in turn, promotes the adoption of process and product innovation. Resource redundancy also fosters collaboration, enabling organisations to unlock their innovation potential by seeking complementary competencies from partners (Jüttner and Maklan, 2011). This promotes collaboration and provides a foundation for experimentation with new products or processes.

There is a lack of significant statistical evidence to support Hypothesis 4b, which suggests that the direct relationship between dyadic-level resilience and innovation performance is not significant. As one dimension of SC resilience, dyadic-level resilience contributes differently to financial performance and innovation performance. While dyadic-level resilience facilitates knowledge resource acquisition, potentially increasing the likelihood of generating innovative outputs (Kim and Zhu, 2018), the results do not confirm direct associations between dyadic-level resilience and innovation performance.

Theoretical reasoning could be provided for potential linkages between SC dependency and innovation. Dyads-level relational resilience can be related to innovation performance (Kim and Zhu, 2018) through factors such as SC leverage, vertical collaboration (Haus-Reve, Fitjar and Rodríguez-Pose, 2019), and financial flexibility. For example, Onofrei et al. (2020) argue that knowledge gained from leveraging suppliers or customers enhances innovation performance by distributing innovation risk among partners and reducing outcome uncertainty. This, in turn, enables SC partners to engage in high-risk, innovative activities beyond the firm's boundaries. Following this logic, a stronger customer concentration implies more opportunities for deep vertical collaboration and external knowledge acquisition, thereby enabling product innovation flexibility under organisational awareness (Liao and Marsillac, 2015). One possible explanation is that informal relationships or connections among SC partners allow firms with a higher level of dependency to achieve better financial flexibility and easier access to knowledge throughout the entire SC (Nguyen et al., 2020; Onofrei et al., 2020, p.1; Oke, 2013).

Finding 8 suggests a direct relationship between network resilience and innovation performance. Obtaining and maintaining network resilience itself is a learning process towards the system dynamism (Chen, Li and Linderman, 2022; Do et al., 2022). Firms allocate resources to drive innovation by utilising internal knowledge and tapping into external intelligence from the SCs within which they operate (Onofrei et al., 2020). Network resilience is theorised to facilitate the pooling of new ideas and the accumulation of technological innovation within the SC network (Delbufalo, 2015), the realisation of these innovation outcomes may be promoted by informal ties and effective leadership. Network resilience reflects the strength of the network in the exchange relationships and communication bandwidth (Choi and Kim, 2008), where external relationships are founded on mutual respect, shared goals, and objectives, enabling focal firms to amass resources that are rooted in the value of knowledge exchanges with other SC members, thereby enhancing their innovation activities (Subramaniam and Youndt, 2005). Network resilience, though reflected in the topological structure, captures the informal and formal interactional ties that span the SC network (Delbufalo, 2015; Tukamuhabwa, Stevenson, and Busby, 2017; Potter and Paulraj, 2020). Consequently, maintaining network resilience is crucial for aggregating knowledge bases along the SC, which benefits innovation performance.

Finding 8 highlights a direct relationship between network resilience and innovation performance, emphasising the importance of network resilience as a learning process that enables adaptation to system dynamism (Chen, Li and Linderman, 2022; Do et al., 2022). Firms allocate resources to drive innovation by capitalising on internal knowledge and tapping into external intelligence from the SCs within which they operate (Onofrei et al., 2020). Network resilience is posited to facilitate the pooling of novel ideas and the accumulation of technological innovation within the SC network (Delbufalo, 2015), with the potential to further enhance these innovation outcomes through informal ties and effective leadership. Network resilience embodies the strength of exchange relationships and communication bandwidth in the network (Choi and Kim, 2008), wherein external relationships are grounded in mutual respect, shared goals, and objectives. This foundation allows focal firms to amass resources rooted in the value of knowledge exchanges with other SC members (Wang, Xue and Yang, 2022), ultimately augmenting their innovation activities. Although network resilience is reflected in the topological structure, it encapsulates both informal and formal interactional ties that span the SC network (Delbufalo, 2015; Tukamuhabwa, Stevenson and Busby, 2017; Potter and Paulraj, 2020). As a result, maintaining network resilience proves critical for consolidating knowledge bases along the SC, thereby fostering innovation performance.

7.3.4.3 Summary of H3a-c and H4a-c

This study contributes to the empirical knowledge of SC resilience performance outcomes and interdisciplinary research on SC resilience and innovation by employing CAS and SNT as theoretical lenses, enabling the identification of distinct performance effects across various SC resilience dimensions. Within this research context, focal-level resilience plays a pivotal role in bolstering both financial and innovation performance; dyadic-level resilience is observed to positively impact financial performance, yet it does not appear to influence innovation performance significantly. Network-level resilience enhances innovation performance but does not exert a considerable impact on financial performance. This analysis emphasises the unique and varied effects of different levels of SC resilience on financial and innovation performance, providing avenues for future research. For example, the missing linkages between network resilience and financial performance would be influenced by other factors (i.e., focal- and dyads-level resilience) or relationships (i.e., network resilience-innovation relationship), warrants further investigation into the examination of mechanisms connecting network resilience with performance outcomes and the interplay of corresponding results (e.g., innovation and financial performance).

Based on the current empirical evidence, this study suggests future research can deploy CASs and SNT theoretical lens and reveal the interaction mechanism among SC resilience dimensions on desirable outcomes. Along with network resilience, other network-based measurements can also be jointly investigated, such as SC complexity (Birkie, Trucco and Fernandez Campos, 2017), network density (Delbufalo, 2015), geographic proximity (Capaldo and Petruzzelli, 2014) and informal network connections, such as political ties (Zhang et al., 2019; Jean, Sinkovics and Zagelmeyer, 2018) can be investigated as joint antecedents of innovation performance.

Though current research has shed light on the interaction of resilience and innovation, this study positions SC resilience as the antecedent of innovation performance, aligning with the notion that innovation is frequently regarded as a performance metric in both SCM and general management literature (Ko et al., 2018; Zang, Wang and Zhou, 2022; Oke, 2013; Capaldo and Petruzzelli, 2014). It is contractor to some other studies also consider innovation as the antecedent of SC resilience (Sabahi and Parast, 2020; Belhadi et al., 2021; Iftikhar et al., 2022;

Gölgeci and Ponomarov, 2015; Malacina and Teplov, 2022), which are mainly based on the dynamic capability perspective. Therefore, the next step of the ongoing research can explore further the interaction mechanisms between SC resilience and innovation with other joint influencing factors or performance outcomes.

7.3.5 Discussion of H5 and H6: moderation effects of SC resilience and SSCM

H5 and H6 propose that SC resilience (or SSCM) can positively moderate the relationship between SSCM practices (or SC resilience) and firm performance (i.e., financial and innovation performance), aiming to examine the synergies between SSCM practices and SC resilience. Different levels of interaction mechanisms have been analysed based on the findings from hypotheses H1 to H4. Given the equal prominence of SSCM and SC resilience, this study examined the interaction mechanisms by adding different interaction terms to regression models. Based on the empirical results, the study suggests that the interaction mechanism between resilience and sustainability is complex and uncovers that the synergy between SSCM and SC resilience is essential for achieving financial and innovation performance. Therefore, the following finding can be summarised:

Finding 9*. The financial benefit of SSCM is higher when SC resilience is high, especially when focal- and dyads-level resilience is higher. It implies SCs can "do well by doing good and being resilient".*

Finding 10*. SSCM has stronger positive impacts on innovation performance when SC resilience is high, especially when network-level resilience is high.*

In this study, SC resilience, as a composite variable, positively moderates all main SSCM-financial performance relationships (i.e., SSCM as an aggregate variable, environmental, social, and governance SSCM). The focal- and dyads-level resilience have significant and positive moderating effects on SSCM-financial performance, but not the network-level resilience. It implies that the financial benefit of SSCM is higher when SC resilience is high, especially when focal- and dyads-level resilience is higher. Recalling results from **H1** and **H3** SSCM and SC resilience have curvilinear impacts on financial performance. SSCM and SC resilience share a common pattern of financial effects, which confirms the similarity between the two concepts and implies the potential of the synergies, which have been empirically verified in this study. At the aggregate level, SSCM and SC resilience are intertwined for better financial benefits. When examining these concepts at the dimensions or constructs level, the study reveals that emphasising resource and relational resilience can amplify the positive impacts of SSCM on financial performance.

The study also finds that SSCM as an aggregate model only contributes to innovation performance with the presence of network-level resilience. SSCM positively moderates the association between network-level resilience and innovation performance. The aggregate level of SSCM enables network-resilient SCs to perform better in terms of knowledge creation. This result firstly confirms the synergies of SSCM and network-level resilience for enhancing innovation. Furthermore, the results highlight that although dyads-level resilience does not have a direct impact on innovation performance, it has a positive moderation effect on the relationships between governance SSCM and innovation performance. The innovation effect of governance SSCM is stronger when firms have more concentrated dyadic relationships.

Empirical evidence suggests that when firms maintain strong SC resilience, the performance effects of SSCM practices are more positively influenced than when firms lack SC resilience. It highlights the importance of integrating SSCM and SC resilience strategies for organisations to achieve optimal innovation and financial performance outcomes.

CAS and SNT suggest that the similarity and complementarity of SSCM and SC resilience in terms of risk management (Subramaniam and Youndt, 2005); stakeholder engagement (or relationships management) (Choi and Kim, 2008; Lu et al., 2018; Borgatti and Li, 2009), and long-term orientation (Chen, Li and Linderman, 2022; Do et al., 2022; Marshall et al., 2015), which can offer the interpretation of the synergic interaction mechanisms between SSCM and SC resilience at different levels.

From the CAS and SNT perspective, SC is a complex adaptive SC system comprising multiple interacting entities with informal and formal connections. Each SC member strives to adapt to the environment and achieve the shared objectives (Borgatti and Li, 2009; Nair and Reed-Tsochas, 2019). The complexity of the environment, the entities, and the interaction among entities make SCs inherently vulnerable to various risks and disruptions (Choi and Krause, 2006). SSCM aims to mitigate these risks by integrating sustainability considerations into SC processes and practices (Gouda and Saranga, 2018), adopting environmentally friendly practices, maintaining ethical standards, and ensuring social responsibility across all SC activities (Carter and Rogers, 2008). SSCM practices can enhance their overall reputation and stakeholder relationships to reduce the exposure to risks associated with unsustainable practices (Nobanee et al., 2021; Pfajfar et al., 2022). By addressing these dimensions, SSCM helps build more transparent, responsible, and ethical SCs less susceptible to reputational, regulatory, and operational risks (Giannakis and Papadopoulos, 2016).

While SC resilience focuses on the capacity to recover from disruptions and maintain or restore SC functionality, it can be viewed as an attribute originating in the topology of the SC system network (Kim, Chen and Linderman, 2015). SC resilience involves developing proactive strategies, such as maintaining alternative suppliers, diversifying sourcing and transportation routes, and investing in advanced monitoring and detection systems, which can increase an organisation's ability to withstand and recover from unexpected events (Al Naimi et al., 2022). In general, SSCM focuses on reducing risks and adversity related to external stakeholders, while SC resilience focuses on risks related to internal functionality (Tukamuhabwa et al., 2015).

Consequently, CAS and SNT suggest that the synergies between SSCM and SC resilience in risk management are evident in their mutual objectives of identifying, assessing, and mitigating potential risks to ensure SC continuity and financial performance and their complementarity in targeting diverse ranges of risks (Ali and Gurd, 2020; Ali and Gölgeci, 2021; Giannakis and Papadopoulos, 2016). By integrating sustainability considerations and resilience strategies, organisations can create SCs that are more environmentally friendly, socially responsible, ethical, and more resilient and adaptable to change (Cotta et al., 2023). This synergy between SSCM and SC resilience ultimately improves SC continuity and performance (Negri, Cagno and Colicchia, 2022; Cotta et al., 2023).

CAS and SNT emphasise the importance of stakeholder engagement and relationship management for managing the system, structural, relational dynamics, and interactions between various stakeholders within or outside SC networks (Borgatti and Li, 2009). Effective stakeholder engagement and relationship management are critical to both SSCM and SC resilience, as they facilitate information exchange (Jean, Kim and Choi, 2021), trust-building (Giannoccaro and Iftikhar, 2022; Amiraslani et al., 2022; Hou et al., 2018; Poppo, Zhou and Li, 2016), and collaboration among SC actors (Cousins et al., 2006).

Information exchange is essential in maintaining transparency (Buell and Kalkanci, 2021), identifying potential risks, and promoting sustainable practices throughout the SC (Cousins et al., 2006). From the SNT perspective, resource sync and collaboration with sustainability orientation across multiple SC actors can help remove the distrust issues with the embedded transparency due to influence network governance. SC players could gain SC transparency for accurate risk monitoring over the previous black box (Buell and Kalkanci, 2021; Gualandris et al., 2021). It could also increase accountability and visibility across SC networks by resolving the geographic, operational, and cultural distance (Farooq, Rupp and Farooq, 2017; Capaldo and Petruzzelli, 2014). By openly sharing information about their operations, practices, and performance, organisations can better align their objectives with their SC partners, ensuring a more seamless and coordinated response to potential disruptions or sustainability challenges.

Moreover, information sharing also facilitates trust-building (Giannoccaro and Iftikhar, 2022), another vital aspect of stakeholder engagement and relationship management. When trust is established among SC partners, it can lead to increased cooperation, reduced transaction costs, and enhanced mutual support during times of crisis or change (Cruz and Wakolbinger, 2008; Choi and Krause, 2006). High levels of trust can also facilitate the adoption and implementation of SSCM initiatives (Amiraslani et al., 2022). Partners are more likely to engage in joint efforts to improve sustainability performance and address shared concerns (Vachon and Klassen, 2008; Arora et al., 2020; Touboulic and Walker, 2015).

Information sharing and trust-building allow collaborative efforts in SSCM and SC resilience among SC actors is crucial for both SSCM and SC resilience. Organisations can develop more efficient and effective solutions to sustainability challenges by working together and pooling resources, such as reducing waste, optimising resource use, and improving social and environmental performance (Beske and Seuring, 2014). Similarly, collaborative efforts can help enhance SC resilience by allowing organisations to share best practices, jointly invest in innovative risk mitigation strategies, and coordinate their responses to disruptions (Dubey et al., 2020; Christopher and Peck, 2004; Kamalahmadi and Parast, 2016).

From CAS and SNT perspectives, SSCM and SC resilience share common attributes in relationship management and stakeholder engagement, which are crucial for establishing and maintaining connections within and beyond the SC network. Information sharing, trust, and collaboration are three major relationship management factors shared as mutual antecedents of SSCM and SC resilience, of which at different scales (e.g., dyads- and network-level, internal or external SC) can leverage SC resilience and SSCM to a different extent among diverse stakeholders. It is valuable to investigate the mutual antecedents of SSCM and SC resilience from CAS and SNT, which could contribute to interpreting the commonalities and interdependencies between SSCM and SC resilience.

Both SSCM and SC resilience adopt a long-term orientation to ensure sustainable and resilient development (Sauer, Silva and Schleper, 2022). Long-term orientation means continuous adaptation and learning process, the structure of SC networks evolves to be constructed and efficient for the external environment outside the boundary of CASs. SC network ties may be disconnected and re-connected among SC agents who can contribute more to the system evolution. The network connection status of each SC agent determines the dependency (Chu et al., 2019; Kim and Zhu, 2018), transparency (Hou et al., 2018), and distance properties (Palit, Hora and Ghosh, 2022) from the view of SNT, which could affect the power and leadership (Carnovale, Yeniyurt and Rogers, 2017), SC visibility and accountability (Taghizadeh, Venkatachalam and Chinnam, 2021), and in turn, SC performance (Chowdhury, Quaddus and Agarwal, 2019). Nevertheless, complex global SCs severely limit the ability to reliably monitor and manage these risks on the ground at geographically and operationally distant raw material suppliers (Jiang et al., 2023). But they employ different approaches in achieving this goal. SSCM focuses on adaptation to the expectations of multiple stakeholders, including employees, the environment, and society (Beske and Seuring, 2014). It emphasises balancing economic performance with social and environmental considerations, ensuring a sustainable and responsible SC. SSCM is an interactive learning process that considers the consequences of interactions with stakeholders and continuously evolves to meet their needs and expectations (Sarkis, 2020).

On the other hand, SC resilience is a learning and adapting process that deals with past or foreseen uncertainties (Chen, Li and Linderman, 2022). It emphasises proactive action to withstand and recover from disruptions, aiming to maintain SC continuity and minimise the negative impacts of disruptions. SC resilience involves monitoring the interaction with stakeholders, learning from experiences, and adjusting strategies to reduce impacts on the SC itself (Chen, Li and Linderman, 2022).

Although SSCM and SC resilience have different focal points, their two dimensions of performance are aligned, as SCs are network-structured adaptive subsystems embedded in a broader sociological and ecological system (Wieland, 2021; Wieland and Durach, 2021; Wieland et al., 2023). As such, the long-term sustainability and resilience of SCs rely on the effective integration of SSCM and SC resilience strategies. By addressing the needs of stakeholders and proactively managing risks and uncertainties, organisations can build SCs that are both sustainable and resilient, ultimately enhancing their long-term performance and viability.

In conclusion, the synergies between SSCM and SC resilience, as elucidated through the CAS and SNT lenses, are evident in their shared emphasis on risk management, stakeholder engagement and relationship management, and long-term orientation. These synergistic interactions contribute to developing more sustainable and resilient SCs, which in turn have positive implications for performance outcomes.

Although, this study serves as a pilot and confirms the synergistic relationship between SSCM and SC resilience (Bellamy, Ghosh and Hora, 2014; Hendricks, Singhal and Zhang, 2009;

Yang, Jiang and Chen, 2021), it does not delve into the relational factors or mutual antecedents that influence the interaction mechanism between SSCM and SC resilience. As such, future research could extend the investigation by examining these aspects. Including relational factors, such as trust, communication, and power dynamics among SC stakeholders, could provide valuable insights into the synergistic relationship between SSCM and SC resilience.

7.4 Summary

Chapter 7 commences with a summary of the main findings from the empirical studies in **Section 7.2**. **Section 7.3** discusses results in the context of extant literature with the support of theoretical lenses of CAS and SNT. The empirical findings reveal the intricate nature of the impact of SSCM and SC resilience on firm performance in terms of financial and innovation performance.

The results suggest that SSCM and SC resilience demonstrate a curvilinear relationship with financial performance, meaning they are too good to be too little. Additionally, SC resilience and SSCM both contribute positively to innovation performance. The empirical findings uncover synergies in the interaction mechanism between SSCM and SC resilience, which positively affect financial and innovation performance. Furthermore, these synergies are present at both the aggregate and sub-construct levels.

By examining the results in light of current knowledge and relevant theoretical frameworks, this chapter provides a comprehensive understanding of the complex interplay between SSCM, SC resilience, and firm performance. The empirical findings indicate potential avenues for future research, including exploring the synergistic effects among SSCM dimensions, SC resilience dimensions, and the interaction between SSCM and SC resilience on various performance outcomes.

Furthermore, the CAS and SNT perspectives suggest that the interpretation of the synergies between SSCM and SC resilience is rooted in their similarities and complementarities, particularly in mutual attributes such as risk management, stakeholder engagement and relationship management, and long-term orientation. These shared attributes warrant further investigation in future research to enhance our understanding of the mechanisms that drive the synergistic relationship between SSCM and SC resilience and their impact on firm performance.

There are ten main findings can be listed below.

Finding 1: this study echoes existing studies on the positive effects of SSCM initiatives on firm performance (Sardana et al., 2020; Ahmad, Mobarek and Roni, 2021; Sarkis, 2020; Foo et al., 2021; Geng, Mansouri and Aktas, 2017; Vishwanathan et al., 2020), confirming a direct and non-linear (i.e., U-shaped) relationship between SSCM and financial performance.

Finding 2: SSCM practices can have a direct and positive influence on innovation performance, but their impact depends critically on resilience at the network level.

Finding 3: All dimensions of SSCM practices – environmental, social, and governance SSCM - exhibit positive influences on financial performance, characterised by non-linear, U-shaped relationships. There is a noticeable congruence among SSCM dimensions on financial performance.

Finding 4: only governance SSCM practices directly contribute to improving innovation performance, while environmental and social SSCM practices do not, indicating a more substantial alignment between governance SSCM and innovation outcomes.

Finding 5: the aggregate SC resilience has a positive relationship with financial performance, which is not strictly linear but a U shape.

Finding 6: the aggregate SC resilience has a U-shaped relationship with innovation performance, similar to financial performance.

Finding 7: Focal- and dyads-level SC resilience positively impacts financial performance, and the magnificence of dyads-level impacts is stronger than focal-level. Network-level resilience has no significant effect on financial performance.

Finding 8: Focal- and network-level SC resilience positively impacts innovation performance, and the magnificence of network-level impacts is stronger than focal-level.

Finding 9. The financial benefit of SSCM is higher when SC resilience is high, especially when focal- and dyads-level resilience is higher. It implies SCs can "do well by doing good and being resilient".

Finding 10. SSCM has stronger positive impacts on innovation performance when SC resilience is high, especially when network-level resilience is higher.

Chapter 8 Conclusions

The overall objective of this study was to investigate the interaction mechanisms between SC resilience and SSCM. **Chapter 2** provided a literature background and a systematic literature review of the co-occurrence of SC resilience and sustainability and identified the common themes between the two research streams, responding to **RQ1**. Drawn upon CAS (complex adaptive systems) and SNT (social network theory), **Chapter 3** proposed a theoretical framework to explain the interaction of SC resilience and SSCM paradigms in a network-structured adaptive SC system driven by evolving environment turbulence and desired performance outcomes, responding to **RQ2**. Based on the theoretical framework, **Chapter 4** reflected on the conceptual frameworks for empirical studies in this field and conducted hypotheses development for the empirical model in this study. **Chapter 5** positioned the philosophical stance of this study, developed the research design (research context and sample), and measured major variables for empirical analyses. **Chapter 6** presented the empirical analysis, including method justification, model interpretation, and empirical results. The empirical model examines the direct effects of SSCM and SC resilience on financial and innovation performance, respectively, along with the moderating roles of SSCM and SC resilience. **Chapter 7** presented the discussion of empirical findings in light of the literature. Finally, **Chapter 8** concludes the study and reflected on the overarching linkages among findings across RQs.

This chapter concludes the study by summarising the key research findings related to the RQs. It then reflects on the research methodology and limitations of this research. The third section justifies the rationale of this study regarding the theoretical and practical contributions, and the final section proposes possible avenues for further research.

8.1 Summary of main findings: answers to RQs

This study aims to investigate the intersection of resilience and sustainability within an integrated framework and provide empirical evidence for their co-occurrence in the context of SCM To achieve this three key issues were addressed: 1) the identification of common themes regarding the interplay of resilience and sustainability in the SCM context, 2) the development of a conceptual framework for the interaction between SC resilience and SSCM, drawing on theoretical lenses, and 3) the empirical examination of the linkages between SC resilience and SSCM, with a focus on the moderating effects of SC resilience (SSCM) on the associations between SSCM (SC resilience) and performance outcomes, including financial and innovation performance. The following section synthesises the research questions and their corresponding answers.

8.1.1 RQ 1. What common themes are developed in the joint research of SC resilience and SSCM in the extant literature?

To answer RQ1, a systematic literature review was conducted to identify the common patterns related to the interplay between SC resilience and SSCM. The study confirmed the co-occurrence and intersection between SS resilience and SSCM in extant literature. It was found that the joint investigation of resilience and sustainability has become more common in the past decade, especially since 2016, with the emergence of new terms that combine both elements, such as LARG (lean, agile, resilient, and green), ecosilient (meaning green and resilient), and viable SC. The literature review identifies the common themes in three clusters of relationships: 1) resilience and sustainability are treated as different objectives; 2) sustainability is considered as a broader objective with resilience as one of the antecedents; 3) resilience is considered as a broader objective with sustainability as one of the antecedents. The study's findings reveal that the intersection of SC resilience and SSCM is complex in the current literature. The complexity of the intersection between SC resilience and SSCM arises from the combination of factors that are investigated, including the SC risks, SC structure, the combination of SC resilience and sustainability paradigms, and the resulting performance outcomes. Therefore, the study suggests that further theoretical development and empirical evidence are needed to unravel the intricate linkages between resilience and sustainability in SCM.

8.1.2 RQ 2. How can SC resilience and SSCM be integrated under the framework of CAS and SNT?

To address RQ2, this study examines the suitability and complementarity of using CAS and SNT as theoretical lenses in the research area. CAS and SNT provide a comprehensive understanding of the dynamic and long-term nature of adaptive and evolving network-structured SC systems, which is highly relevant to this study's focus. According to CAS and SNT, SC systems adapt to the turbulent environment while pursuing desired performance outcomes. This adaptation involves the evolution of network structures and internal mechanisms, including SC resilience and sustainability paradigms. Based on this understanding, a theoretical framework is proposed that integrates SC risks, SC resilience, sustainability paradigms, performance outcomes, and SC structure. The proposed framework is grounded in CAS and SNT and provides equal emphasis on SC resilience and sustainability as levers for achieving targeted performance outcomes. The proposed framework serves as a theoretical foundation for the subsequent empirical investigation, highlighting the intricate mechanisms through which SC risks affect the adoption of SC paradigms and their impact on composite performance outcomes.

From the theoretical lenses of CAS and SNT, this study posits that SC risks are the sources of environmental turbulence that stem from both internal and external factors of the SC system. These risks include sustainability and non-sustainability issues. Environmental turbulences drive the design of dynamic internal mechanisms, referred to as SC resilience and sustainability paradigms in this study, which can be supported by the dynamic adaptation of the SC network structure. The dynamism of SC systems can be understood in three ways: firstly, through the dynamic paradigm of SC resilience and SSCM that provides a range of solutions for confronting SC risks; secondly, through the dynamic adaptation of SC network structure to achieve the SC resilience and SSCM paradigm; and finally, through the dynamic outcomes of SC systems, which are influenced by the system environment and can therefore drive the adaptation of SC systems.

The conceptual framework is the first comprehensive assessment of the interplays between resilience and sustainability in the SCM field with the complementary theoretical lenses of CASs and SNT, which considers SCs as network-structured adaptive systems and with SC risks as external turbulences and SC resilience and SSCM paradigms as the internal mechanism for targeted performance outcomes, which could self-evolve with the environment by adjusting SC network structures. Moreover, this framework raised critical theoretical issues that have a bearing on whether resilience and sustainability can synergise on performance outcomes and how can the two paradigms synergise.

8.1.3 RQ 3: What is the nature of the relationship between SC resilience and SSCM in terms of their impacts on firm performance?

Driven by findings from the literature review and theoretical framework, it is still being determined whether it is a synergy or paradox between SC resilience and SSCM. RQ3 aims to uncover the role of SC resilience (SSCM) in the associations between SSCM (SC resilience) and performance outcomes (i.e., financial and innovation performance). To provide a straightforward answer to this research question, this study examined the moderating roles of SC resilience and SSCM dimensions by conducting a longitudinal study with archival data from Chinese public companies. The empirical study involves multiscale resilience constructs from the SNT perspective: the focal-level resource resilience (i.e., capacity, inventory, and SC slacks), the dyads-level relational resilience (i.e., customer and supplier base concentration), and the network-level resilience (i.e., network resilience composited by network size, network density, network connectivity and centrality). SSCM practices are categorised into three dimensions based on ESG measurements. Each pair of SSCM (SC resilience) and performance are examined along with the moderating effects of SC resilience (SSCM).

The empirical study's results confirm the existing knowledge on the complex nature of SC resilience and sustainability, highlighting the importance of aligning SC resilience and SSCM practices to achieve desirable performance outcomes. The study reveals that SSCM practices positively impact financial performance, irrespective of whether it's measured as a composite variable or across environmental, social, and governance dimensions. The positive effect of SSCM practices on financial performance is consistent across all three dimensions. However, the study also finds that SSCM practices at the aggregate level are not linked to innovation performance, except for governance-related practices. Governance SSCM practices positively affect innovation performance, while environmental and social SSCM practices do not.

In terms of SC resilience, the study shows that it, as a composite variable, contributes to both financial and innovation performance. However, the impact of SC resilience on performance outcomes also differs depending on the level of analysis. Focal-level and dyads-level resilience positively impact financial performance, whereas network-level resilience does not. On the other hand, network-level resilience has a more significant impact on innovation performance than focal-level resilience, but dyads-level resilience has no effect.

Surprisingly, the empirical results confirm that the synergy between SSCM and SC resilience is essential for achieving both financial and innovation performance. The study suggests that the interaction mechanism between resilience and sustainability is complex. As a composite variable, SC resilience positively moderates all main SSCM-financial performance relationships (i.e., SSCM at the aggregate level, environmental, social, and governance SSCM). Looking at the SC resilience dimensions, the focal- and dyads-level resilience have significant and positive moderating effects on SSCM-financial performance, but not the network-level resilience. This implies that the financial benefit of SSCM is higher when SC resilience is high, especially when focal- and dyads-level resilience is higher.

The study finds that SSCM at the aggregate level does not contribute to innovation performance without the presence of network-level resilience. SSCM positively moderates the association between network-level resilience and innovation performance. A higher level of SSCM enables network-resilient SCs to achieve stronger innovation performance. This result firstly confirms the synergies of SSCM and network-level resilience for enhancing innovation. Furthermore, the results highlight that although dyads-level resilience does not directly impact innovation performance, it has a positive moderation effect on the relationships between governance SSCM and innovation performance. The innovation effect of governance SSCM is stronger when firms have more concentrated dyadic relationships.

8.2 Discussion of findings from RQs

8.2.1 Interplay of findings from RQs

The exploration into the intertwined relationship between SC resilience, SSCM, and firm performance unfolded through the interplay of three sequential research questions. A narrative was woven from the findings of these questions, creating a unified understanding of the complex dynamics between resilience and sustainability in SCM.

RQ1 embarked on the journey by methodically investigating the common themes in the combined study of SC resilience and SSCM through a systematic literature review. The literature review process unravelled underlying patterns, thematic correlations, and identified trends. Most importantly, it underscored the intricate intersection between resilience and sustainability. The complexity of the intersection between SC resilience and SSCM arose from the combination of factors that were investigated, including the SC risks, SC structure, the combination of SC resilience and sustainability paradigms, and the resulting performance outcomes. These foundational insights derived from RQ1 set the stage for the development of the integrated theoretical framework in RQ2 and offered a broader, nuanced perspective for the empirical investigation conducted in RQ3.

In response to RQ2, this study ventured into the creation of an integrated theoretical framework rooted in the principles of CAS and SNT. The conceptual framework, moulded by the insights derived from RQ1, assigned equal importance to SC resilience and sustainability. It proposed that SC systems adapt to the turbulent environment while pursuing desired performance outcomes, and that this adaptation involves the evolution of network structures and internal mechanisms, including SC resilience and sustainability paradigms. Such a balanced viewpoint facilitated a comprehensive and profound investigation of the influence of SC resilience and SSCM on performance outcomes in RQ3. It also provided a sound theoretical foundation for subsequent empirical investigations.

RQ3, driven by the rich insights from RQ1 and the solid theoretical grounding provided by RQ2, was an empirical foray into the complex relationships between SC resilience, SSCM, and performance outcomes. The empirical examination highlighted the importance of aligning SC resilience and SSCM practices to achieve desirable performance outcomes. Specifically, the study revealed the positive impacts of SSCM practices on financial performance and the significant role of SC resilience in shaping both financial and innovation performance. The synergetic findings from all three RQs highlighted the multifaceted dynamics between SSCM and SC resilience, emphasising the importance for firms to synchronise these two aspects in their SCM strategies.

8.2.2 Integrated insights and implications

The collective responses to the three RQs culminate in several enlightening insights. The most notable of these insights is the illustration of the complex interconnections between resilience and sustainability in SCM. The complexity and intricacy of these connections underscore the necessity for organisations to orchestrate these aspects strategically. While resilience and sustainability have been commonly examined in their individual capacities, the findings of this study uncover the tangled nature of the two concepts and underscore the significant impact of their synergies on performance consequences.

By answering all three RQs, this study proposes an encompassing view of the intricate relationships between resilience and sustainability. Through the application of CAS and SNT lenses, it delves deeper into the understanding of the complex interrelationships of SC resilience and SSCM, where both are essential for adaptive SC network systems evolving towards the external environment. In particular, the synthesis of CAS and SNT perspectives in the context of SCM research is a novel contribution. This study has adopted these theories to reveal the underlying mechanisms and dynamic interactions in SC resilience and SSCM. The integrated application of CAS and SNT not only deepens the understanding of SC resilience and SSCM individually, but also explicates their interrelationships and combined effects on firm performance.

The theoretical foundation of the association of SC resilience and SSCM guides this study to explore the empirical examination of complex resilience-sustainability relationships. The analysis of overall effects and breakdown effects of SC resilience and SSCM practices on firm performance present a novel and comprehensive picture that allows for the integrated study of these elements at difference dimensions (e.g., ESG) or scales (i.e., the node, dyads, and network levels). In addition, the exploration of the moderating effect of SC resilience on the relationship between SSCM and firm performance is an innovative step forward in research on SCM, resilience and sustainability. This study has unpacked the complexities in these relationships and highlighted the interdependencies among them. It demonstrates that SC resilience and SSCM are not simply two separate entities; they are deeply interconnected, and their interactions exert substantial influences on firm performance.

8.3 Reflection on the empirical method

In the field of sustainable SCM, quantitative empirical tools have primarily been used to answer "what-type" questions rather than "how" questions (Carter and Liane Easton, 2011; Pagell and Shevchenko, 2014). However, the literature indicates that mathematical modelling is the prevalent research methodology when examining the intersection between SC resilience and sustainability, which aligns with previous research on SC resilience. Measuring SC resilience, a latent variable, is inherently challenging. Previous empirical studies have utilised questionnaire measurement scales (Ambulkar, Blackhurst and Grawe, 2015; Han, Chong and Li, 2020) and case studies (Negri, Cagno and Colicchia, 2022) to assess SC resilience. However, these methods are limited in terms of sample size and generalisability. To tackle this limitation, this study adopted a secondary data analysis method to provide objective and independent results with a large sample size to present the overall population.

The first challenge is the measurement of SC resilience capability with secondary data. As emphasised in previous chapters, it is challenging to operationalise SC resilience due to its multidimensional and latent nature. Drawn upon CAS and SNT, this study proposes that SC resilience can be conceptualised as a meta capability rooted in the resource redundancy at focal firms, the interfirm relationships, and the overall structure of the SC network. To operationalise SC resilience using secondary data, this study suggests a two-pronged approach: measuring focal- and dyads-level resilience with financial and SC data and calculating network-level resilience with network attributes in network analysis.

The second challenge is data collection and construction. The research design aims to provide objective results with secondary data analysis. Therefore, the quality of the archival data can significantly affect the empirical results, regardless of the rigorousness of the analysis processes. Hence, this study gathered financial and SC data from CSMAR and CNRDS, the two most widely used databases for Chinese public companies. To construct SC resilience, resource redundancy in capacity, inventory and cash cycle is measured as the proxy of the focal-level resilience (Azadegan, Modi and Lucianetti, 2021; Hendricks, Singhal and Zhang, 2009; Essuman et al., 2022), while customer and supplier base concentration serve as the dyads-level resilience proxy (Gu et al., 2022; Chen et al., 2023; Han et al., 2022). The network-level SC resilience was measured through a composite variable calculated by multiple network characteristics (i.e., network density, network size, network connectivity, centrality) (Dixit, Verma and Tiwari, 2020).

One weakness in this study is the limited network size. This study uses the data of the first-tier major suppliers and customers to configure the SC network structure and measure network resilience. However, it is not mandatory for Chinese public companies to disclose the names of their major SC suppliers and customers. This has reduced the sample size due to the exclusion of firms that did not report the names of their major SC partners ((Yang et al., 2022). Furthermore, due to data availability, it is difficult to uncover indirect linkages in SC networks, such as shared suppliers and customers and extended SC networks. To address this limitation, the study focused on the first-tier suppliers and customers while also considering indirect linkages in the extended SC if major suppliers and customers are public firms, with the aim of including second-tier SC partners in the analysis.

The weakness in this empirical study is the evolution of the research development process. Initially, the resilience measurement is focused on the firm level, which is hard to distinguish from organisational resilience (Novak, Wu and Dooley, 2021). Later, SNT was introduced to develop the measurement of SC resilience and the theoretical framework. Although I have attempted to make the research coherent and justify the underlying logic, it would have been more consistent if the SNT had been used throughout the entire PhD work to develop the theoretical framework.

8.4 Contribution of the study

8.4.1 Theoretical contribution

The theoretical contribution of this study can be summarised as follows:

- The literature review constructively reveals the co-occurrence of resilience and sustainability in SCM literature, which echoes the findings of Negri et al. (2021) and Negri, Cagno and Colicchia (2022). With a systematic literature review, this study has presented the common patterns of the interplay of SC resilience and SSCM in three clusters of SC resilience and SSCM relationships (i.e., separate objectives or one as the component of the other). This is a departure from Negri et al. (2021), where SSCM and SC resilience were treated as distinct objectives. The review confirms the growing relevance of SC resilience and SSCM in risk management (Gouda and Saranga, 2018; Hofmann et al., 2014; Giannakis and Papadopoulos, 2016) and the pursuit of long-term continuity, which echoes the previous conclusion (Negri et al., 2021).

- This study proposes a theoretical framework to untangle the linkages between SC resilience and sustainability with the theoretical lens of CAS and SNT. This study also contributes to the development of CASs and SNT in SCM studies. It is the first study to advocate the suitability and complementarity of CAS and SNT in the intersection of SC resilience and SSCM, where SCs can be defined as network-structured adaptive systems towards dynamic environments. Unlike previous scientific discussions (Negri et al., 2022, 2021), this study also highlights the dynamism and evolution of SC network structure as well as the interaction mechanism of SC resilience and sustainability paradigms. The emphasis on SC structure echoes the promotion of network structure in SSCM (Alinaghian, Qiu and Razmdoost, 2021) and SC resilience studies (Iftikhar, Purvis and Giannoccaro, 2021; Han, Chong and Li, 2020). The theoretical framework integrating the interaction of SC resilience and SSCM can contribute to further empirical studies, as the increasing importance of both concepts in the turbulent ecological and sociological environment (Wieland, 2021; Wieland and Durach, 2021; Wieland et al., 2023).
- This study also contributes to the measurement of SC resilience. Despite significant attention given to SC resilience by researchers and practitioners due to the global SC's increased susceptibility to disruptions, there is still a need for universally accepted conceptualisation and operationalisation for SC resilience (Raza et al., 2021; Han, Chong and Li, 2020). Review studies on SC resilience measurement metrics suggest that there is yet to be an agreement (Han, Chong

and Li, 2020; Negri et al., 2021; Ali, Mahfouz and Arisha, 2017; Iftikhar, Purvis and Giannoccaro, 2021), given that SC resilience is a latent variable with multidimensional attributes. This study developed the SC resilience measurement hierarchy from a multi-level network perspective, which can capture resilience at the scale of SC rather than at the organisation level (Novak, Wu and Dooley, 2021) by incorporating focal-level resource resilience, dyads-level relational resilience, and network-level structural resilience. This approach to measurement can help operationalise SC resilience and provide a measurement method for further empirical studies that enable the analysis of SC resilience with firm-level financial and SC data.

- This study is one of the pioneering empirical investigations highlighting the crucial interplay between SC resilience and SSCM (Negri, Cagno and Colicchia, 2022; Negri et al., 2021), aligning with the call for viable and transformative approaches in social-ecological systems (Ivanov, 2020; Ivanov and Dolgui, 2022; Wieland, 2021; Wieland et al., 2023). The study confirms that the interaction mechanism between resilience and sustainability is complex, contributing empirical evidence to the synergies of SC resilience and SSCM on financial and innovation performance at different scales. The study discovered that SSCM and SC resilience have a beneficial influence on financial and innovative outcomes, with the alignment of SC resilience and SSCM enhancing performance even further. The financial benefit of overall SSCM is higher when SC resilience is high, especially when focal- and dyads-level resilience is higher. Network-level resilience plays a crucial role in enhancing the innovation effects of SSCM practices, where governance-related SSCM practices, including SSCM information disclosure and product quality control, should be promoted for knowledge creation.

8.4.2 Practical contribution

From a managerial perspective, it is crucial to comprehend the factors that influence business continuity and SCs' sustainability by maximising the advantages of SC resilience and sustainability paradigms. This study provides a better understanding of the alignment of these two essential SC paradigms for SCs that are often disrupted by uncertain events or potential sustainability risks, particularly in the auto, food, and heavily polluting SCs in China. SC managers can utilise the findings to equip their firms with the relevant SC resilience capabilities to match SSCM initiatives and targeted performance. Additionally, from the SC network perspective, decision-makers can refine their thinking about SC relationships to strengthen SC resilience in terms of supplier-customer relationships and extended SC relationships.

This study highlights the importance of aligning SC resilience and SSCM to achieve both financial and non-financial benefits, and recommends that companies can do well by doing good and being resilient. Building SC resilience and implementing SSCM may require significant resources, however, the study confirms that the benefits of these practices, in terms of financial rewards and innovativeness, increase as the level of effort increases. The study suggests that SC managers should select the most effective combination of SC resilience and sustainability paradigms to achieve desired performance outcomes. For example, they should focus on strengthening network-level resilience and promoting governance-related SSCM practices for innovation performance. By understanding the synergies between SC resilience and SSCM, SC managers can effectively use their resources to enhance their resilience and sustainability efforts and achieve their performance goals.

This study provides an alternative approach to achieving resilient and sustainable SCM through the lens of CAS and SNT. Specifically, the study emphasises the importance of network thinking in developing SC resilience and advocates the equal prominence of SC resilience and SSCM in the pursuit of financial and innovation performance outcomes. By better understanding the importance of SC resilience and the synergies between SC resilience and SSCM, companies can leverage their internal and SC resources to facilitate SSCM initiatives and SC resilience capabilities. The study confirms that SC resilience and SSCM are interrelated and mutually reinforcing in financial and innovation performance at various levels (i.e., at the aggregate level or dimensional level). By deploying SC resilience and SSCM as a compounder or a booster for each other, SC managers can make more informed decisions regarding the focal, relational and network resources and effectively manage their SSCM practices in their respective industries.

8.5 Research limitation and future research

8.5.1 Research limitation

One limitation of this study is the sample size. This study collected the formal contracting relationships between focal firms, major suppliers, and major customers, and had to remove samples with missing values due to the non-disclosure of suppliers' and customers' information. Therefore, the final sample does not cover all the Chinese public companies in targeted industries (i.e., automobile, food, and heavily polluting industries). The sample size could be improved by using alternative measurements for SC resilience or including more industrial sectors.

Secondly, while the model considers all dimensions of SC resilience and SSCM practices and their overall relationships, the study's performance outcomes focus on both financial and non-financial dimensions. However, other performance outcomes such as risk reduction and sustainability performance might be investigated by employing appropriate measurement proxies.

Thirdly, this study focuses on SC resilience from formal contracting relationships. However, informal relationships as the "soft" side of SC resilience could be considered in variable operationalisation. Therefore, the current study could be extended to informal relationships, such as political connections or CEO networks.

The final limitation is the generalisability of the findings. The tangled relationship between SC resilience and SSCM could be generalised under different industries and country contexts. Comparison studies on this topic across industrial and country contexts need further investigation.

8.4.2 Future research

Through this study, there are a few critical paths to be provided for further research:

- From the perspective of SC resilience measurement, first, this study views SC resilience as network-based capabilities from SNT, which promote the resource, relation and structure dimensions at the node, dyads, and network level of SC systems. Rigorous and exploratory empirical studies are needed to justify the proposed metrics with empirical evidence. Future studies can work further on empirical studies of SC resilience by deploying this measurement approach, which can contribute to the empirical knowledge of SC resilience studies (Han, Chong and Li, 2020).

- This study offers SC resilience measurement hierarchy from SNT. In this study, formal contracting data were used to assess SC resilience due to the availability of secondary data. Therefore, SC resilience measurement in this study is limited to enhancing the understanding of formal contracting relationships across SC networks, which could be extended to informal types. Further studies can evaluate SC resilience from informal relationships under the same measurement hierarchy. In general, future researchers would follow up the SC resilience research to better understand how SC resilience capabilities metrics can be effectively generated and developed.
- To address the methodological limitations of longitudinal data analysis, hybrid research methods could be adopted to strengthen the depth of the research. Case studies have been proven particularly useful in exploring the interactions among SC resilience, SSCM practices, and performance outcomes (Negri, Cagno and Colicchia, 2022). Hence, employing empirical studies that combine case studies with quantitative methods to validate both theoretical concepts and practical models would be an effective approach for future research.
- Although this study used panel data across nine years from 2010 to 2018, future studies may continuously work on examining the interplay between SC resilience and SSCM practices with updated data, considering the ever-changing environment. One suggestion is to investigate the model in different scenarios (e.g., disruption and post-disruption) and evaluate the effectiveness of SC resilience and SSCM for performance under a dynamic context, such as the epidemic outbreaks (e.g., COVID-19).
- While this study has applied SNT and social network analysis to investigate the network structure for data construction, future research could aim to combine CAS and SNT theories in the study of SC resilience. One promising direction is to incorporate dynamic and evolutionary factors in the model setting and variable measurement, such as suppliers (in)stability (Yang et al., 2022), network dynamism, and firm cycle (Yang et al., 2022). This could provide a more

comprehensive understanding of how SC resilience evolves over time and adapts to environmental changes.

- The study promotes SNT and CAS, where multiple stakeholders were involved, including focal firms, suppliers, customers, employees, society, and the environment. The model considers the node-level attributes as the basis. However, it would be an interesting research topic to investigate the intra-firm stakeholders and look into personal characteristics and personal connections as the individual-level enablers of SC resilience and SSCM paradigms (Buyl, Boone and Wade, 2019; Sajko, Boone and Buyl, 2021).
- Another interesting research topic would be to examine the recursive relationships between SC resilience and sustainable SCM with the risk-driven perspective, as proposed in theoretical frameworks for empirical testing. That is, whether or to what extent SC resilience would promote the implementation of SSCM under SC risks, and vice versa. For example, future studies would empirically examine whether the social sustainability benefits obtained from SSCM would improve the connection between firms and society and whether the engagement with external stakeholders would benefit future collaborations and improve SC resilience (Chaudhuri et al., 2021).

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