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**Exploring supply chain resilience enhancers: a multi-level
study through systematic review, case studies, and
quantitative analysis**

Coordinatore:

Ch.mo Prof. Eugenio Anessi Pessina

Supervisor(s):

Prof. Alberto Grando

Prof.ssa Valeria Belvedere

Tesi di Dottorato di:

Marianna Lo Zoppo

N. Matricola: 5113361

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Disclaimer: This thesis was developed with the aid of AI tools to enhance language, clarity and readability of the content.

Introduction

1. Introduction

Supply chain resilience (SCRES) is a complex, multidimensional, and multidisciplinary concept (Priya Datta, Christopher, and Allen, 2007; Ponomarov and Holcomb, 2009) that lies at the intersection of supply chain management and risk management (Paulsson, 2004).

A universally accepted definition of SCRES has not yet been established, and existing definitions frequently incorporate key elements from resilience frameworks in other disciplines, such as physics, ecology and psychology¹. In this study, SCRES is defined as "*the adaptive capability of a supply chain 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 plans to transcend the disturbance and restore the supply chain to a robust state of operations*" (Kamalahmadi and Parast, 2016, p. 121), in an "acceptable" cost and time (Ribeiro and Barbosa-Povoa, 2018).

The concept of SCRES gained prominence in the early 2000s, particularly following the influential work of Christopher and Peck (2004), who outlined the key principles guiding resilience. These include a comprehensive understanding of the supply chain network, implementing reengineering practices, employing a collaborative supplier strategy that emphasizes information sharing, and fostering a culture of supply chain risk management. According to Pettit, Croxton, and Fiksel (2019), two key factors have driven the integration of resilience into supply chain management:

1. The growing volatility of the business environment, primarily due to globalization in procurement and distribution, further intensified by numerous unforeseen crises and the impacts of climate change;
2. The recognition that traditional risk management practices are inadequate for building SCRES.

First of all, the globalization of supply chains in recent decades has led to increased outsourcing and more interconnected and complex supply chain networks, intensifying organizations' dependence on external partners (Christopher, Mena, Khan, and Yurt, 2011). While such interconnections have enhanced efficiency under stable conditions, they have also increased supply chains' vulnerability to risks and disruptions (Kamalahmadi and Parast, 2016). As

¹ The term "resilience" in physics is used to describe the ability of certain materials to withstand impacts without breaking, while in ecology it refers to the speed at which an ecological system returns to its initial state after being disturbed. In psychology, resilience is the capacity of an individual to adapt and recover from stress, adversity, or trauma, maintaining or quickly regaining mental well-being.

Christopher and Peck (2004, p. 1) assert regarding global supply chains, “*no organization is an island and even the most carefully controlled processes are still only as good as the links and nodes that support them*”. Moreover, strategies focused on efficiency, such as just-in-time and Six Sigma, have reduced buffers and operational flexibility, making supply chains more streamlined but also more vulnerable to changes (Revilla and Saenz, 2017). In this regard, comparing efficient and resilient supply chains highlights how different principles characterize these strategies and influence decisions related to network design, sourcing, inventory, and production strategies. While efficient supply chains aim to meet demand at the lowest possible cost, resilient supply chains focus on ensuring that demand is fulfilled even during disruptions (Ivanov and Dolgui, 2019). Consequently, efficient supply chains typically feature globalization and centralization, whereas resilient supply chains are characterized by decentralization, diversification, localization, and fortification. Practices such as standardization, single sourcing, and inventory reduction improve efficiency, but decrease the supply chain's resilience to disruptions. By contrast, approaches such as backup or dual sourcing, postponement, capacity pooling, lead time reserves, and buffer inventory enhance resilience (Ivanov and Dolgui, 2019). As companies implemented lean strategies that prioritize efficiency over resilience, they began to recognize the shortcomings of such approaches in dealing with the increasing uncertainty caused by unexpected crises (Mason-Jones, Naylor, and Towill, 2000).

Second, the complex and dynamic nature of modern global supply chains necessitates continuous monitoring to identify potential vulnerabilities, thereby surpassing the limitations of traditional risk-management approaches such as Enterprise Risk Management (ERM). Although ERM is widely implemented by large corporations, it often operates within a reductionist framework, treating risks as isolated events, and overlooking large-scale, unpredictable disruptions that have become increasingly prevalent (Pettit et al., 2019). These conclusions align with prior research, which indicates that numerous professionals face challenges in identifying effective methodologies to manage the diverse spectrum of potential risks and that conventional business continuity management is often insufficient to address risks that emanate from the extended supply and demand network (Christopher and Peck, 2004). These findings underscore that many threats to business continuity exist beyond the focal company, emphasizing the necessity for a more comprehensive approach to construct a resilient supply chain.

In conclusion, the growing complexity and vulnerability of supply chains, combined with the inability of traditional risk management approaches to detect risks arising from the broader supply and demand network, has drawn increasing attention to the factors that enhance resilience at the supply chain level (Al Naimi, Faisal, Sobh, & Bin Sabir, 2022; Katsaliaki, Galetsi, and Kumar, 2021; Shekarian and Parast, 2021). These factors have been extensively explored in the literature, with various studies examining supply chain capabilities, specific practices, and technologies, that positively influence SCRES. Consequently, a range of terminologies has been employed to describe these factors, including 'resilience strategies' (Alikhani, Torabi, and Altay, 2021), 'SCRES antecedents' (Nikookar and Yanadori, 2021), 'SCRES elements' or 'formative elements'

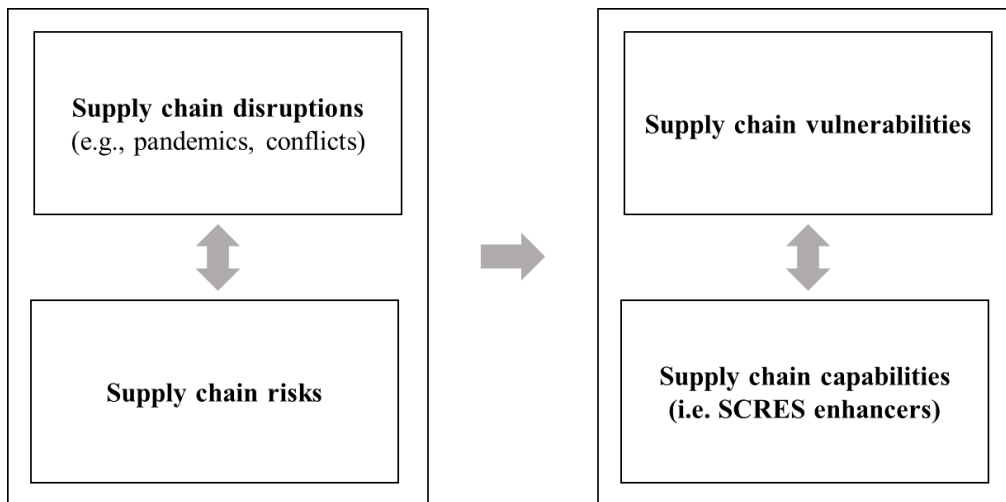
(Hohenstein, Feisel, Hartmann, Giunipero, 2015; Sawyerr and Harrison, 2020), 'SCRES enablers' (Jain, Kumar, Soni, and Chandra, 2017), and 'SCRES enhancers' (Shekarian and Parast, 2021). For this study, the expression 'SCRES enhancers' is utilized, encompassing capabilities, practices, and technologies that have been found in the literature to positively affect SCRES (i.e., to be formative elements of SCRES).

Four key concepts that impact SCRES emerge in the literature: disruptions, risks, vulnerabilities, and capabilities, which can be configured through a broader cluster of elements referred to as SCRES enhancers. Section 1.1 will provide a detailed illustration of each concept through an analysis of foundational literature.

1.1 Background literature

Supply chain disruptions, risks, vulnerabilities, and capabilities (i.e., SCRES enhancers) are interrelated concepts that constitute the elements of SCRES. Supply chain disruptions and risks represent external factors, whereas vulnerabilities and capabilities are internal factors shaped by the supply chain's design and operational configuration. A framework illustrating these connections is presented in Figure 1, based on the work of Kochan and Nowicki (2018). Each component of the framework is examined in detail in the following subsections.

Figure 1. Internal and external factors impacting supply chain resilience



Source: Author's elaboration, adapted from Kochan and Nowicki (2018)

1.1.1 Supply chain disruptions

Disruption is a term used to denote unforeseen and unintentional events that pose significant risks to the supply chain (Hohenstein et al., 2015). Numerous studies have sought to classify supply chain disruptions and explore this concept from various perspectives. For instance, Ivanov et al. (2019) categorized disruptions based on the affected stage, distinguishing between those that impact production, procurement, or transportation. Another approach classifies disruptions according to their frequency, differentiating between smaller, more regular interruptions (related to procurement, processes, or demand volatility) and rarer, more significant crises (Tang and Tomlin, 2008). Disruptions can also vary in scope: they may have an individual impact, affecting only a specific node within the supply chain; a local impact, targeting companies in a particular geographic area; or a global impact, simultaneously affecting multiple nodes of one or more supply chains. Natural disasters and unexpected events such as pandemics, wars, and economic crises have a relatively low probability of occurrence, but when they do happen, they often disrupt all three levels -individual, local, and global- simultaneously.

Several significant disruptions over the past few decades have impacted global supply chains. The September 11 attacks represented one of the first catastrophic event that highlighted the necessity of identifying supply chain risks and vulnerabilities (Kamalahmadi and Parast, 2016). More recently, the Covid-19 pandemic, the Russia-Ukraine conflict, and the Red Sea crisis have further intensified research and focus on SCRES (Remko, 2020), as market volatility and supply chains' susceptibility to disruptions have become undeniable realities. The Covid-19 pandemic, in particular, has been characterized by Araz, Choi, Olson, and Salman (2020) as an unprecedented and severe disruption to global supply chains, with profound effects on both upstream and downstream operations. Labor shortages, production delays, and heightened consumer demand during the pandemic have led to significant imbalances between supply and demand. This volatility, compounded by logistical impediments and shipment delays, severely disrupted the global flow of essential and non-essential goods (Nikolopoulos, Punia, Schäfers, Tsinopoulos, & Vasilakis, 2021). The ongoing conflict in Ukraine has further exacerbated supply chain disruptions, increasing the costs of key imports, particularly in the agriculture and energy sectors, and compelling companies to either absorb these additional expenses or transfer them to consumers (Jagtap et al., 2022). The Red Sea crisis created another significant disruption, particularly in global shipping and logistics. Numerous major container carriers have suspended operations in the region, with a 2023 Goldman Sachs report estimating that the crisis has affected approximately 30% of global container trade, with 70-80% of vessels having been rerouted (Notteboom, Haralambides, and Cullinane, 2024).

1.1.2 Supply chain risks

Any disruption engenders multiple consequences that can be linked to specific risks encountered by individual organizations or the entire supply chain (Chopra and Sodhi, 2004). Although there

is a lack of consensus regarding the classification and definition of risks (Harland, Brenchley, Walker, 2003), these discrepancies tend to be marginal rather than substantive (Ritchie and Brindley, 2004). According to Christopher and Peck (2004) and Manuj and Mentzer (2008), risks in global supply chains primarily comprise four categories: supply, demand, operational/process, and security/control risks. Supply risk encompasses the challenges associated with suboptimal supplier performance, including unfulfilled orders, quality deficiencies, and deviations from agreed-upon delivery schedules. Demand risk arises from factors such as demand fluctuations, inaccurate or distorted information from end customers regarding orders or quantities, market shifts, and increased market competition from highly innovative competitors. Operational risk originates from internal events that impact an organization's ability to produce goods and services, thus affecting production quality and profitability. Security risk results from events that jeopardize human resources, operational integrity, and information systems, potentially leading to data or intellectual property theft, vandalism, criminal activities, and sabotage.

1.1.3 Supply chain vulnerabilities

As risk levels escalate, supply chains become increasingly vulnerable to potential disruptions and unexpected crises, which can negatively affect their operational effectiveness and efficiency (Kochan and Nowicki, 2018). According to Wagner and Bode (2009), the characteristics of a supply chain, including its structure and upstream/downstream operations, are precursors to its vulnerability and influence both the probability of disruptions and the magnitude of their consequences (Wagner and Neshat, 2010). Crises such as that caused by Covid-19 function as assessments of SCRES, albeit not without consequences. A widespread vulnerability elucidated by the pandemic is the dependence of numerous companies on single suppliers or specific markets. As global lockdowns disrupted transportation networks, organizations reliant on sole sourcing experienced delays in receiving critical raw materials and sudden production cessations, with severe consequences on reputation and business performance. In particular, this circumstance underscores the significance of diversifying supply sources when companies are not integrated upstream, as well as the necessity to integrate logistics (at least partially) when it plays a crucial role in the business model. However, dependence on a single supplier represents just one of the many potential supply chain vulnerabilities, which can arise from a variety of factors (Kim, Chen, and Linderman, 2015; Kamalahmadi and Parast, 2016; Ivanov and Dolgui, 2019).

1.1.4 Supply chain capabilities (i.e., SCRES enhancers)

To enhance resilience, organizations must proactively address these vulnerabilities and develop capabilities that minimize the likelihood of disruptions while improving their ability to respond effectively when disruptions occur. Numerous studies have sought to review the key principles of SCRES (Christopher and Peck, 2004; Hohenstein et al., 2015; Ali, Mahfouz, and Arisha, 2017; Al Naimi et al., 2022). These studies typically compile a range of SCRES enhancers, encompassing both capabilities (such as flexibility, agility, or visibility) and specific practices that organizations

can implement to develop these capabilities. As research has progressed, scholars have increasingly focused on the specific enhancers that contribute to SCRES. For instance, Iftikhar, Ali, Arslan, and Tarba (2022) emphasized the significance of digital technologies in strengthening resilience, linking them to SCRES capabilities such as flexibility and visibility. Similarly, Fowler, Epiphaniou, Higgins, and Maple (2023) explored how advanced smart manufacturing technologies can enhance resilience by optimizing processes, improving decision-making, and facilitating real-time monitoring. Other recent studies have highlighted collaboration as a critical strategy for enhancing resilience. Duong and Chong (2020) investigated how collaborative mechanisms support supply chains in responding to and recovering from disruptions. Additionally, some scholars have integrated sustainability considerations into resilience discourse (e.g., Cherrafi, Chiarini, Belhadi, El Baz, and Chaouni Benabdellah, 2022). Finally, the impact of global disruptions, particularly the Covid-19 pandemic, has prompted a reevaluation of supply chain design principles. A seminal study by Ivanov and Dolgui (2019) introduced the concept of low-certainty-need supply chains, advocating designs that prioritize flexibility and structural variety to enhance SCRES.

1.2 Research objective, methodologies and dissertation structure

The aim of this thesis is to investigate the formative elements of SCRES with a specific focus on examining how supply chain management decisions shape these elements and explore the relationship between resilience and sustainability in depth. Additionally, it seeks to analyze the interplay among disruptions, risks, vulnerabilities, and SCRES enhancers by adopting a contingent perspective on SCRES. To achieve these objectives, this thesis is structured into three distinct yet interconnected research papers (RPs). The subsequent section addresses the specific research gaps identified, outlining how each RP contributes to filling these gaps and detailing the methodologies employed.

Table 1 provides an overview of the papers in this research project, illustrating the aim, methodology, and data sources of each paper.

Table 1. Research papers’ aim, methodology, and data source

Research Paper	Aim	Methodology	Data source
RP1	This study seeks to systematize the elements that enhance SCRES, focusing on the capabilities, practices, and technologies recognized in the literature	A systematic literature review (SLR) is conducted by analyzing articles published in major academic and practitioner journals from 2013 to 2023.	The databases used to collect scientific studies are ISI Web of Science and Scopus. Only peer-reviewed journal articles published in English within the last 10 years and

	as having a positive impact on SCRES. Furthermore, it aims to explore the role of supply chain management decisions in developing a resilient supply chain.		relevant to the field of study are selected for analysis.
RP2	Using a contingency perspective on SCRES, this research aims to investigate which SCRES enhancers were most effective in mitigating supply and demand risks during the Covid-19 pandemic and the Russia-Ukraine conflict. Drawing lessons from these crises, it also examines how organizations are redesigning their supply chain and operations to improve resilience.	The study adopts a case-based descriptive research approach, relying on multiple case studies. The purposive sample utilized in this study comprises six distinct supply chains within the agri-food industry, encompassing durum wheat, dairy, fruit and vegetables, meat and cold cuts, and wine.	Data is gathered through both semi-structured interviews and secondary data sources. The semi-structured interviews are conducted with key respondents, including CEOs, CFOs, procurement directors, and supply chain and operations managers.
RP3	This study investigates the relationship between SCRES and sustainability. More in detail, it analyses the impact of SCRES on firms' sustainability and financial performance, evaluating the mediating role of investments in sustainability.	A structural equation modeling (SEM) approach using partial least squares (PLS) is adopted to test the model.	The study is based on secondary data collected through a survey conducted as part of the Growing Resilient, Inclusive and Sustainable (GRINS) project. The final database, comprising responses from 713 companies, includes small, medium, and large firms operating across various sectors.

RP1 - A systematic literature review on supply chain resilience enhancers as strategic, tactical and operational decisions

The extant literature on SCRES enhancers reflects a comprehensive and evolving discourse, progressing from foundational definitions and principles to a more in-depth examination of SCRES enhancers. However, in light of the advancements made by these studies, there is an increasing necessity to better conceptualize and operationalize resilience. To date, numerous

studies have tended to treat resilience as a unidimensional construct, often presenting a list of elements that enhance SCRES, without a distinction between capabilities that depend on supply chain design or operational and tactical decisions, and elements that extend beyond traditional supply chain management. Consequently, further research is required to categorize the factors that enhance SCRES from a more unified perspective while treating SCRES as a multidimensional construct (Parast, 2022).

Building on this research gap, the first research paper (RP1) in this thesis aims to develop an updated and comprehensive framework that encompasses all the elements associated with SCRES and examines their origins within (or outside) strategic, tactical, and operational decisions in supply chain management. Specifically, this study investigated two research questions:

- RQ1: *What elements have been associated with supply chain resilience in previous studies?*
- RQ2: *Which of these elements originate from strategic, tactical, and operational decisions?*

To address these research questions, articles published in major academic and practitioner journals from 2013 to 2023 were reviewed using a systematic literature review (SLR) process (Denyer and Tranfield, 2009). The databases utilized for collecting scientific studies were ISI Web of Science and Scopus. After applying a set of inclusion and exclusion criteria, a comprehensive analysis of the final sample of 60 studies led to the identification of 163 SCRES enhancers. Homogenization and integration processes were subsequently conducted to eliminate redundancies and repetitions and construct three clusters of SCRES enhancers, in alignment with the objective of this study, which was to integrate the literature to generate novel insights into the subject matter that could not be discerned from examining each article in isolation (Denyer and Tranfield, 2009).

RP2 - Navigating uncertainties: a multi-case study examination of supply chain resilience enhancers in agri-food supply chains facing supply and demand risks

Excessive investment in resilience can lead to financial constraints, necessitating organizations to allocate resources in accordance with their specific priorities (Pettit, Croxton, and Fiksel 2013). Furthermore, while the extant literature has extensively examined and categorized SCRES enhancers, a significant gap persists in understanding which SCRES enhancers are most effective in mitigating specific supply chain risks precipitated by disruptive events (Shekarian and Parast, 2021). RP2 aims to address this gap by adopting the contingency perspective of SCRES, which posits that there is no universal set of SCRES enhancers; rather, these elements must be evaluated in relation to specific organizational and contextual factors (Parast, 2022). Within this framework, this research investigates which SCRES enhancers were most effective in mitigating the impacts of the Covid-19 pandemic and the Russia-Ukraine conflict. Additionally, this study examines the reconfiguration of supply chains and operations in direct response to the vulnerabilities exposed

by these crises, with the objective of enhancing resilience. Specifically, this study addressed the following research questions:

- RQ1: *Which SCRES enhancers have proven crucial in mitigating supply and demand risks during recent disruptions?*
- RQ2: *How are organizations redesigning their supply chain structures and operations to enhance SCRES?*

A qualitative, case-based research approach was employed to address both research questions by examining various agri-food supply chains, including durum wheat, dairy, fruit and vegetables, meat and cold cuts, and wine. The focal companies within these supply chains represent the primary units of analysis. Case selection followed a theoretical sampling method (Eisenhardt and Graebner, 2007), deliberately choosing companies to ensure a wide range of viewpoints and significant variations across crucial aspects. These aspects include company size, initial operational and supply chain structures, and the extent of the disruption impact experienced.

RP3 - The impact of supply chain resilience on sustainability and financial performance: the mediating role of investments in sustainability

In contemporary academic and practitioner discourse, a key element associated with SCRES is sustainability. Indeed, sustainability has become a central theme of discussion, driving changes in both business practices and the social fabric. Numerous scholars have endeavored to elucidate the relationship between SCRES and sustainability, and have yielded diverse conclusions regarding the nature of this association. Certain scholars posit that sustainability practices contribute to enhanced SCRES, while others propose that resilience constitutes a component of sustainability, which is considered the ultimate objective, or contend that integrating these concepts is unfeasible, asserting that no hierarchical relationship exists between the two (Marchese, Reynolds, Bates, Morgan, Clark, and Linkov, 2018). This study addresses the following overarching research question:

- RQ: *What is the impact of SCRES on sustainability?*

Specifically, RP3 develops and empirically tests a model that conceptualizes SCRES as a component of sustainability, with investments in sustainability (e.g., investments in renewable energy, electric vehicles or employee well-being) mediating the relationship between SCRES and sustainability and financial performance. The research was based on secondary data obtained from a survey of 713 Italian firms, conducted as part of the Growing Resilient, Inclusive and Sustainable (GRINS) project. The model was tested using a structural equation modeling (SEM) approach with partial least squares (PLS).

1.3 Summary of findings and contributions

This thesis contributes to the current academic discourse on SCRES by examining its formative elements, their roles in mitigating supply and demand risks, and the relationship between SCRES and sustainability. Table 2 provides a summary of the major findings and contributions for each RP, with further detailed analyses in the following sections.

Table 2. Research papers' findings and contribution

Research Paper	Findings	Contribution
RP1	The study identifies three clusters of SCRES enhancers: SCRES capabilities, factors determined at the organizational level, and contingency factors. While supply chain management decisions, particularly the strategic and tactical ones, are crucial for developing SCRES capabilities, they do not influence the other two clusters.	This study assesses the current state of knowledge on SCRES enhancers and develops a comprehensive framework. It explores the pivotal role of strategic, tactical, and operational decisions in fostering resilience.
RP2	The findings identify a core set of SCRES enhancers that are critical for addressing supply and demand risks. However, not all enhancers are effective across different types of businesses. The study also highlights new SCRES enhancers developed in response to vulnerabilities exposed during recent disruptions.	This paper contributes to the existing SCRES literature by deepening understanding of the strategies that effectively mitigate supply and demand risks, particularly within the agri-food sector.
RP3	The study reveals that SCRES exerts a direct and positive influence on firms' sustainability and financial performance. Moreover, the developed model highlights the mediating role of investments in sustainability in the relationship between resilience and sustainability.	This study contributes to theory by empirically testing the relationship between SCRES and sustainability using structural equation modeling (SEM) and by separately evaluating economic sustainability from environmental and social sustainability.

The three RPs provide a comprehensive view of SCRES, revealing that resilience is not a fixed trait that merely exists or does not. Instead, resilience must be intentionally designed in a supply chain, just as a culture of resilience must be cultivated within organizations. In particular, RP1 demonstrates that strategic, tactical, and operational decisions play a crucial role in building capabilities associated with SCRES. Furthermore, certain elements not determined by supply chain management decisions, such as organizational culture, human resource management, market position and financial strength, also positively affect SCRES. However, there is no universal set of SCRES enhancers applicable across all companies and industries; rather, each company must

prioritize investments in different SCRES enhancers based on its specific business characteristics. RP2 also highlights how unexpected crises often drive transformations in supply chain design and operations. Recent disruptions, such as the Covid-19 pandemic and the Russia-Ukraine conflict, have acted as catalysts for many companies to revisit and improve their processes, particularly through the adoption of digital technologies. Lastly, RP3 demonstrates that resilience and sustainability are not conflicting concepts and that SCRES positively impacts economic, environmental, and social sustainability.

The following subsections elaborate on these three contributions.

1.3.1 Clustering SCRES enhancers

RP1 identifies three clusters of SCRES enhancers:

- SCRES capabilities
- Factors determined at the organizational level
- Contingency factors

The first cluster includes nine capabilities that should guide supply chain design or reengineering and stem from SCM decisions. These are collaboration, flexibility, visibility, agility, redundancy, efficiency, robustness, sustainability, and ambidexterity. The second cluster consists of factors determined at the organizational level that impact SCRES, but are not rooted in SCM decisions. Instead, these elements relate to intangible aspects such as trust, leadership, organizational culture, social capital, knowledge, and human resource management. This corresponds with the findings of Seville et al. (2006), who observed that resilience issues often relate more to the intangible, softer dimensions of an organization, such as its culture, vision, leadership, and soft managerial practices, such as effective communication. Notably, as supply chains have evolved into complex, interconnected systems, effective communication and information sharing, which are the core principles of collaboration, emerged as the foundation of SCRES, proving crucial in mitigating uncertainty (Gölgeci, Gligor, Bayraktar and Delen, 2023). The third cluster encompasses a set of elements, termed contingency factors. A company's market position, industry sector, age, size, and financial strength are key indicators of stability when facing disruptions, thus influencing SCRES. These elements, combined with those identified in the second cluster, collectively enhance a firm's ability to withstand and adapt to disruptions, creating a resilient foundation that extends beyond supply chain design and operations.

Additionally, RP1 emphasizes the critical importance of SCM decisions in establishing resilient supply chains. Specifically, SCRES capabilities are predominantly derived from long-term strategic decisions that configure networks for procurement, manufacturing, assembly, and logistics. These decisions substantially influence capabilities such as flexibility, redundancy, robustness, and collaboration. Tactical decisions, including technology implementation,

equipment maintenance, assembly policies, and inventory and production management also play a significant role in enhancing SCRES. Conversely, while operational decisions focusing on daily activities are essential for maintaining efficient operations, they have a moderate impact when addressing unexpected crises.

1.3.2 A set of SCRES enhancers to address supply and demand risks

RP2 identifies a common set of SCRES enhancers that are crucial for addressing supply and demand risks in the agri-food industry. To address supply risk, upstream integration, strategic supplier management, diversification of supply sources and markets, flexible supplier contracts, integrated inbound logistics, and energy efficiency have become essential. In contrast, to mitigate demand risk, the most impactful SCRES enhancers were the diversification of distribution channels and markets, flexible customer contracts, buffer inventory, and capillary distribution. Additionally, a set of SCRES enhancers was identified as cross-functional, which is crucial for addressing both supply and demand risks, including process automation, digitalization, collaboration, human resource management, contingency and recovery planning, financial solidity, brand positioning, and organizational longevity. These results support the findings of Shekarian and Parast (2021), who argued that flexibility, collaboration, agility, and redundancy are vital for mitigating supply and demand risks. However, consistent with the contingent perspective on SCRES, RP2 demonstrates that no universal set of SCRES enhancers applies across all companies and industries. Instead, each company must prioritize investments in different SCRES enhancers based on its specific business characteristics. Within the agri-food industry, significant differentiators among businesses include product shelf life, focus on commodities versus specialty products, and the nature of sourcing markets. For example, maintaining buffer inventory, a common strategy for redundancy, may introduce financial risks for companies operating in volatile commodity markets or prove impractical for perishable products with a limited shelf life.

Additionally, RP2 supports Weick and Sutcliffe's (2011, p. 1) observation that "*unexpected events often audit resilience*". Notably, many forward-thinking companies use adversity as an opportunity to rethink their operations and emerge stronger, rather than merely bouncing back to their previous state. Recent disruptions have accelerated the need for global supply chains to adapt to changing environments, speeding up innovation adoption and driving the shift toward more sustainable production systems. Four prominent trends emerged among the companies in our sample in response to recent disruptions and vulnerabilities: (i) prioritizing flexibility by adopting supply chain strategies that keep multiple options open and promote diversification of supply sources, markets, and distribution channels; (ii) adopting advanced planning and forecasting tools to enhance visibility and traceability; (iii) improving information-sharing mechanisms; and (iv) investing in human resource management and recruiting new professional figures. Furthermore, several of these companies are focusing on product innovation to reduce their dependence on critical materials and are also investing in energy efficiency improvements. Nearly all the

companies in the sample made significant efforts to transform their organizational cultures, with an emphasis on enhancing interdepartmental communication. Investments in automation are also increasing, reducing reliance on human labor, especially during health-related disruptions such as pandemics. Finally, companies are embracing uncertainty and volatility by designing and managing operations that are better equipped to handle unexpected crises.

1.3.3 The direct and positive influence of SCRES on sustainability

RP3 demonstrates that resilience directly and positively influences sustainability. Specifically, this study reveals that SCRES exerts a stronger impact on environmental and social sustainability than on economic sustainability, which is measured using financial performance metrics. Furthermore, the model underscores the mediating role of investments in sustainability in the relationship between resilience and sustainability. These results align with those of previous studies, suggesting that the link between resilience and sustainability lies in the ability to anticipate and recover from disruptions, which are fundamental aspects of resilience. Although building SCRES often requires substantial investment, its implementation enables supply chains to thrive amid political, social, and market changes, thereby enhancing sustainability and continuity (Jüttner and Maklan, 2011). In terms of managing disruptions, as discussed in RP1, resilient supply chains are better equipped to handle unexpected crises because of their enhanced capabilities and a culture that prioritizes communication and information sharing. For instance, SCRES capabilities such as flexibility and collaboration are crucial for a firm's social sustainability initiatives, thus supporting overall sustainability (Shen and Sun, 2023). Additionally, companies that adopt a comprehensive view of resilience and incorporate a socio-ecological perspective are better positioned to achieve long-term economic, environmental, and social sustainability (Negri, Cagno, Colicchia, and Sarkis, 2021).

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RP1: A systematic literature review on supply chain resilience enhancers as strategic, tactical and operational decisions

Abstract

Introduction - This study systematizes the elements that enhance supply chain resilience (SCRES), focusing on the capabilities, practices, and technologies recognized in the literature as having a positive impact on SCRES. Furthermore, it explores the role of Supply Chain Management (SCM) decisions in developing a resilient supply chain.

Methods - A systematic literature review (SLR) is conducted by analyzing articles published in major academic and practitioner journals from 2013 to 2023.

Findings - The study findings indicate three clusters of SCRES enhancers: SCRES capabilities, factors determined at the organizational level, and contingency factors. While SCM decisions play a crucial role in developing SCRES capabilities, they do not influence the other two clusters of elements. Strategic decisions that shape the supply chain's design and tactical decisions are essential for enhancing SCRES.

Originality/Value - This study critically assesses the current state of knowledge regarding the formative elements of SCRES, specifically SCRES enhancers, and develops a comprehensive framework. In addition, it explores the pivotal role of strategic, tactical, and operational decisions in fostering these enhancers, offering insights into the interplay between managerial practices and resilience-building strategies.

1. Introduction

The role of global supply chains has expanded significantly, leading to increased interconnectedness among supply chain actors, resulting in higher dependency among nodes and a higher level of supply chain complexity (Christopher, Mena, Khan and Yurt, 2011). This has resulted in supply chains that are efficient during stable times and in a steady business environment but are highly unstable and vulnerable to risks and disruptions (Kamalahmadi and Parast, 2016). The Covid-19 and recent geopolitical tensions represent a clear example of disruptions that highlight these vulnerabilities. More specifically, the outbreak of the Covid-19 pandemic in late 2019 led to widespread lockdowns and forced factories to close abruptly, resulting in labor shortages and production delays across industries. Moreover, the pandemic's uneven impact on consumer demand disrupted the balance between supply and demand, with some industries experiencing a sharp decline while others witnessed an unprecedented surge in demand. This unpredictability posed significant challenges for sourcing, forecasting, and inventory management. Additionally, travel restrictions and port closures have led to delays in shipping and transportation, affecting the movement of goods on a global scale (Magableh, 2021; Xu, Z., Elomri, A., Kerbache, L., & El Omri, A., 2020). Concurrently, trade tensions and wars resulted in the imposition of tariffs and trade restrictions, further complicating the global supply chain landscape.

In this scenario, some supply chains exhibited more vulnerabilities than others. For example, companies relying on a single supplier in regions affected by recent tensions have experienced shortages of materials and components. Firms with low visibility of nodes in their supply chains or with minimal inventory face greater risks compared to those that had already developed mechanisms to enhance visibility or maintained buffer inventories (Fonseca, L. M., & Azevedo, A. L., 2020). These examples illustrate supply chain vulnerabilities, which are generally described as a supply chain's susceptibility to disruptions that could negatively impact its ability to operate effectively and efficiently (Wagner & Bode, 2006). According to these authors, supply chain characteristics act as antecedents of vulnerability, influencing both the likelihood and severity of disruptions. To enhance supply chain resilience (SCRES), organizations proactively address these vulnerabilities by implementing strategies and practices that mitigate their impact and improve their recovery from disruptions.

A significant body of literature has emerged in recent years focusing on supply chain capabilities and strategies aimed at reducing vulnerabilities and enhancing SCRES (Al Naimi, Faisal, Sobh and Bin Sabir, 2022). However, the absence of consensus regarding the theorization and operationalization of SCRES has led to the emergence of a wide range of resilience capabilities, ranging from flexibility, redundancy, and visibility to behavioral elements such as trust, cooperation, and learning. While this diverse array of SCRES-related capabilities provides advancements from a theoretical standpoint, it also creates confusion from practical and managerial viewpoints (Juttner & Maklan, 2011; Parast, 2022). Consequently, there is a growing need to further categorize and clarify the elements that enhance SCRES from a more unified perspective (Parast, 2022). Moreover, to the best of our knowledge, much of the existing research

on SCRES tends to treat resilience as a unidimensional construct, often presenting a list of elements that enhance SCRES without accounting for their emergence from decisions made at various levels, ranging from strategic to operational and tactical. In light of this, Parast (2022) emphasizes the importance of recognizing SCRES as a multidimensional construct and highlights the need for further research in this direction. This study addresses this gap by providing an updated and comprehensive framework that encompasses the elements associated with SCRES, and examines their origins in strategic, tactical, and operational decisions within Supply Chain Management (SCM). Specifically, we aim to understand how these decision levels contribute to the development of key capabilities for building a resilient supply chain. Accordingly, the research questions (RQs) are the following:

RQ1: *What elements have been associated with supply chain resilience in previous studies?*

RQ2: *Which of these elements originate from strategic, tactical, and operational decisions?*

We address these research questions by reviewing articles published in major academic and practitioner journals from 2013 to 2023 using a systematic literature review (SLR) process (Denyer and Tranfield, 2009).

The remainder of this paper is organized as follows. In Section 2, we review the existing literature on SCRES and its enhancers, and highlight the connection between SCM decisions and SCRES. Section 3 presents the research methodology. Section 4 provides descriptive statistics, while Section 5 presents the content analysis and illustrates the framework that emerges from the study. Section 6 discusses the major findings in detail, and Section 7 outlines the conclusions, the study's limitations, and future research directions.

2. Theoretical background

2.1 Formative elements of SCRES

SCRES is a multidimensional and multidisciplinary phenomenon (Priya Datta, Christopher and Allen, 2007; Ponomarov and Holcomb, 2009). Several definitions exist, borrowing significant characteristics from resilience definitions in other disciplines such as ecology and psychology. After being discussed by researchers either as part of supply chain vulnerability studies (Svensson, 2000) or as a component of supply chain risk management (Juttner, Peck and Christopher 2003), SCRES has gained prominence in studies aiming to define it and deepen the understanding of its formative elements, which are considered essential for supply chain design or reconfiguration (Al Naimi et al., 2022). Table 1 summarizes the definitions of SCRES provided in the academic literature over the past 20 years.

Table 1. Existing definitions of SCRES from the literature

Authors /year	SCRES definition
Rice and Caniato (2003)	“The ability to react to unexpected disruptions and restore normal supply network operations”
Christopher and Peck (2004)	“The ability of a system to return to its original state or move to a new, more desirable state after being disturbed”
Priya Datta et al. (2007)	“Not only the ability to maintain control over performance variability in the face of disturbance, but also a property of being adaptive and capable of sustained response to sudden and significant shifts in the environment in the form of uncertain demands”
Ponomarov and Holcomb (2009)	“The adaptive capability of the supply chain 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”
Barroso, Machado, V. H., and Machado V. C. (2011)	“The supply chain’s ability to react to the negative effects caused by disturbances that occur at a given moment in order to maintain the supply chain’s objectives”
Jüttner and Maklan (2011)	“The apparent ability of some supply chains to recover from inevitable risk events more effectively than others”
Ponis and Koronis (2012)	"The ability to proactively plan and design a supply chain network for anticipating unexpected disruptive (negative) 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"
Carvalho, Barroso, Machado, Azevedo and Cruz-Machado (2012)	“The ability of supply chains to cope with unexpected disturbances”
Melnyk (2014)	“The ability of a supply chain to both resist disruptions and recover operational capability after disruptions occur”
Brandon-Jones, Squire, Autry and Petersen (2014)	“The ability of a supply chain to return to normal operating performance, within an acceptable period of time, after being disturbed”
Roberta Pereira, Christopher and Lago Da Silva (2014)	“The capability of supply chains to respond quickly to unexpected events so as to restore operations to the previous performance level or even to a new and better one”
Kim, Chen and Linderman (2015)	“A network-level attribute to withstand disruptions that may be triggered at the node or arc level.”
Kamalahmadi and Parast (2016)	“The adaptive capability of a supply chain 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 plans to transcend the disturbance and restore the supply chain to a robust state of operations”
Hohenstein, Feisel, Hartmann and Giunipero (2015)	“The supply chain’s ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state in order to increase customer service, market share and financial performance”
Ribeiro and Barbosa-Povoa (2018)	“A resilient supply chain should be able to prepare, respond and recover from disturbances and afterwards maintain a positive steady state operation in an acceptable cost and time.”

Just as there are numerous terms in the literature that describe unexpected crises that threaten the normal operation of a supply chain (e.g., disruption, disturbance, and risk event), there are also many terms and perspectives used to identify the factors that enhance the resilience of a supply chain and reduce its vulnerabilities. For example, the capability perspective has been widely used to understand SCRES (Parast, 2022). Research on SCRES has primarily focused on identifying organizational and supply chain resilience capabilities that are crucial for improving SCRES in the face of severe disruptions (Han, Chong and Li, 2020; Chowdhury and Quaddus, 2017). In recent years, a dynamic capabilities perspective has also gained prominence among scholars studying SCRES (Irfan, Sumbal, Khurshid and Chan, 2022; Kazancoglu I., Ozbiltekin-Pala, Kumar Mangla, Kazancoglu Y. and Jabeen, 2022). According to Bahrami and Shokouhyar (2022), dynamic capabilities such as flexibility and agility represent the strategic capabilities of enterprises, institutions, and organizations concerning innovation and change that go beyond their routine activities. Other terms that have been widely used to describe the factors contributing to the enhancement of SCRES in an organization or supply chain include resilience strategies (Alikhani, Torabi and Altay, 2021), SCRES antecedents (Nikookar and Yanadori, 2021), SCRES elements or formative elements (Hohenstein et al., 2015; Sawyerr and Harrison, 2020), SCRES enablers (Jain, Kumar, Soni and Chandra, 2017), and SCRES enhancers (Shekarian and Parast, 2021). For the purposes of this study, the broad expression "SCRES enhancers" is utilized, encompassing capabilities, practices, and technologies that have been found in the literature to have a positive influence on SCRES (i.e., to be formative elements of SCRES).

To date, several studies have focused on SCRES enhancers. The first studies emerged around the year 2000. Authors such as Christopher and Peck (2004) outlined key principles that guide resilience, such as having a comprehensive understanding of the supply chain network, implementing reengineering practices, employing a collaborative supplier base strategy that emphasizes information sharing, and fostering a culture of supply chain risk management. Later, several SLRs were used to revise SCRES enhancers (Hohenstein et al., 2015; Ali, Mahfouz and Arisha, 2017; Al Naimi et al., 2022). Ali et al. (2017) analyzed 103 peer-reviewed journal articles from 2000 to 2015 and identified five core SCRES capabilities: anticipation, adaptation, response, recovery, and learning. Additionally, they identified 13 essential elements and 84 managerial practices that support organizations in achieving these capabilities. Al Naimi et al. (2022) reviewed

94 articles published between 2009 and 2019 and identified 36 SCRES enhancers with collaboration, flexibility, and visibility being the most frequently cited. Similarly, Hohenstein et al. (2015) conducted a structured review of 67 peer-reviewed studies and found that supply chain flexibility, redundancy, collaboration, and agility were the most commonly referenced SCRES enhancers in the literature.

Moreover, a body of literature has concentrated on particular practices or technologies that enhance SCRES. Digital technology is frequently associated with SCRES. For instance, Fowler, Epiphaniou, Higgins, and Maple (2023) investigated how advanced smart manufacturing technologies, including cloud computing, big data analytics (BDA), the Internet of Things, and Artificial Intelligence (AI), can bolster resilience in manufacturing systems, optimizing processes, improving decision-making, and enabling real-time monitoring and control. Balakrishnan and Ramanathan (2021) demonstrated the positive impact of digital supply chain technology competency on SCRES, particularly during the Covid-19 pandemic. Zamani Smyth, Gupta and Dennehy (2022) found that the application of AI and BDA leads to increased visibility, transparency, and responsiveness, which positively impact SCRES. Likewise, Tortorella, Fogliatto, Gao, and Chan (2022) examined the positive effects of integrating Industry 4.0 technologies into supply chains on SCRES. Finally, there is a set of articles that investigate the impact of specific managerial practices on SCRES. For example, Duong (2020) examined how collaboration mechanisms help supply chains respond and recover from a disruption, while Shivajee, Singh, and Rastogi (2023) explored the role of the procurement function in building SCRES.

2.2 Strategic, tactical and operational decisions in SCM

This study explores the role of SCM decisions in building SCRES. As noted previously, the structural characteristics of a supply chain are key determinants of its vulnerability, influencing both the likelihood and severity of potential disruptions (Wagner & Bode, 2006). From a different perspective, this implies that supply chain design and operational decisions can bolster resilience by fostering capabilities, such as redundancy, visibility, and flexibility, which help mitigate the impact of disruptions.

SCM decisions occur on three levels: strategic, tactical, and operational. The strategic level involves making long-term decisions that determine logistics network design, including the number and locations of facilities, production technologies, and plant capacities (Schmidt and Wilhelm, 2000). These decisions shape the network for sourcing, production, assembly, and distribution in order to serve the marketplace. Examples of strategic decisions include choosing between single or multiple suppliers, sharing technologies, and selecting facility locations. Tactical decisions involve developing specific plans to achieve objectives within the scope of the strategic plan, including setting targets, establishing priorities, and designing strategies to achieve these targets. At the tactical level, material flow management policies are prescribed, including production levels at all plants, assembly policies, inventory levels, and lot sizes. Tactical decisions

also determine whether finished products should be assembled in large lots and held in centralized warehouses or assembled at multiple locations only on demand. Instead, operational decisions involve implementing tactical plans to achieve the company's objectives. This requires coordination with various departments, establishing support systems and procedures, and keeping relevant stakeholders informed of progress. The operational level is a consequence of strategic and tactical decisions, and is responsible for scheduling operations to ensure timely delivery of final products and coordinating the logistics network to be responsive to customer needs. In contrast to strategic and tactical planning, operational planning is concerned with day-to-day tasks that must be carried out to achieve the company's objectives. This includes setting schedules, maintaining inventory levels, coordinating resources, ensuring quality, on-time delivery, and cost effectiveness.

Several studies have highlighted the critical impact of structural supply chain properties on the robustness and resilience of supply chains (Ambulkar, Blackhurst and Grawe, 2015; Kim et al., 2015; Kamalahmadi and Parast, 2016; Ivanov and Dolgui, 2019). For example, Ivanov and Dolgui (2019) compare efficient and resilient supply chains by examining SCM decisions made at strategic, tactical, and operational levels. They highlight how different objectives shape decisions regarding network design, sourcing, inventory, and production strategies. Efficient supply chains focus on meeting demand at the lowest possible cost, whereas resilient supply chains prioritize ensuring demand fulfilment in the face of disruptions. Consequently, globalization and centralization are typical features of efficient supply chains, whereas decentralization, diversification, localization, and fortification are the key characteristics of resilient supply chains (Ivanov and Dolgui, 2019). Decisions such as standardization, single sourcing, inventory reduction, and lean practices enhance efficiency, but reduce the supply chain's ability to withstand disruptions. Conversely, strategies such as backup or dual sourcing, postponement, capacity pooling, lead-time reserves, and buffer inventory strengthen the SCRES. Ivanov (2017) demonstrated some of these findings in a discrete-event simulation study. This study indicates that upstream disruptions are more likely to trigger ripple effects when a single-source policy is in place. Additionally, it demonstrates that maintaining higher inventory levels in the downstream supply chain helps mitigate the propagation of ripple effects on customers.

3. Methodology

3.1 Search strategy

To investigate the research questions, we adopted a SLR. Unlike conventional literature reviews, an SLR strictly adheres to a set of guidelines and employs a replicable, scientific, and transparent process to synthesize results by combining evidence from existing studies, thereby generating novel insights (Tranfield, Denyer, Smart, 2003).

The steps of the implemented SLR are depicted as follows:

1) The databases used for collecting scientific studies are ISI Web of Science, and Scopus.

2) Only *peer-reviewed journal articles* published in English (note, exclusions are: books, book chapters, reviews, practitioner papers, conference proceedings, working papers, reports, and unpublished works) have been considered to enhance quality control (Tranfield et al., 2003).

3) In line with other systematic reviews on SCRES (Al Naimi, 2022; Han et al., 2020; Hohenstein et al., 2015; Jain et al., 2017; Shekarian and Parast, 2021; Ribeiro and Barbosa-Povoa, 2018), several defined keywords were used as the search criteria. The keywords consisted of the phrases “supply chain resilien*” or “supply chain” and “resilien*” combined with the following keywords: “capabilit*”, “enhancer*”, “enabler*”, “component*”. The selected keywords were then used to construct search strings with Boolean connectors (e.g., AND and OR) using a combination of search fields.

4) The substantive relevance of contributions to the SCRES theme has been ensured by requiring that the selected articles contained in their titles, abstracts or keywords the words “supply chain” and “resilien*” combined with at least one of the following keywords: “capabilit*”, “enhancer*”, “enabler*”, “component*”. The timeframe considered for identifying studies spanned from 2013 to 2023, aiming to encompass a selection of studies in this research domain that notably expanded following the occurrence of the Covid-19 pandemic (Al Naimi et al., 2022). The search was first conducted in November 2022 and repeated in January 2023. Overall, 95,733 and 783 results were produced on Web of Science and Scopus, respectively.

5) The resulting articles were filtered within the database, with a deliberate emphasis on selecting categories that closely align with the central research inquiry: Operations Research, Management Science, Business, Management and Accounting. This process facilitated the identification and prioritization of topics pertinent to the research question and as a result of this process, 409 articles were obtained.

6) The resulting articles were scanned and all authors’ abstracts were read to ensure their coherence with the aim of this review. As a result, 339 articles were excluded because they did not focus on the topic investigated, and three articles were excluded because they were not fully available.

7) The remaining papers were fully read to ensure alignment with the research objective. Of the 67 articles, 7 were excluded because they did not provide sought-after information. The final result of 60 SCRES articles was then analyzed in depth and synthesized to address the underlying research questions.

The systematic mapping review process is shown in Figure 1. The inclusion and exclusion criteria are detailed in Table 2 (Thomé, Scavarda, L. F., and Scavarda, A. J., 2016).

Figure 1. The systematic mapping review process

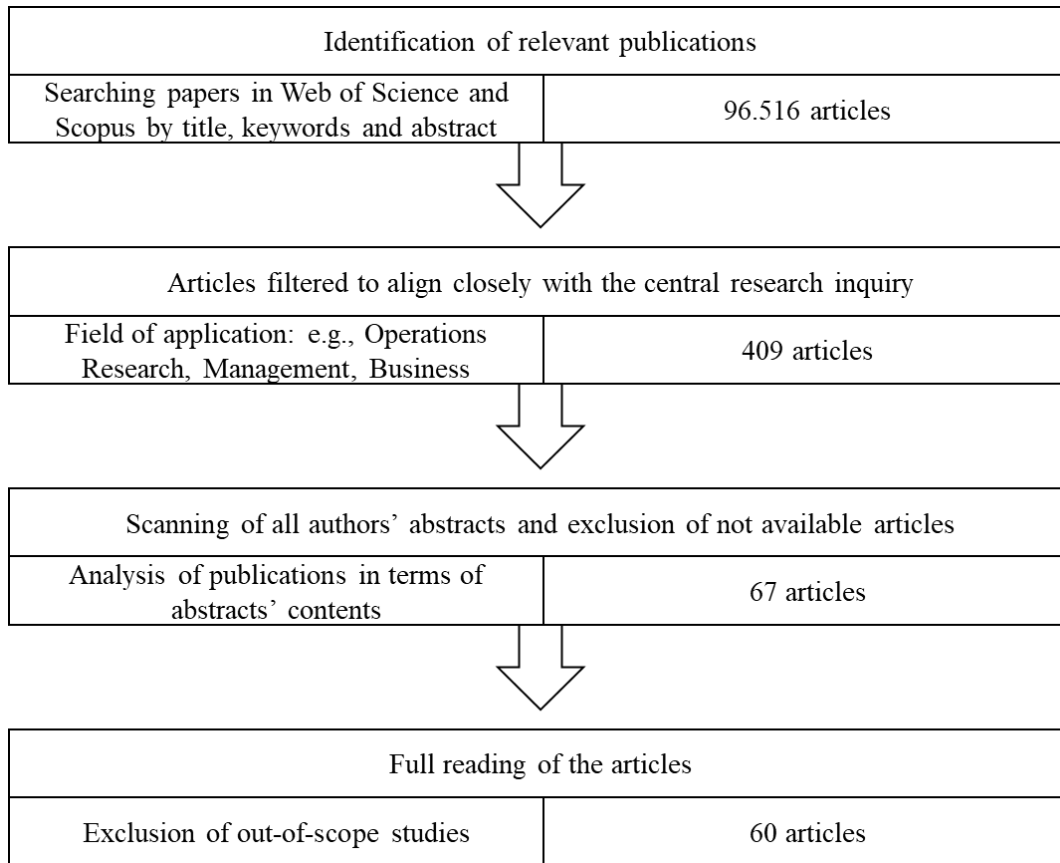


Table 2. Inclusion and Exclusion criteria

Criteria (Inclusion)	Justification
Peer-reviewed journal articles published in English	Ensures the reliability and academic rigor of the sources, and accessibility for reviewers
Published within the last 10 years	Ensures that the review includes the most recent and up-to-date research findings
Field of application (Management and Operations Management)	Filters articles relevant to the field of study
Relevant to the research question or objectives	Ensures that the articles provide meaningful contributions to the topic being studied
Criteria (Exclusion)	Justification
Paper out of the field of application	Excludes studies that do not address the specific area of interest, maintaining relevance
Abstract or article's content not relevant	Filters out articles that do not directly contribute to the research objectives

Non-availability of full-text articles	Ensures that only accessible and fully reviewable articles are included
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3.2 Data Extraction

The selected articles were subjected to systematic scrutiny to extract pertinent information essential for systematic mapping reviews (Table 3). This encompassed details such as author names, publication year, title, journal source, industry analyzed, methodology employed, formative elements of SCRES (i.e., SCRES enhancers), and their corresponding definitions. Subsequently, the extracted data from the identified studies were synthesized and organized into tabular formats to consolidate evidence and address mapping inquiries effectively.

Table 3. Data extraction

Data item	Value
Study ID	Integer ID
Article Title	The article label name
Author Name	Set of authors' names
Year of Publication	Year of Publication
Journal source	Journal where the article is published
Industry analysed	Focus of the article
Research Methods	The method(s) used in the study
SCRES enhancers	The list of SCRES enhancers reported
SCRES definitions	Corresponding definitions in the article analysed

4. Descriptive analysis

The 60 reviewed articles were published in 27 interdisciplinary academic journals. More than one-third of the articles (23) were published in four leading journals in the field of Operations and SCM. The following leading journals published the highest proportion of reviewed studies: International Journal of Production Economics, International Journal of Production Research, Supply Chain Management: An International Journal, and International Journal of Physical Distribution and Logistics Management. Table 4 lists the journals in which the papers included in the SLR were published, in descending order of frequency.

Table 4: Number of articles published in leading journals in the field of Operations and SCM

Academic journal	N° of papers	Percentage
International Journal of Production Economics	7	12%
International Journal of Production Research	6	10%
Supply Chain Management: An International Journal	5	8%

International Journal of Physical Distribution and Logistics Management	5	8%
The International Journal of Logistics Management	4	7%
International Journal of Logistics Research and Applications	3	5%
International Journal of Operations & Production Management	3	5%
Benchmarking: An International Journal	3	5%
Production Planning and Control	3	5%
Annals of Operations Research	2	3%
Engineering, Construction and Architectural Management	2	3%
Journal of Global Operations and Strategic Sourcing	2	3%
Other journals	15	25%

The 60 studies covered a range of industries, with the majority (45 studies) focusing on generic supply chains (i.e., supply chains across various sectors). Eight percent of the studies (five articles) focused on agri-food supply chains, five percent (three articles) examined industrialized construction supply chains, and three percent (two articles) analyzed automotive supply chains. Table 5 provides a detailed breakdown of the industries investigated.

Table 5: Industries analysed in SCRES literature

Industry	N° of papers	Percentage
Generic supply chain	45	75%
Agri-food supply chain	5	8%
Industrialized construction supply chain	3	5%
Automotive supply chain	2	3%
Apparel supply chain	1	2%
Consumer electronics supply chain	1	2%
Cosmetic supply chain	1	2%
Fashion apparel supply chain	1	2%
Healthcare supply chain	1	2%

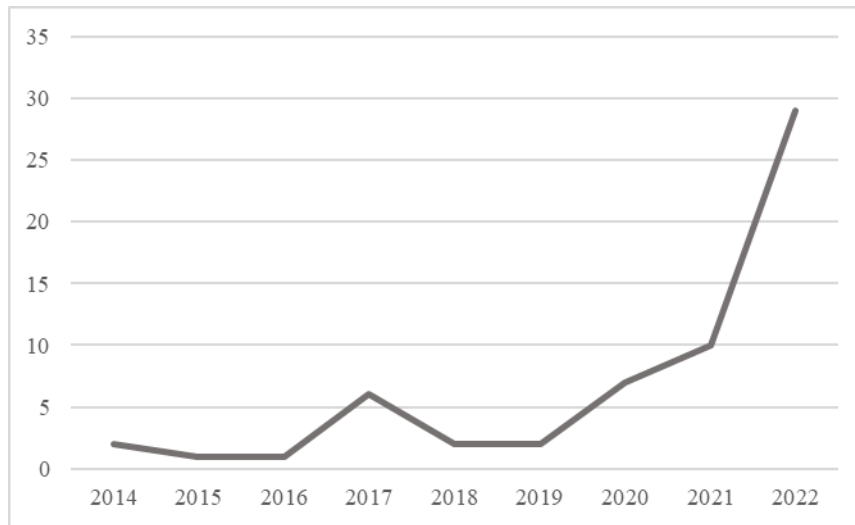
In the literature scrutinized, various research methodologies have been used to investigate SCRES enhancers, in line with the complex and multidimensional nature of SCRES research, which requires a combination of empirical and analytical research methods to both advance theory and assess its implementation (Ali et al., 2017). As illustrated in Table 6, one-third of the papers (twenty articles) were quantitative empirical studies, twenty-seven percent (sixteen articles) were SLRs, twenty-three percent (fourteen articles) were qualitative research primarily based on case studies. The remainder of the papers were based on the following methodologies: literature reviews, conceptual papers, and mixed methods.

Table 6: Classification of SCRES methodologies

Methodology	N° of papers	Percentage
Quantitative	20	33%
Systematic Literature Review	16	27%
Qualitative	14	23%
Literature review	7	12%
Conceptual paper	2	3%
Mixed methods	1	2%

As for the frequency of publications during the 10 years analyzed, Figure 2 highlights a clear increase in the number of publications starting from 2019, following the two major crises that are the focus of this study's analysis.

Figure 2. Frequency of publications over the last 10 years



5. Content Analysis

5.1 The homogenization and integration processes

A comprehensive analysis of the final sample of 60 studies led to the identification of 163 SCRES enhancers. The analysis was conducted using a Microsoft Excel spreadsheet, where each article was summarized and a list of SCRES enhancers was generated for each study. A homogenization process was then carried out to eliminate redundancies and repetitions in line with the objective of

this study, which was to integrate the literature to generate novel insights into the subject matter that could not be discerned from examining each article in isolation (Denyer and Tranfield, 2009). Table 7 illustrates this step of the analysis, providing some examples of the homogenization process.

Table 7: Homogenization process, some examples

SCRES enhancer as mentioned in the paper	SCRES enhancers after the homogenization process	References
Supply flexibility	Flexibility	Agarwal N., Seth, and Agarwal A., (2022)
Collaborative capabilities	Collaboration	
Capability to modify supply chain design	Supply chain reengineering/design	
Backup capacity	Reserve capacity	Al Naimi et al. (2022)
Adaptive capability	Adaptability	Alikhani et al. (2021)
Safety stock	Inventory and stock buffer	
Visibility and transparency	Visibility	Cherrafi, Chiarini, Belhadi, El Baz, and Chaouni Benabdellah (2022)
Digital Technologies	Digitalisation	
IoT, Big data analytics, blockchain, AI, additive manufacturing	Digitalisation	Iftikhar et al. (2022)
Supply chain reengineering	Supply chain reengineering/design	Kamalahmadi et al. (2015)
SCRM culture	Risk management culture	
Buyer-supplier collaboration	Collaboration	Shishodia, Sharma, Rajesh, and Munim (2023)
Technology adoption	Digitalisation	
Process flexibility	Flexibility	Ivanov and Dolgui (2019)
Vertical integration	Integration	Ali et al. (2017)
Responsiveness to customers' needs	Responsiveness	
Responsiveness to competitors' strategies	Responsiveness	
Multi sourcing	Multiple sourcing	
Public private collaboration	Collaboration	

Following this initial screening, 51 elements were consolidated with others already present in the list based on their definitions, resulting in 112 SCRES enhancers. An integration process was then employed to address the heterogeneous nature of the analyzed articles and to synthesize multiple studies and methods to answer the review questions, according to Rousseau et al. (2008). During this phase, based on the definitions provided by the analyzed studies, we consolidated a list of 112 SCRES enhancers into a final set of 80 elements representing capabilities, practices, and technologies that, according to our SLR, enhanced SCRES: 18 elements were integrated with other SCRES enhancers as the terms were synonyms or were characterized by definitions that could be

traced back to another term. In addition, 15 SCRES enhancers were excluded from the analysis because their definitions were either lacking or too vague to be traced back to any of the other SCRES enhancers on the list. Detailed exclusion criteria and the full integration process are presented in Appendix 1.

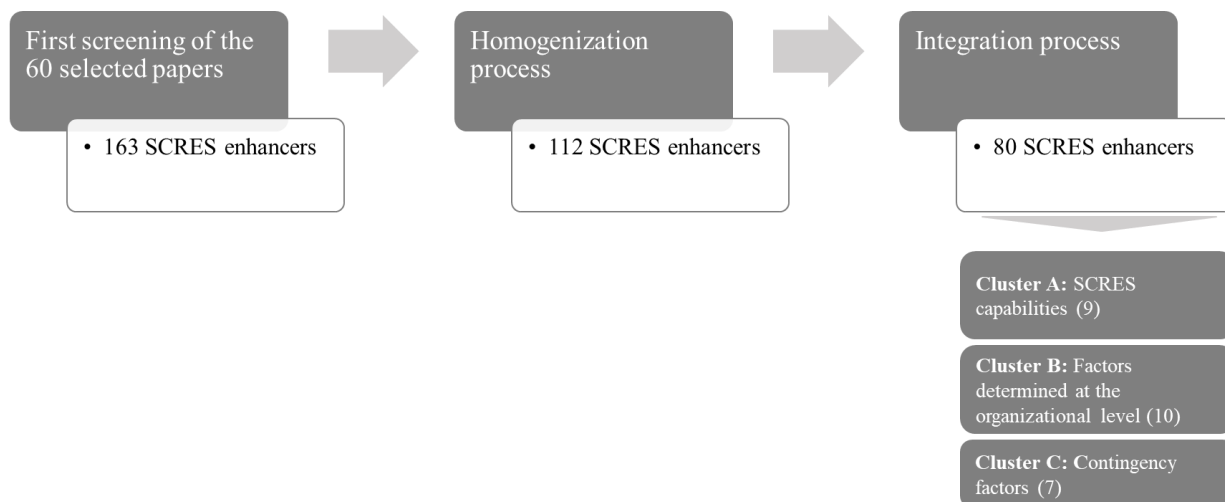
5.2 A framework to classify SCRES enhancers

We finalized the content analysis by classifying the aforementioned list of 80 elements, derived from previous homogenization and integration processes, into a framework that identifies three clusters of SCRES enhancers:

- A. SCRES capabilities
- B. Factors determined at the organizational level
- C. Contingency factors

This phase addresses our first research inquiry, namely, “*What elements have been associated with SCRES in previous studies?*”. The analysis uncovered the multifaceted nature of resilience, primarily rooted in the supply chain’s capabilities such as flexibility, visibility, redundancy, and agility, which are influenced by its design and operations. Additionally, resilience is closely linked to a company’s organizational culture and its ability to manage human resources, while it is also influenced by contingency factors, such as industry type, company longevity, and financial stability. Furthermore, many elements mentioned in previous studies can be traced back to specific SCRES capabilities; in this case, these elements act as practices and technologies that enable the aforementioned capabilities. Figure 3 illustrates the comprehensive analysis process culminating in the final framework.

Figure 3: Content analysis



6. Findings

6.1 Cluster A: SCRES capabilities

The first cluster encompasses nine SCRES capabilities. This cluster represents the core of SCRES, encapsulating the most frequently cited capabilities regarded as resilience enhancers. These capabilities include collaboration, flexibility, visibility, agility, redundancy, efficiency, robustness, sustainability and ambidexterity. Each capability is discussed in detail below, with its derivation from strategic, tactical, and operational decisions further examined in Subsection 6.4.

Collaboration

One of the most cited capabilities enhancing SCRES is collaboration, which encompasses coordination, cooperation or cooptation, joint decision-making and mutual sharing of benefits and risks, knowledge and information sharing, cooperative planning, and shared supply chain intelligence (Pettit et al., 2013; Tukamuhabwa, Stevenson, Busby and Zorzini 2015). Effective communication across departments, individuals, and supply chain stakeholders is crucial for exchanging information, applying shared knowledge to reduce uncertainty, enhancing visibility, improving operational effectiveness and efficiency, and elevating customer service levels (Pettit et al., 2013). Moreover, engaging in collaborative efforts with supply chain partners such as suppliers enables organizations to respond efficiently to market dynamics and unforeseen crises.

Flexibility

Another crucial element in fostering SCRES is supply chain flexibility. “*A supply chain is said to be flexible if it can ensure smooth uninterrupted supply of the products from supplier to the end user under all risks and uncertainties in the environments, with the least variation in the difference between the demand and supply at every demand-supply node, and without much penalty or impact on the supply chain resources and the costs incurred*” (Tiwari, A. K., Tiwari, A., Samuel and Bhardwaj, 2013, pp. 212-213). According to Christopher (2016), flexibility can be achieved by combining operational and sourcing strategies. For instance, having multiple suppliers offers diverse sourcing options and mitigates the risk of supply disruption. Flexible manufacturing processes and resources, warehousing, and logistics contribute significantly to supply chain flexibility (Gosling, Purvis, and Naim, 2010), enabling adjustments to production based on demand fluctuations. Postponement strategies, in which the final product configuration is delayed until it is closer to the point of sale, exemplify flexible manufacturing processes. Other aspects of supply chain flexibility include backup suppliers, ease of supplier switching, and alternative distribution channels, which collectively safeguard the continuity of supply, even during disruptions like the Covid-19 pandemic (Christopher, 2016). Finally, advancements in technology, such as additive manufacturing and Industry 4.0, bolster supply chain flexibility by reducing the need for backup contingency suppliers, enhancing automation, and facilitating decentralized control and risk diversification.

Visibility

Visibility is the ability to monitor and understand the status of current operating resources within the supply chain as well as the broader supply chain environment (Ekanayake et al., 2021). Supply chain visibility is an important antecedent to risk reduction because it allows organizations to proactively track products and identify potential disruptions, thus reducing the risk of unexpected events (Sheffi and Rice, 2005). Effective supply chain visibility requires tools such as early warning communication, information sharing, real-time monitoring, and financial monitoring that allow a company to understand the status of its supply chain at any given time (Christopher, 2016). Digitalization, enabled by the integration of various technologies, such as digital twins, blockchain, Internet of Things, and Big Data, can play a key role in creating more integrated, well-organized, and transparent global supply chains. By providing end-to-end visibility of the supply chain, firms can gain crucial information that allows them to effectively make sense of potential threats to the environment, including supply chain disruptions (Cherrafi et al., 2022). According to Zamani et al. (2020), leveraging AI and BDA enhances supply chain responsiveness, which refers to a chain's ability to react to demand fluctuations during crises. This capability facilitates informed decision making among top management, leveraging data-driven insights over reliance solely on experience and intuition. Integrated IT systems also aid in identifying risks from suppliers, assessing their likelihood and impact on operations, and enabling proactive adjustments to schedules and tasks as needed (Cavalcante, Frazzon, Forcellini, Ivanov, 2019).

Agility

Agility is indispensable for a firm to quickly and smoothly bounce back in dynamic and evolving scenarios (Wieland and Wallenburg, 2013), and to adapt to rapid changes in market demand or supply (Ali et al., 2017). Velocity is a critical component of agility (Scholten, Sharkey Scott and Fynes 2014), as it determines the extent of loss incurred per unit of time during a risk event (Jüttner and Maklan, 2011). At the same time, agility is associated with responsiveness, enabling a supply chain to adjust tactics and operations promptly during crises (Scholten et al., 2014; Tukamuhabwa et al., 2015). Overall, this capability hinges significantly on a well-designed supply chain with efficient interconnections between facilities and virtual networks.

Redundancy and Efficiency

Another frequently mentioned capability related to SCRES is redundancy, which involves utilizing excess capacity in production or transportation, maintaining the safety stock, engaging multiple suppliers, adopting emergency backup or storage facilities, and operating at low capacity utilization (Christopher and Peck, 2004; Ali, Golgeci and Arslan, 2021). Redundancy is acknowledged as an expensive approach to bolstering SCRES. Therefore, it is crucial to strike a delicate balance between efficiency and resilience (Sajjad, 2021), where efficiency denotes the ability to produce outputs using minimal resources. According to Sajjad (2021), an excessive focus on operational efficiency within value chains may create vulnerabilities that could potentially undermine SCRES.

Robustness

Robustness is the ability to sustain operations during disruptions (Purvis, Spall, Naim, and Spiegler, 2016; Behzadi, O’Sullivan, Olsen, Scrimgeour and Zhang, 2017). Factors related to supply chain infrastructure, such as its configuration, segmentation, decentralization, density, complexity, node or location criticality, product flow, product design, and supply base strategy, have been identified in the literature as key components of robustness (Ali et al., 2023). Some researchers argue for a trade-off between robustness and flexibility (Jüttner and Maklan, 2011), where flexibility enables supply chains to take on a wider range of forms and robustness increases the number of changes that the supply chain can handle. Therefore, achieving an optimal balance between these factors is essential to maintain a resilient supply chain that can effectively adapt to evolving circumstances while remaining stable and resilient in the face of disruptions.

Sustainability

Sustainability is widely recognized as the practice of using resources to meet the needs of the present generation without compromising the ability of future generations to meet their own needs (Jain et al., 2017). Several practices aimed at enhancing supply chain sustainability have been proposed as contributing factors to SCRES. For instance, Ahi and Searcy (2013) found that a supply chain with a diversified economic portfolio is more sustainable from an economic perspective and less vulnerable to location-specific downturns. They also proved that providing high-quality healthcare to employees is less likely to result in loss of workforce capacity during a disease outbreak. Likewise, Cherrafi et al. (2022) found that a circular economy combined with the adoption of digital technologies is positively associated with SCRES.

Ambidexterity

Ambidexterity refers to the ability to balance the exploitation of current certainties with the exploration of new possibilities (Duncan, 1976). Organizations that exhibit ambidexterity in both exploitation and exploration can enhance their competitive position and adapt swiftly to uncertain environments by integrating resources, thus gaining a competitive edge (Duncan, 1976). Exploitation focuses on efficiency and execution, leveraging existing resources and current competitive advantages, while exploration aims to discover new resources, innovate, and expand markets (March, 1991). Therefore, supply chain ambidexterity is the capability to adjust supply chain design to respond to market changes while aligning the incentives of supply chain partners. It positively affects SCRES by fostering environmental awareness (Aslam, Khan, Rashid and Rehman, 2020), which is useful for reconfiguring the resource base in the face of disruptions (Ambulkar et al., 2015).

Table 8 lists the number of papers citing each capability in the literature.

Table 8. Cluster A: SCRES capabilities

SCRES enhancers	Number of citing papers	References
Collaboration	24	Ali et al. (2021), Agarwal et al. (2022), Agarwal et al. (2022), Al Naimi et al. (2022), Alemsan et al. (2021), Han et al. (2020), Honhstein et al. (2015), Jain et al. (2017), Kamalahmadi et al. (2015), Munch et al. (2021), Parast (2022), Razak et al. (2021), Sawyerr et al. (2020), Scholten et al. (2014), Shekarian and Parast (2021), Silva et al. (2022), Priya Datta et al. (2007), Zhou et al. (2022), Shivajee et al., (2023), Ekanayake et al. (2021)*, Hendry et al. (2019), Ali et al. (2017)
Flexibility	21	Ali et al. (2021), Agarwal et al. (2022), Brusset et al. (2017), Chowdhury and Quaddus (2017), Duong (2020), Ekanayake et al. (2022), Han et al. (2020), Honhstein et al. (2015), Kamalahmadi et al. (2015), Kaviani et al. (2020), Kazancoglu et al. (2022), Nikookar et al. (2021), Razak et al. (2021), Sarkar et al. (2022), Sawyerr et al. (2020), Shekarian and Parast (2021), Shin (2021), Ivanov & Dolgui (2019), Ekanayake et al. (2021), Ekanayake et al. (2021), Liu (2022)
Visibility	17	Ali et al. (2021), Alemsan et al. (2021), Brandon-Jones et al. (2014), Cherrafi et al. (2022), Duong (2020), Han et al. (2020), Honhstein et al. (2015), Jain et al. (2017), Kamalahmadi et al. (2015), Kaviani et al. (2020), Munch et al. (2021), Nikookar et al. (2021), Razak et al. (2021), Sajjad (2021), Sawyerr et al. (2020), Silva et al. (2022), Ekanayake et al. (2021), Ekanayake et al. (2021)
Agility	16	Ali et al. (2021), Agarwal et al. (2022), Al Naimi et al. (2022), Aslam et al. (2020), Cherrafi et al. (2022), Han et al. (2020), Honhstein et al. (2015), Jain et al. (2017), Kamalahmadi et al. (2015), Kazancoglu et al. (2022), Munch et al. (2021), Sawyerr et al. (2020), Scholten et al. (2014), Shekarian and Parast (2021), Shin (2021), Priya Datta et al. (2007)
Redundancy	12	Ali et al. (2021), Agarwal et al. (2022), Chowdhury and Quaddus (2017), Han et al. (2020), Honhstein et al. (2015), Kamalahmadi et al. (2015), Munch et al. (2021), Sajjad (2021), Sawyerr et al. (2020), Shekarian and Parast (2021), Ivanov & Dolgui (2019),), Liu (2022)
Efficiency	8	Agarwal et al. (2022), Alemsan et al. (2021), Chowdhury and Quaddus (2017), Kaviani et al. (2020), Parast (2022), Shin (2021), Ekanayake et al. (2021), Ekanayake et al. (2021)
Robustness	4	Ali et al. (2021), Al Naimi et al. (2022), Sarkar et al. (2022), Liu (2022)
Sustainability	4	Jain et al. (2017), Sarkar et al. (2022), Silva (2022), Dolgui et al. (2020)
Ambidexterity	3	Agarwal et al. (2022), Aslam et al. (2020), Wang et al. (2021)

6.2 Cluster B: Factors determined at the organizational level

The second cluster (Table 9) encompasses factors determined at the organizational level that influence SCRES, but do not stem from traditional SCM decisions. Rather, these factors are linked to intangible aspects such as trust, leadership, organizational culture, social capital, knowledge, and human resource management. This aligns with Seville et al. (2006), who noted that resilience issues often relate more to the softer, less tangible dimensions of an organization, such as its culture, vision, leadership, and soft managerial practices like effective communication. Similarly, Moore and Manring (2009) argued that organizational behavior and characteristics are critical drivers of resilience. Sheffi (2005) echoes this sentiment, asserting that the key differentiator between successful and unsuccessful responses to disruption lies in organizational culture. Organizational culture can be defined as a set of beliefs and values shared by members of an organization that influence the behavior and decisions of organizational members (Schein, 2010). These factors play a critical role in fostering a resilient supply chain by building strong cooperative relationships both within the company and externally with clients and suppliers. Additionally, they help to create a supportive organizational environment that is capable of learning from previous disruptions. However, within the process of cultural change at the organizational level, nothing is possible without the support and commitment of leadership (Kamalahmadi et al., 2015). According to Shin and Park (2021), leadership responsibility is crucial for managing the overall resilience capabilities of supply chain network members. Similarly, trust is an important facilitator in building a resilient supply chain (Jain et al., 2017). Lack of trust and collaboration can limit flexibility in the supply chain (Jüttner and Maklan, 2011). The interrelationship between trust, cooperation, and commitment helps supply chain partners reduce network uncertainty (Chowdhury and Quaddus, 2016). Other fundamental elements in this cluster include HRM and knowledge management. Educating and training employees and fostering a risk-sensitive culture and mindset are crucial for enhancing SCRES (Honhstein et al., 2015). This involves simulations, exercises, dedicated risk management departments, inter-organizational learning, post-disruption feedback, exploring opportunities amidst risks, and enhancing innovativeness in contingency planning and continuity management (Ali et al., 2023). Finally, supply chains can collaborate through various methods, one of which is governance practices such as rules, regulations, and policies that guide organizations, systems, and activities (Duong and Chong, 2020). Governance, therefore, influences collaboration mechanisms, which, in turn, impact SCRES.

Table 9: Cluster B: Factors determined at the organizational level

SCRES enhancers	Number of citing papers	References
Trust	5	Kamalahmadi et al. (2015), Jain et al. (2017), Duong (2020), Al Naimi et al. (2022), Acar et al. (2022)
Knowledge management	4	Scholten et al. (2014), Duong (2020), Ali et al. (2021), Irfan et al. (2022)

Human resource management	4	Honhstein et al. (2015), Ali et al. (2017), Munch et al. (2021), Sawyerr et al. (2020)
Learning culture	2	Parast (2022), Acar et al. (2022)
Organizational culture	2	Duong (2020), Sawyerr et al. (2020)
Leadership	2	Kamalahmadi et al. (2015), Shin (2021)
Social capital	2	Ali et al. (2022), Nikookar et al. (2021)
Governance and control	1	Cherrafi et al. (2022)
Governance practices	1	Duong and Chong (2020)
Relationship management	1	Duong and Chong (2020)

6.3 Cluster C: Contingency factors

The third cluster (Table 10) encompasses elements that are classified as contingency factors. These include aspects such as market share, brand reputation among consumers, financial strength, company size, and company age. For instance, financial strength enables organizations to absorb cash flow fluctuations (Pettit et al., 2013). Specific characteristics associated with financially strong organizations include insurance coverage, portfolio diversification, financial reserves and liquidity, price margins, profitability, and availability of funds (Pettit et al., 2013; Chowdhury and Quaddus, 2015). Previous research indicates that older firms that have experienced more disruptions have developed greater knowledge and expertise in mitigating various types of disruptions. This enhances their learning capabilities, enabling them to leverage their prior experiences to respond and recover more effectively (Parast, 2022). On the other hand, larger firms often possess more slack resources, enabling them to be more responsive to supply chain disruptions (Safari et al., 2023). Empirical studies have also demonstrated that firm size moderates the relationship between service disruptions and service quality (Parast and Golmohammadi, 2020). Similarly, a strong market position, characterized by a well-recognized competitive strategy, high market share, and higher margins, enables investments in supply chain resilience (SCRES) (Sheffi and Rice, 2005). These investments help maintain healthy customer relationships following disruptions (Melnyk, 2014). Finally, the industry in which a company operates plays a critical role, as the same disruption can affect different sectors in diverse ways.

Table 10: Cluster C: Contingency factors

SCRES enhancers	Number of citing papers	References
Financial strength	5	Al Naimi et al. (2022), Chowdhury and Quaddus (2017), Silva et al. (2022), Ekanayake et al. (2021), Ekanayake et al. (2021)*
Market position	4	Ali et al. (2022), Han et al. (2020), Kaviani et al. (2020), Ekanayake et al. (2021)*
Competitive strategy	1	Parast (2022)
Firm age	1	Parast (2022)
Firm size	1	Parast (2022)
Industry type	1	Parast (2022)
Market strength	1	Chowdhury and Quaddus (2017)

6.4 SCRES capabilities as resulting from strategic, tactical and operational decision

To address our second research question concerning which SCRES enhancers stem from strategic, tactical, and operational decisions within the realm of SCM, we examined the practices and technologies identified in our SLR, which are linked to the nine capabilities that enhance SCRES (refer to Annex 1 for further details). Clusters B and C fell outside this classification because of their distinct nature. Table 11 provides a visual summary of these findings.

Table 11: SCRES capabilities as resulting from strategic, tactical and operational decisions

SCRES capabilities	Type of decisions involved		
	Strategic	Tactical	Operational
Collaboration	Risk and revenue sharing (Al Naimi et al., 2022); Joint practices, assessment practices, contractual and economics practices (Duong and Chong, 2020).	Inventory sharing (Alikhani et al., 2021); Information sharing (Jain et al., 2017)	
Flexibility	Multiple-set covering (Alikhani et al., 2021); Reserve capacity and additional shifts (Munch et al., 2022)	Direct-to-store delivery (Alikhani et al., 2021); Maintenance of critical machines (Munch et al., 2022); Additive manufacturing / Industry 4.0 (Tortorella et al., 2022)	

Visibility		Information sharing (Al Naimi et al., 2022); Digitalisation (Cherrafi et al., 2022) ; Connectivity (Brandon-Jones et al., 2014)	Sensing and interpreting events, continuity planning, mapping of supply chain vulnerabilities, warning strategies, risks identification (Han et al., 2020); Minimising uncertainty, market sensitiveness (Jain et al., 2017)
Agility		Additive manufacturing / Industry 4.0 (Tortorella et al., 2022); Contingency planning (Han et al., 2020)	
Redundancy	Supplier risk mitigation, multiple sourcing, balanced diversification (Al Naimi et al., 2022); Multiple-set covering (Alikhani et al., 2021)	Inventory and stock buffer (Alikhani et al., 2021)	
Efficiency		Quality management (Parast, 2022)	
Robustness	Decisions concerning complexity, supply base and nodes criticality (Brandon-Jones et al., 2014); Density (Chowdhury and Quaddus, 2017); Diversification and structural variety (Ivanov & Dolgui, 2019); Facility fortification (Alikhani et al., 2021)		
Sustainability	Circular economy practices (Cherrafi et al., 2022)	Additive manufacturing / Industry 4.0 (Tortorella et al., 2022)	
Ambidexterity	Innovation (Kamalahmadi et al., 2015)		

From the table above, it can be observed that SCRES capabilities are primarily influenced by strategic and tactical decisions and, to a lesser extent, by operational decisions. Specifically, collaboration, flexibility, and redundancy are SCRES capabilities determined at both the strategic and tactical levels. Strategic decisions that enhance supply chain flexibility and redundancy include relying on multiple set coverings (Alikhani et al., 2021), multiple suppliers (Al Naimi et

al., 2022), and reserve capacity (Munch and Hartmann, 2022). Tactical decisions include direct-to-store delivery, inventory, stock buffering (Alikhani et al., 2021), and maintenance of critical machines (Munch et al., 2022).

Furthermore, resiliency can be achieved by designing sustainable and robust supply chains, and these characteristics can be determined at a strategic level. Firms are increasingly integrating sustainable practices into their operations to reduce environmental impacts and enhance social responsibility as part of their strategic objectives. In this context, Cherrafi et al. (2022) suggest that circular economy practices are an effective approach to achieving sustainability by increasing resource-use efficiency. Robustness, defined as the ability to maintain operations during disruptions, is influenced by strategic decisions related to supply chain complexity, density, node criticality (Chowdhury and Quaddus, 2017), diversification and structural variety (Ivanov and Dolgui, 2019), and facility fortification (Alikhani et al., 2021).

Visibility, a key enhancer of SCRES, is determined at operational and tactical levels. Achieving effective supply chain visibility requires firms to engage in information-sharing, sensing and interpreting events, continuity planning, vulnerability mapping, and warning strategies (Al Naimi et al., 2022). Digitalization, enabled by integrating technologies such as the Internet of Things and Big Data, helps create more integrated and transparent supply chains, providing firms with end-to-end visibility (Cherrafi et al., 2022). Notably, digital maturity and interoperability are critical factors that significantly influence the adoption of digital tools and positively impact resilience capabilities (Agarwal et al., 2022).

According to our findings, agility is determined at a tactical level through contingency planning (Han et al., 2020) and Industry 4.0 technologies (Tortorella et al., 2022). Finally, ambidexterity is an SCRES capability developed mainly at a strategic level. It involves a company's ability to exploit its current competitive advantages while exploring and innovating to identify new opportunities. This can be described as both an attitude and a strategic approach to markets and consumers.

In conclusion, when making long-term decisions that define the network design, including the locations of facilities, production technologies, and plant capacities, or when defining tactical decisions, such as production levels at all plants, assembly policy, inventory levels, and lot sizes, managers should consider the impact of their decisions on SCRES capabilities. This perspective has been confirmed by previous studies. For example, Al Naimi et al. (2022) recommended that supply chains must possess specific characteristics, such as flexibility and redundancy, to effectively manage disruptions. Similarly, Agarwal et al. (2022) argued that supply chains should be designed to accommodate design changes at any stage, emphasizing the critical role of technological capabilities in facilitating these adaptations.

7. Conclusion, limitations and future research directions

This study falls within the realm of literature on SCRES enhancers and addresses two key research questions: “*What elements have been associated with supply chain resilience in previous studies*” and “*Which of these elements originate from strategic, tactical, and operational decisions?*”.

To address our research questions, we conducted an SLR of articles published in leading academic and practitioner journals from 2013 to 2023 following the methodology outlined by Denyer and Tranfield (2009). This review developed a framework that organizes the key elements influencing SCRES into three primary clusters. The first cluster identifies nine capabilities (collaboration, flexibility, agility, visibility, redundancy, efficiency, robustness, sustainability, and ambidexterity) that should guide supply chain design or reengineering and stem from SCM decisions. The second cluster identifies intangible dimensions of an organization, such as its culture, leadership, and social capital, the ability to learn from previous disruptions, and trust among supply chain partners. These are essential predictors of a resilient supply chain. For example, the capability to acquire, apply, and leverage knowledge is crucial for fostering a risk management culture and enhancing resilience (Ali et al., 2023). Similarly, HRM, encompassing employee training and education, a culture and mindset prioritizing risk management, and the integration of cross-functional teams, significantly influences managers' capacity to effectively communicate and comprehend diverse information types, including opportunities and threats (Hohenstein et al., 2015). The third cluster encompasses a set of contingency factors. A firm's market position, industry, age, size, and financial strength, including liquidity and access to funds, are key predictors of stability in the face of disruptions, thereby influencing SCRES. These elements, combined with those identified in cluster B, collectively enhance a firm's capacity to endure and adjust to disruptions, forming a resilient foundation that transcends the traditional supply chain design.

Regarding the second research question, the findings indicate that SCM decisions play a crucial role in developing SCRES capabilities, which primarily result from strategic choices that shape supply chain design. In particular, the long-term decisions that shape the network for sourcing, production, assembly, and distribution are critical for building resilience. Tactical decisions also play a fundamental role in enhancing SCRES. Key components of these decisions include the adoption of technology, which provides advanced tools for monitoring and managing supply chain activities, effective asset maintenance to ensure the availability of critical infrastructure, and careful balancing of production levels across all plants to meet demand without overextending resources. Moreover, assembly policies, inventory levels, localization strategies, and lot sizes must be managed strategically to maintain flexibility and redundancy. Collectively, these tactical choices create buffers that enable faster adjustments to supply chains in response to disruptions. In contrast, operational decisions, which focus on day-to-day activities, are essential for maintaining smooth operations, but are less significant in addressing unexpected crises. Notably, among SCRES capabilities, visibility is the only one that is significantly influenced by operational decisions.

7.1 Theoretical and practical implications

This study has significant implications for academic research and practical applications. Prior investigations into SCRES frequently overlooked specific enhancers, thereby underscoring the absence of a comprehensive framework that encapsulates all SCRES enhancers. Furthermore, to the best of our knowledge, there is a dearth of studies that examine the relationship between SCRES enhancers and the managerial decisions that influence them. Notably, none has specifically investigated the role of SCM decisions in cultivating SCRES capabilities. In light of these research gaps, this study delineates itself from the existing literature on SCRES in several ways. First, rather than merely focusing on the concept of resilience and its definitions (Ali et al., 2017; Hohenstein et al., 2015), this study aimed to provide a comprehensive review of the various elements associated with SCRES identified in the existing literature. Second, recognizing SCRES as a multidimensional construct (Parast, 2022), this study systematically investigated how the three levels of SCM decisions contribute to building SCRES capabilities. Finally, it sets forth an agenda for future research endeavors aimed at deepening our understanding of SCRES and exploring new dimensions of resilience-enhancing strategies in SCM. In particular, existing literature on SCRES examines a wide range of practices and technologies that positively influence SCRES capabilities. However, numerous studies still have the potential to address the gaps identified in our framework, as each SCRES capability can be further examined through the lens of strategic, tactical, and operational decisions that contribute to its development.

From a practical standpoint, the framework developed as a result of the SLR facilitates managerial decision-making in enhancing SCRES. It provides a structured and comprehensive categorization of the existing literature on this topic, thereby offering clarity to practitioners in navigating this complex field. Additionally, the framework presents practical guidelines aimed at improving SCRES capabilities and equipping managers with actionable strategies to foster resilience within their supply chains.

7.2 Limitations and future research directions

Although this study significantly contributes to the state of the art pertaining to SCRES, it suffers from a few limitations. First, the review was confined to 60 peer-reviewed articles, intentionally excluding other sources, such as book chapters, conference proceedings, working papers, reports, and unpublished works. This restriction may limit the breadth of the perspectives considered and potentially overlook relevant insights from diverse sources. Second, the qualitative nature of this study implies that the developed theory requires validation through empirical methods, which could further substantiate its findings and applicability in practical settings. Additionally, although digital technology and additive manufacturing have been acknowledged in the literature as significant contributors to enhancing visibility, flexibility, agility, and sustainability within supply chains, only a limited number of other technologies have been identified as SCRES enhancers.

This narrow focus on specific technologies may restrict the comprehensive understanding of the diverse technological landscape that supports SCRES. Future research should explore a wider array of technological innovations that may play pivotal roles in bolstering SCRES. Furthermore, subsequent studies could investigate which combinations of elements identified in our framework are most commonly associated with SCRES, and explore successful configurations of SCRES enhancers tailored to different supply chain characteristics or industries. Additionally, it is important to recognize that not all supply chains can encompass all the capabilities listed above. Given the constraints of limited resources, it is crucial to avoid overinvestment in resilience to achieve a state of 'balanced resilience' (Pettit et al., 2013). This necessitates a nuanced understanding of the strategies that are most appropriate for addressing specific vulnerabilities. Accordingly, research efforts should focus on determining which SCRES enhancers are most effective in mitigating particular vulnerabilities and supply chain risks (Shekarian and Parast, 2021).

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Appendix 1

Table I. Integration process: reasons for exclusion

SCRES enhancers	Reasons for exclusion
Supply chain reengineering/design	It is a term that encompass various capabilities and practices.
Resourcefulness	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list
Supplier risk mitigation	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list
Activate	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list
Market factor	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list
Analytical orientation	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list
Business certifications	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list
Decision making	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list
Enablers at operational level	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list.
Enablers at strategic level	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list.
Enablers at tactical level	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list.
Globalisation	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list.
Measurement issues	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list.
Empowerment	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list.
Organization	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list.
Readiness, recovery, and response	These SCRES enhancers represent the definition of SCRES
Resilience	Resilience cannot represent its own enhancers
Resources	The definition is either lacking or too vague to trace the term back to any of the other SCRES enhancers present in the list.

Table II. Integration process: Identification of practices and technologies

SCRES enhancers	Definition	Integration process	Classification
Digitalisation	Supply chain digitalisation is based on two concepts: the adoption of Digital Supply Chain (DSC) tools and the degree of digital maturity. The digital maturity variable not only significantly influence the adoption of DSC tools, but it also positively influences SCRES capabilities (Zouari et al., 2020).	Visibility	Practices
Information sharing	It relates to the nature, speed, and quality of the information being conveyed (Brandon-Jones et al., 2014). Relevant information shared effectively and efficiently between supply chain partners can enhance collaboration by maintaining transparency and building trust (Mandal, 2017).	Collaboration	Practices
Risk management culture	It is defined as ‘infusing a culture of resilience and risk awareness to make it the concern of everyone’ (Liu et al., 2018). It has been argued by many researchers that the culture of managing the risk in the supply chain should not be limited to business continuity and corporate risk (Scholten et al., 2014; Liu et al., 2018). In this sense risk management culture is highly desirable for improved resilience in any organization (Jain et al., 2017).	Visibility	Practices
Capacity	Capacity construct covers the availability of resources for continuous supply chain operation. Having backup supply chain equipment, including machinery at the factory and on-site equipment, (Ekanayake et al., 2020d) dependable back-up utilities (water, electricity, etc.) and access to redundant resources is beneficial (Kaviani et al., 2020). Redundancy as a capacity measurement item facilitates quick recovery after disruption despite the failure of the entire system (Sheffi and Rice, 2005).	Redundancy	Practices
Contingency planning	Contingency planning refers to the ability to recover from disruptions by utilizing methods such as scenario analysis, recovery plans, and resource reconfiguration (Han et al., 2020). This approach can result in various outcomes, including supply chain reconfiguration (Ali et al., 2021).	Agility	Practices
Dispersion (vs centralization)	Dispersion is illustrated by Kaviani et al. (2020) as the distribution of production facilities at diverse locations, the geographical diversity in customers	Robustness	Practices

	locations, and the access to a decentralized network of suppliers for providing key inputs of the company.		
Inventory and stock buffer	The use of inventory and safety stocks to buffer disruptions (Honhestein et al., 2015). Holding extra inventory in the system creates redundancy, which is a form of adaptive capability (Alikhani et al., 2021). Although buffer are expensive and cost to business and leaders may have a hard time justifying keeping excessive inventory, building inventory is the most straightforward way to enhance resilience in procurement function, whether in the form of underutilised production facilities or inventory in excess of safety stock requirements (Shishodia et al., 2023).	Redundancy	Practices
Security	Security is defined by Kaviani et al. (2020) as a set of practices including the provision of a high level of security in information systems of the company, training personnel for security programs, collaboration with governmental and expert organizations to improve the cybersecurity defensive systems.	Robustness	Practices
Localization	Value chains are likely to become more localized to boost resilience and sustainability. Micro supply chains are more secure, resilient, and less vulnerable. However, the opportunity to localize sourcing depends on the presence of resources in each area (Cherrafi et al., 2022).	Robustness	Practices
Logistics capabilities	Optimizing the logistics system enable the company to minimize the total delivery time by utilizing efficient modes of transport, closeness to suppliers and delivery flexibility (Dwaikat, 2022).	Flexibility	Practices
Multiple sourcing	Multiple or dual sourcing mitigates the risk of disruption by having multiple suppliers or expanding the supply base to include new suppliers (Behzadi et al., 2017). Organizations need to invest in preventive measures, such as multiple suppliers, to ensure resilience and maintain strong readiness and growth phases (Hohenstein et al., 2015). Similar to a backup capability, multiple sourcing acts as a redundancy component used to prevent stockouts (Hohenstein et al., 2015; Kamalahmadi and Parast, 2016; Ali et al., 2017).	Redundancy	Practices
Quality management	Quality management refers to a set of comprehensive management practices that aim at continuous	Efficiency	Practices

	improvement and customer satisfaction (Parast, 2022). The central tenant of quality management is to provide a systematic approach to organization-wide quality efforts that centers on both technical and managerial practices (Safari et al., 2022). A review of the literature suggests that organizations that adhere to the principles of quality management are expected to become more resilient (Madani and Parast, 2021).		
Reserve capacity	Reserve (or back up) capacity enables the system to continue to operate and remove potential bottlenecks during disruptions. Some nodes would expand their capacity and operate below their full capacity, keeping the excess reserved for emergencies (Alikhani et al., 2021).	Redundancy	Practices
Risk and revenue sharing	Sharing the risk and revenue across supply chains is highly desirable (Al Naimi et al., 2022). Previous studies have found that it is essential for both long-term focus and collaboration among supply chain partners (Pettit et al., 2013; Jain et al., 2017). Partners should collaborate to identify direct supply chain risks and their possible causes or source. Sharing revenue is a key factor in increasing competitive advantage for all the supply chain partners (Jain et al., 2017).	Collaboration	Practices
Situation awareness	It is the ability to forecast a possible disruption (Han et al., 2020).	Visibility	Practices
Additive manufacturing	The integration of AM technology with sensors, data integration, modelling approaches and predictive analysis can develop sensing capabilities. This capability can provide insightful data that can be analysed to enhance product quality, reduce rework, quality defects and maintenance cost. Moreover, AM technology can predict maintenance failures, which will ensure high utilization and lower costs (Belhadi et al., 2022).	Efficiency	Technology
Alertness	It is defined as a supply chain's capability to detect changes in either the surrounding business environment or an internal supply chain network quickly (Shin, 2021).	Visibility	Practices
Analyse	It is critical to prepare the supply chain with better analysing and processing capabilities. These capabilities can only be developed if the supply chains are well trained, whether it be by testing their survival with multiple scenarios or analysing the	Agility	Practices

	elements of realistic customer demand (Modgil et al., 2021).		
Assessment practices	They are a collaboration mechanism. These practices help supply chain partners provide feedback, make better decisions, and motivate for better performance (Duong, 2020).	Collaboration	Practices
Avoidance	Being able to avoid risks by dropping products with uncertain demands, avoiding specific markets in certain geographical locations and avoiding suppliers with high-risk profiles (Sawyer et al., 2020).	Visibility	Practices
Balanced diversification	Production and sourcing of components from multiple places and multiple suppliers (Sajjad, 2021). According to Cherrafi et al. (2022), the diversification of a logistics network is likely to be the “new normal” and the implementation of a multi-sourcing strategy will be important to ensure the viability and survival of organizations by minimizing the risk of future disruptions.	Robustness	Practices
Repurposing	Repurposing can be referred to as the business temporarily switching from the existing products and markets to a new or different one (that has not been produced before in the factory) in response to the supply chain disruption (Dwaikat, 2022).	Agility	Practices
Circular economy practices	The circular economy is proposed as a practical approach to the sustainable use of finite natural resources (Aranda-Uson et al., 2020). The circular economy has replaced traditional industrial practices and introduced new closed-loop economic models entirely centered on balancing the economic, environmental, and societal impacts of products and processes (Elia et al., 2017). According to Sarkis et al. (2020), circular economy practices can serve as a driver of change to increase sustainability, leading to resilience (Bag et al., 2019).	Sustainability	Practices
Complexity	Complexity is related to both the number of nodes in a supply chain and the interconnections between those nodes (Craighead et al., 2007). A less complex supply chain would have fewer nodes and/or fewer interconnections between nodes (Craighead et al., 2007; Falasca et al., 2008). Increased complexity in the supply chain usually creates more vulnerabilities (Craighead et al., 2007; Falasca et al., 2008).	Robustness	Practices

Contractual and economics practices	They are a collaboration mechanism. They include economics practices such as profit-sharing, rewards, and incentive alignments (Duong, 2020).	Collaboration	Practices
Criticality	Node criticality depends on the relative importance of a given node or set of nodes within a supply chain (Craighead et al., 2007). A very important node (e.g., an important distributor or supplier on which others in the supply chain are highly dependent) makes the supply chain critical and vulnerable. Thus, supply chain node criticality is an important element of supply chain vulnerability and SCRES.	Robustness	Practices
Density	Node density is high in a supply chain where a large number of nodes exist in a limited geographical area (Craighead et al., 2007; Falasca et al., 2008). Supply chain nodes exist in high-density clusters when the sources of supply or distribution markets are concentrated in a particular area. Craighead et al. (2007) and Falasca et al. (2008) emphasize that increased density in the supply chain creates more vulnerabilities and reduces SCRES.	Robustness	Practices
Direct-to-store delivery	Direct-to-store delivery increases network flexibility by bypassing disrupted nodes and is another proactive/adaptive resilience capability (Alikhani et al., 2021).	Flexibility	Practices
Employee protection	According to Sajjad (2021), companies need to actively collaborate with their employees, industry partners, government agencies, development agencies and other stakeholders to determine the right policy measures that could support health and mental well-being and the livelihood of workers.	Robustness	Practices
Facility fortification	It implies mitigating risks by protecting a facility such as installation of structural reinforcements and barriers, keeping backup emergency equipment, preventive maintenance, and monitoring (Alikhani et al., 2021).	Robustness	Practices
Improved risk awareness and pro-activeness	These are supply chain capabilities used to advance supply chain transparency and visibility by providing traces of the provenance, location, status, composition etc. through all stages of production, processing and distribution (Razak et al., 2021).	Visibility	Practices
Innovation	Reinmoeller and Van Baardwijk (2005) stated that companies could be able to overcome disturbances and disruptions, and adapt to rapid changes in the environment, only when they allocate enough	Ambidexterity	Practices

	resources to innovation. Golgeci and Ponomarov (2013) demonstrated that the impact of firm innovativeness on effective responses to supply chain disruptions indicated that both firm innovativeness and innovation magnitude are positively associated with supply chain resilience.		
Interoperability	Helps in determining which operations adhere to standard operating procedures and the level at which the products/production flexibilities are offered (Scholten et al., 2014).	Visibility	Technology
Inventory sharing	Agreeing upon a pre-established mechanism for inventory transshipment between two retail supply chain networks would allow the network to respond quickly to post-disaster demand (Alikhani et al., 2021).	Collaboration	Practices
Joint practices	They are a collaboration mechanisms. They address mutual reactions among supply chain partners from joint planning to joint control activities (Duong and Chong, 2020).	Collaboration	Practices
Retooling	Retooling can be referred to as equipping a factory with new or adjusted tools, machines and equipment to temporarily switch production from one product to another in response to the supply chain disruption (Dwaikat, 2022).	Agility	Practices
Market sensitiveness	It means that the supply chain is capable of interpreting and reacting to actual demand (Jain et al., 2017).	Visibility/Agility	Practices
Multiple-set covering	The minimum number of preceding nodes for set covering can be determined based on the importance and the demand of each following node. Multiple-set covering, an adaptive capability, increases the flexibility and redundancy of the network (Alikhani et al., 2021).	Redundancy/Flexibility	Practices
Planning capabilities	Firms that are technologically well capable with their assortment planning process could ensure demand fulfillments and reduced chances of lost sales, thereby improving supply chain resilience (Scholten et al., 2014).	Agility	Practices
Reconfiguring	Reconfiguring can be referred to as redesigning supply chain planning to respond to high supply-demand volatility and increase supply chain responsiveness (Dwaikat, 2022). Supply chains need to reconfigure their network mapping to balance supply and demand during disruption events This	Agility	Practices

	reconfiguration of network alignment needs to be on a continuous basis and must track whether the effort is going in the right direction (Modgil et al.,2020).		
Recognise	Identification of operational risks can help improve real-time visibility and indicate mitigating solutions. Tactical risk recognition helps with better sales and operations planning, whereas strategic risk identification helps with network planning and multi-sourcing options (Modgil et al., 2020).	Visibility	Practices
Structural variety	It can be achieved through decentralisation, diversification, localisation, segmentation, fortification (Ivanov & Dolgui, 2019).	Robustness	Practices
Supply Base Complexity	It relates to the number of suppliers (scale complexity), delivery reliability of suppliers (delivery complexity), differentiation between suppliers, and geographic dispersion (Brandon-Jones et al., 2014).	Robustness	Practices
Technological capability	Focusing on collaboration, the level of supply chain collaboration depends, among other things, on a partner's technological capability among partners (Jain et al., 2017).	Collaboration	Technology

RP2: Navigating uncertainties: a multi-case study examination of supply chain resilience enhancers in agri-food supply chains facing supply and demand risks²

Abstract

Introduction – Using a contingency perspective on supply chain resilience (SCRES), this research explores which SCRES enhancers were most effective in mitigating supply and demand risks during the Covid-19 pandemic and Russia-Ukraine conflict. Drawing lessons from these crises, this study also examines how organizations redesign their supply chain structures and operations to improve resilience.

Methods – This study adopts a case-based research approach, relying on multiple case studies. The purposive sample utilized in this study comprises six distinct supply chains within the agri-food industry: durum wheat, dairy, fruit and vegetables, meat and cold cuts, and wine.

Findings – This study identifies a core set of SCRES enhancers within the agri-food sector that proved critical in addressing supply and demand risks, while also demonstrating that not all enhancers were equally effective across different business types. The study also highlights which new SCRES enhancers have been developed post-crises in response to the vulnerabilities exposed during these disruptions.

Originality/Value – Previous studies have often overlooked the interaction between various SCRES and specific risks that arise during disruptive events. This study contributes to the existing SCRES literature by deepening the understanding of strategies and practices that effectively mitigate supply and demand risks, particularly within the agri-food sector, a critical area in resilience research due to its pivotal role in food security and the increasing complexity and vulnerability of agri-food supply chains.

² This paper was co-authored with Vitaliano Fiorillo, Associate Professor of Practice at SDA Bocconi School of Management and Director of Invernizzi AGRI Lab.

1. Introduction

Several factors, including globalization, outsourcing, and the shift towards lean and agile operations, along with external factors such as conflicts, the recent Covid-19 pandemic, and the increase in extreme natural events, have heightened the importance of supply chain risk management over the past decade. This emerging field has evolved at the intersection of supply chain management and risk management (Paulsson, 2004). Notably, supply chain resilience (SCRES), a fundamental aspect of supply chain risk management that focuses on abrupt and difficult-to-predict crises, addresses various types of risks across multiple stages of the risk management process at the supply chain level of analysis. In particular, research on SCRES has received substantial attention in two distinct phases. First, the September 11 attacks highlighted the importance of recognizing the vulnerabilities and sources of disruption risks in supply chains (Kamalahmadi and Parast, 2016). More recently, globally impactful events such as the Covid-19 pandemic and the Russia-Ukraine conflict have further stimulated research on SCRES (Remko, 2020). Araz, Choi, Olson, and Salman (2020) characterized Covid-19 as an unparalleled and highly severe disruption within global supply chains, representing an event of unprecedented magnitude. The ramifications of this disruption have reverberated profoundly throughout both upstream and downstream operations of supply chains worldwide. On the other hand, the ongoing conflict in Ukraine has resulted in elevated costs for several imported goods, affecting particularly agriculture and energy intensive industries, presenting companies with the challenging dilemma of either absorbing additional expenses or transferring them to consumers (Jagtap, Trollman, H., Trollman, F., Garcia-Garcia, Parra-López, 2022).

Following these events, renewed interest has emerged in analyzing the factors that enhance SCRES, specifically the capabilities, strategies, and practices that strengthen resilience at the supply chain level (Al Naimi, Faisal, Sobh, & Bin Sabir, 2022; Katsaliaki, Galetsi, and Kumar, 2021; Shekarian and Parast, 2021). These studies brought to the rise of a body of literature that provides overarching definitions of SCRES, frameworks that synthesize the various SCRES enhancers for the ex-ante and ex-post disruption stages, and illustrate SCRES measurement through performance metrics (Han, Chong, and Li, 2020; Agarwal N., Seth, and Agarwal A., 2022; Al Naimi et al., 2022). Other qualitative and quantitative studies have focused on specific elements that facilitate SCRES, such as digital technologies (Belhadi, Kamble, Venkatesh, Jabbour, Benkhati, 2022; Zamani, Smyth, Gupta, Dennehy, 2022), organizational learning culture, suppliers' trust (Acar, Özer Torgalöz, Eryarsoy, Zaim, 2022) and R&D activity (Parast, 2020), just to mention a few.

To the best of our knowledge, these studies tend to overlook the interaction between various SCRES enhancers and specific risks manifesting during disruptive events (Shekarian and Parast, 2021). Given that organizations must allocate resources in alignment with their specific priorities and recognizing that overinvestment in resilience can lead to financial strain, it is crucial to identify which SCRES enhancers have been most effective in mitigating specific supply chain risks

triggered by disruptive events. These risks are closely linked to supply chain vulnerabilities, which are shaped by supply chain structures and operations. In particular, we found that the most severe impacts of the aforementioned crises occurred at the procurement and distribution levels, primarily due to factory closures, abrupt shifts in consumer needs, and logistics disruptions, which in turn led to supply shortages, market shutdowns, and demand volatility (Nikolopoulos, Punia, Schäfers, Tsinopoulos, and Vasilakis, 2021). Consequently, this study focuses primarily on supply and demand risks (Mason-Jones and Towill, 1998). Additionally, it is crucial to examine not only the SCRES enhancers that were vital in addressing disruptions as they occurred but also those that were developed in response to the crises. To explore this aspect, we need to understand how organizations are restructuring their operations and supply chain configurations to enhance resilience, drawing on the lessons learned from recent crises. To address this research gap, this study examines two key research questions (RQs) focused on the impacts of the Covid-19 pandemic and the Russia-Ukraine conflict.

- RQ1: *Which SCRES enhancers have proven crucial in mitigating supply and demand risks during recent disruptions?*
- RQ2: *How organizations are redesigning their supply chain structures and their operations to enhance SCRES?*

Both research questions were addressed using a qualitative case-based research design, focusing on diverse agri-food SCs marked by sector-specific characteristics. The agribusiness sector stands out as a critical focus for resilience studies, owing to its provision of essential goods and its intricate operational dynamics. A research stream dedicated to SCRES within this sector has emerged in the last decade (e.g., Ali, Golgeci, & Arslan, 2023; Mishra, Singh, & Subramanian, 2022). Only a few publications address specific supply chain risks (e.g., Zhao et al., 2022), with most focusing on the broad implications of the Covid-19 pandemic on the agri-food industry or discussing resilience in relation to the food system's broader challenges, such as its failure to grow sustainably and ensure global food security (e.g., Hobbs, 2021; Kumar and Kumar Singh, 2022). Additionally, to the best of our knowledge, there is a lack of studies examining the operational impacts of recent crises on agri-food supply chains, as well as the strategies employed to mitigate the vulnerabilities highlighted by these disruptions (Kumar and Kumar Singh, 2022).

This study addresses this gap by identifying various SCRES enhancers, representing distinct pathways to achieve a higher level of resilience in response to supply and demand risks within the agri-food industry, offering substantial managerial insights for selecting optimal resilience strategies based on varying initial conditions, including supply chain and operations configurations, and vulnerabilities.

The structure of this paper is organized as follows. The next section presents the theoretical background, followed by the methodology in Section 3. Sections 4 and 5 present the findings and

discussion, respectively. Finally, Section 6 provides conclusions, outlines the study's limitations, and suggests directions for future research.

2. Theoretical background

2.1 Supply chain risks

In the last 20 years of scholarly discourse on SCRES, alternative terms, including disturbance (Kamalahmadi and Parast, 2016), disruption (Hohenstein, Feisel, Hartmann, Giunipero, 2015), or incident (Closs and McGarrell, 2004), have been employed to denote unforeseen and unintentional events posing significant risks to the supply chain. These events exhibit diverse manifestations and magnitudes, typically stemming from wars, natural calamities, pandemics, geopolitical tensions, and economic downturns. However, a common trait of such events is that they occur rapidly without warning. Uncertain events lead to risks (Manuj and Mentzer, 2008). This means that any disruption causes several impacts that can be traced back to specific risks faced by individual organizations or the entire supply chain (Chopra and Sodhi, 2004).

Although there is a lack of consensus regarding the classification and definition of risks (Harland, Brenchley, Walker, 2003), these differences tend to be marginal rather than substantive (Ritchie and Brindley, 2004). According to Christopher and Peck (2004) and Manuj and Mentzer (2008), there are four main risks in global supply chains: supply, operational, demand, and security risks. Supply risk encompasses the challenges associated with incoming supplies, which could either arrive behind a schedule or fail to meet specified quality or quantity standards. Key contributors to supply chain risk involve subpar logistical performance from suppliers, as evidenced by inconsistent deliveries or an inability to fulfil orders, supplier quality concerns, disruptions in the markets or sectors where suppliers are active, and deviations in prearranged delivery schedules. Operational risk derives from adverse events that affect a firm's internal ability to produce goods and services, production quality, and/or profitability. Instead, demand risk arises from fluctuations in demand, inadequate or distorted information provided by end customers regarding orders or required quantities, market changes, forecasting errors, and increased levels of competition in the market, triggered by highly innovative competing companies. Security risk is the result of adverse events that threaten human resources, operational integrity, and information systems and, as a consequence, lead to freight breaches, stolen data or proprietary knowledge, and sabotage.

Other authors state that risks can be categorized into those encountered by individual enterprises and those encountered by the whole supply chain (i.e., supply chain risks), which pertain to risks that have an impact on the entire supply network (Leat and Revoredo-Giha, 2013). The latter can stem from a single company within the supply chain or have external origins, potentially affecting multiple companies across the supply network simultaneously. For example, farmers' production

risks may contribute to the supply risks encountered by downstream entities such as the food industry and mass distributors. Similarly, the market risks faced by retailers can manifest as demand risks for the entire supply chain, often triggering the bullwhip effect throughout the network.

According to Mason-Jones and Towill (1998), supply chain risks include supply, demand, processes, control, and environmental risks. Supply and demand risks have already been illustrated, whereas process risks are those associated with interruptions in the process of creating value. On the other hand, control risks are linked to breakdowns or misapplications of the systems and standards used to control these processes. These definitions resemble those of operational and security risks provided by Manuj and Mentzer (2008). Finally, environmental risk encompasses events in the social, political, economic, technological, or natural environment that influence the conditions in which the supply chain functions. Notably, environmental risks can simultaneously impact all businesses within a supply chain, leading to disruptions in processes, controls, supply, and demand. The Covid-19 pandemic is a prime example, causing widespread lockdowns that forced factories to shut down, resulting in labor shortages and significant production delays, which in turn led to supply shortages across various industries. Furthermore, the pandemic disrupted the balance between supply and demand, compelling many industries to reconsider their distribution channels and market strategies. Other authors provide a more general definition of supply chain risks, stating that they encompass any risk associated with the flow of information, materials, and products from initial suppliers to final delivery (Christopher, Peck, Rutherford, and Juttner, 2003).

2.2 From risks to SCRES enhancers: a comprehensive framework

If a disruption triggers the occurrence of supply chain risks, the latter are closely linked to supply chain vulnerability. As the level of risk increases, a supply chain becomes more vulnerable to potential disruptions and unexpected crises, which could negatively impact its ability to operate effectively and efficiently (Kochan and Nowicki, 2018). According to Wagner and Bode (2009, p. 278), *“While a supply chain disruption is the trigger that leads to the occurrence of risk, it is not the sole determinant of the final loss. It seems consequential that also the susceptibility of the supply chain to the harm of this situation is of significant relevance. This leads to the concept of supply chain vulnerability. The basic premise is that supply chain characteristics are antecedents of supply chain vulnerability and impact both the probability of occurrence as well as the severity of supply chain disruptions”*. This means that the supply chain structure and upstream/downstream supply chain operations affect both the likelihood of disruptions and the severity of their impacts (Wagner and Neshat, 2010). Decisions related to safety stock levels, number and type of suppliers, localization of supply markets, distribution channels, and degree of vertical integration, among others, serve as precursors to supply chain vulnerability (Ambulkar, Blackhurst and Grawe, 2015; Kim, Chen, and Linderman, 2015; Kamalahmadi and Parast, 2016; Ivanov and Dolgui, 2019). To

maximize resilience, companies must proactively address their vulnerabilities. This involves implementing strategies and developing capabilities (i.e., SCRES enhancers) that reduce the incidence of disruptions and enhance their ability to respond to them. A significant body of literature, which has increased after the Covid-19 pandemic, has focused on the technologies, capabilities, and supply chain features that positively impact SCRES (Al Naimi et al., 2022). Although various terms have been used to describe these factors, in this article we refer to them as "SCRES enhancers."

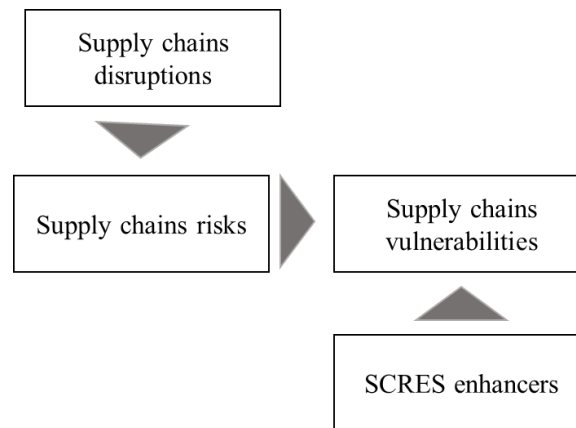
According to the literature, SCRES enhancers, such as flexibility, visibility, and redundancy, primarily stem from decisions made within operations and supply chain management (SCM). For example, a supply chain with full visibility across all nodes can anticipate issues related to supplies that fail to meet specified quality or quantity standards as well as detect and respond to changes in consumer needs. Visibility is in turn linked to the supply chain's digitalisation (Cherrafi, Chiarini, Belhadi, El Baz, and Chaouni Benabdellah, 2022) and practices such as information sharing (Al Naimi et al., 2022), sensing and interpreting events, continuity planning, and mapping of supply chain vulnerabilities (Han et al., 2020). Additionally, during an unexpected crisis, a flexible supply chain can adapt to shifts in demand by temporarily revising its product portfolio, packaging requirements, or production schedules. Although redundancy is an expensive strategy, it provides the ability to rely on stock buffers, ensuring that production can continue uninterrupted during demand spikes and avoid negative consequences such as the ripple effect (Ivanov, 2017). SCM decisions that enhance supply chain flexibility and redundancy include relying on multiple set covering (Alikhani, Torabi, and Altay, 2021), multiple suppliers (Al Naimi et al., 2022), direct-to-store delivery, inventory and stock buffering (Alikhani et al., 2021), reserve capacity, and critical machine maintenance (Munch and Hartmann, 2023).

Other SCRES enhancers mentioned by previous studies are agility, collaborative attitude, robustness, efficiency, ambidexterity, and sustainability (Agarwal et al., 2022; Al Naimi et al. 2022, Ali, Golgeci, and Arslan 2021; Jain, Kumar, Soni, and Chandra, 2017). However, SCRES is influenced by a range of factors, not all of which are directly related to SCM decisions. For instance, a company's culture, leadership, social capital, human resource management (HRM), ability to learn from past disruptions, and level of trust among supply chain partners are crucial determinants of a resilient supply chain (Duong and Chong, 2020; Jain et al., 2017; Hohenstein et al., 2015). Moreover, factors such as a firm's competitive strategy, the industry in which it operates, company's age, size, market position, and financial strength (including liquidity and access to funds) are key predictors of a company's stability and resilience during disruptions, thereby affecting SCRES (Ali et al., 2021; Chowdhury and Quaddus, 2017; Parast, 2022). While reducing a firm's vulnerabilities, these elements enhance its capacity to withstand and adapt to disruptions, creating a resilient foundation that extends beyond the supply chain design.

Our comprehensive research model is depicted in Figure 1. The figure summarizes the interplay of the aforementioned factors linked to SCRES, namely, supply chain disruptions, supply chain

risks, supply chain vulnerabilities, and SCRES enhancers. More specifically, disruptions trigger certain supply chain risks that are closely linked to underlying vulnerabilities, as previously explained. Vulnerabilities and SCRES enhancers are closely related, with the latter mitigating the former (Kochan and Nowicki, 2018).

Figure 1. Research framework (adapted from Kochan and Nowicki, 2018)



3. Methodology

To address these research questions, this study employs a case-based descriptive research approach that relies on multiple case studies. This methodology is particularly appropriate for examining emerging and complex real-life phenomena within real-life settings, which cannot be investigated independently of the context in which they occur, and is considered a relevant research approach when answering research questions such as ‘how’ and ‘why’ (Eisenhardt, 1989; Voss, Tsikriktsis, Frohlich, 2002). Furthermore, case study research is recommended for theories in their formative stages (Voss et al., 2002), as is the case with SCRES.

3.1 Case design and selection

As mentioned above, this study focuses on the agri-food industry, which is characterized by increasingly global and complex supply chains that have been significantly impacted by recent crises. Moreover, the emphasis on agri-food supply chains in our study was driven by the need to identify the specificities associated with the distinctive dynamics of this particular industry. In fact, it exhibits peculiarities that differ across various segments within the same industry, including variations in product shelf life, production cycles, consumer perceptions, and willingness to pay. These nuances call for the evaluation of disparities among companies operating within the same industry to determine whether specific SCRES enhancers are effective or ineffective in responding

to similar disruptions. This approach aligns with the contingency perspective of SCRES proposed by Parast (2022), which, reflecting the contingent resource-based view (Brandon-Jones, Squire, Autry, and Petersen, 2014), argues that there is no universal set of SCRES enhancers. Instead, these elements must be evaluated in relation to specific organizational and contextual factors. Furthermore, this theory supports the use of qualitative research designs. Owing to the complexity of SCRES enhancers, large-scale surveys may be difficult to implement. By contrast, qualitative research offers a more robust alternative, as it allows for a deeper examination of the dynamics between variables and facilitates the development of insightful conceptual frameworks.

The purposive sample utilized in this study comprises six distinct supply chains within the agri-food industry: durum wheat, dairy, fruit and vegetables, meat and cold cuts, and wine. The units of analysis were focal companies within these supply chains. The selection of cases was informed by a theoretical sampling approach (Eisenhardt and Graebner, 2007), whereby companies were purposefully chosen to ensure a comprehensive spectrum of perspectives and significant variations across key dimensions, such as their size, initial operational and supply chain configurations, and the impacts of disruptions experienced. It is noteworthy that the study of extreme events such as the Covid-19 pandemic and the Russian-Ukrainian war can be considered a source of significant theoretical contributions, aligning with our research objectives (Sodhi and Tang, 2021). In this study, the two crises are considered in conjunction as their effects overlap in time and scale. Furthermore, the focus is not on the specific effects of a single crisis; rather, they provide the ideal background for investigating our research questions.

Focal companies were selected based on two main criteria: (i) they must have a global orientation in their supply chain operations and (ii) they must have experienced recent disruptions affecting either the demand or supply side, or both. The resultant sample comprised a mixture of medium, large, and very large companies. Table 1 provides an overview of the selected case studies, including company descriptions, turnovers expressed in euro, details of their supply chains, mainly concerning supply and distribution strategies, and a characterization of logistics on a scale that ranges from totally outsourced to insourced. Appendix 1 provides more details on the sample companies.

Table 1. Case studies overview

Case study	Company description	Turnover in EUR (2022)	Supply chain	Supply chain features
Barilla	The company specializes in the production of pasta, baked goods, and related food products.	€ 4.6 bln	Durum wheat	<ul style="list-style-type: none"> · Strategic partnerships with suppliers, spot market · Low diversification of distribution channels

				· Outsourced logistics
La Linea Verde	The company is a producer of fresh and ready-to-eat fruits and vegetables, with a focus on the fourth range.	€ 340 mln	Vegetables, fourth range	<ul style="list-style-type: none"> · Upstream integration, strategic partnerships with suppliers, spot market · Low diversification of distribution channels · Partially insourced logistics
Berlucchi	The company is a sparkling wine producer, recognized as the creator of the Franciacorta DOCG.	€ 52 mln	Sparkling wine	<ul style="list-style-type: none"> · Upstream integration, strategic partnerships with suppliers · High diversification of distribution channels · Outsourced logistics
The Orsero Group	The company is a European leader in the distribution of fresh fruit and vegetables.	€ 1.2 bln	Fruit & vegetables	<ul style="list-style-type: none"> · Strategic partnerships with suppliers, spot market · High diversification of distribution channels · Partially insourced logistics
Lactalis (Meat and Cold Cuts Division)	The Lactalis Group in Italy is part of the French Lactalis Group, the world leader in dairy products.	€ 2.8 bln	Meat & cold cuts	<ul style="list-style-type: none"> · Sourcing from spot market · High diversification of distribution channels · Outsourced logistics
Fattorie Garofalo	The company is a global leader in buffalo farming and buffalo milk production.	€ 140 mln	Dairy	<ul style="list-style-type: none"> · Upstream integration, spot market · High diversification of distribution channels · Outsourced logistics

3.2 Data collection and analysis

To gather insightful and rich information and for triangulation, this study employed both semi-structured interviews with key respondents and secondary data sources (Voss et al., 2002). Specifically, we primarily collected data through semi-structured interviews carried out from September 2023 to December 2023. Interviews were conducted with key respondents, including Chief Executive Officers (CEOs), Chief Financial Officers (CFOs), Procurement Directors, and Supply Chain and Operations Managers, both in person and online, allowing for flexibility in

accommodating participants' preferences and geographical locations. On average, each interview session lasted approximately one hour, ensuring an in-depth exploration of the topics under investigation. To maintain the accuracy and comprehensiveness of the data collected, all interviews were recorded, transcribed, validated with the respondents and subsequently analysed, in line with Yin (1993) and Stuart, McCutcheon, Handfield, McLachlin, and Samson (2002) recommendations.

The research variables in the data collection encompassed descriptions of the company and its initial supply chain configuration, the impacts of recent disruptions, the vulnerabilities identified and highlighted by the unexpected crisis, as well as the SCRES enhancers existing before and developed after the crisis. Appendix 2 provides an extended version of this survey. Secondary data sources (internal company documents provided by interviewees and publicly available materials such as income statements, balance sheets, and annual and sustainability reports) were consulted between September 2023 and February 2024. For each case study, we searched for general companies' information and in-depth supply chain and operations descriptions.

Regarding data coding and analysis, relevant dimensions for the case study analysis were selected based on the reviewed literature and adopted research framework (Kochan and Nowicki, 2018; Shekarian and Parast, 2021). Specifically, we structured the coding around those dimensions deemed most suitable for explicating and organizing the case analysis: supply chain risks, vulnerabilities, and capabilities (i.e., SCRES enhancers). To broaden the investigation, we inquired about all elements crucial in addressing the disruptions encountered, ranging from strategic, tactical, and operational decisions within the SCM domain to softer organizational and cultural aspects, as well as contingent factors such as the company's longevity and financial stability, in line with previous research on SCRES.

The two coding steps are further detailed below, starting from the material collected through the interviews. The first stage of coding (Table 2) involved summarizing the effects of supply chain disruptions and vulnerabilities identified for each case study, as described by the interviewees. Furthermore, the critical capabilities, strategies, measures, and technologies essential for mitigating the repercussions of disruptions have been detailed, distinguishing those possessed before and those developed after the recent crisis.

Table 2: Framework for case analysis: first order code

	Disruptions that impacted the SC	Vulnerabilities highlighted by disruptions	SCRES enhancers available before the disruptions	SCRES enhancers developed after the disruptions
Case study A				
Case study B				
...				

The subsequent stage of coding (Table 3) aimed to establish a direct correlation between the impacts of disruptions and supply and demand risks, as well as between these risks and SCRES enhancers, whether pre-existing or developed post-disruptions, in addition to horizontal SCRES enhancers (i.e., those not only tailored to supply or demand risks).

Table 3: Framework for case analysis: second order code

	SCRES enhancers available before the disruptions and useful to face:		SCRES enhancers developed after the disruptions and useful to face:	
	Supply risk	Demand risk	Supply risk	Demand risk
Case study A				
Case study B				
...				

Finally, a cross-case analysis was conducted to enhance the robustness of the results, mitigate bias (Eisenhardt and Graebner, 2007; Yin, 2018), and enrich the findings (Yin, 2018). The cases were combined, resulting in a shortlist of SCRES enhancers that were deemed relevant for addressing demand risks, supply risks, or both. The coding process and results were externally validated by expert colleagues specializing in operations and supply chain management to ensure the reliability and credibility of the analysis in accordance with Yin’s (2003, p.34) recommendations.

4. Findings

The analyzed case studies unveiled varied impacts associated with the crisis under examination on the demand and supply sides. Across all the companies studied, there was consensus among managers that they had negative impacts on their profit margins due to increases in the prices of primary inputs, such as energy and fuel, as well as various raw materials. Moreover, each company encountered the consequences of fluctuating demand or disruptions within particular markets and sales channels, exhibiting varying outcomes contingent on their choices regarding buffer inventory levels and distribution channels. Regarding the supply side, disruptions’ impacts differ among the sample firms as they diverge in some crucial dimensions, such as vertical integration and shelf-life duration of their core products, which are crucial differences in the agri-food industry supply chains. For example, Orsero and Lactalis’s Meat and Cold Cuts Division experienced challenges in raw material sourcing because of delays in deliveries, logistics blockages, and constraints in certain geographies, while other companies have only been impacted by the rising costs of inputs such as energy, raw material, and packaging. On the demand side, the most evident negative impacts were related to rising and fluctuating prices of energy, raw materials, and currencies. This exacerbated negotiations with clients, often large retailers, making discussions more complex because of an increased demand for flexibility. For example, in the case of Lactalis, the closure of

deli counter sections disrupted forecasting mechanisms, leading to significant challenges in planning. While sales in traditional channels increased, those in deli counters and out-of-home consumption decreased, resulting in excess stock for certain products and stockouts for others.

In light of these crises, the most significant vulnerabilities identified included geographical dependence on specific markets for sourcing, fragmentation, and lack of standardization in sourcing routines. Additionally, inadequate supply chain planning -ranging from raw material availability to product placement on shelves- and a lack of coordination, particularly insufficient information exchange between departments, such as sales and operations, were also highlighted as critical issues.

At the same time, a series of SCRES enhancers have emerged as crucial to mitigate the abovementioned disruptions and related risks. Specifically, all firms within our sample, regardless of their level of vertical integration, emphasized the significance of strategic supplier management characterized by long-term partnerships, investments in suppliers' education, and research aimed at enhancing the quality of agricultural production. This strategic approach was deemed fundamental in addressing supply risk, with some companies continuing to invest in this SCRES enhancer beyond the cessation of the crisis. For instance, an interviewee underscored the importance of "*trust, long-term relationships, information exchange, and liquidity support through advance payments*" in suppliers' management. This is especially crucial in the agri-food sector, where farms are often small in terms of scale and financial resources. Moreover, we found upstream integration to be relevant in tackling shortages of raw materials and price volatility of raw materials. Another notable aspect of resilient supply chains was the diversification of supply sources and markets, sometimes in addition to a multiple sourcing policy, as observed in the practices of Barilla, Orsero, La Linea Verde, and Fattorie Garofalo among the cases analysed. This strategic decision is necessary, especially when upstream integration is partial or absent. Furthermore, according to the CFO of the Orsero Group, flexible contracts with suppliers and partially integrated inbound logistics, which enable logistics and sourcing flexibility, proved essential in managing the volatility of input prices and delays in the delivery of supplies, supporting the findings of Shekarian and Parast (2021). Additionally, certain companies were able to mitigate the negative impact of rising energy costs through pre-existing investments in energy efficiency enabled by photovoltaic panels, biogas, or inverter technologies.

Our study underscores the critical importance of the diversification of distribution channels and target markets in addressing demand risk. For instance, the General Manager of the Lactalis' Meat and Cold Cuts Division observed that "*the closure of fresh food counters during the pandemic disrupted predictive mechanisms, thereby challenging our planning processes. However, our adoption of a multichannel approach facilitated the mitigation of demand volatility.*" Similarly, Berlucci developed an online channel during the pandemic that is now a fully operational alternative channel. Additionally, strategic and tactical decisions in supply chain management, such as implementing capillary distribution networks and maintaining buffer inventory, positively

contribute to business continuity during the crisis for some companies. Nevertheless, our research reveals that not all SCRES enhancers yield benefits for all types of businesses. For instance, buffer inventory can present financial risks for companies such as Barilla, which operates in a market characterized by commodity price volatility, or it may prove impractical for products with a limited shelf life. Finally, where feasible, the adoption of flexible contracts with customers has emerged as an effective strategy to mitigate rising production costs.

Among the factors contributing to SCRES that are not directly associated with supply and demand risks, we found brand strength, company longevity, and financial stability, in line with the findings of Chowdhury and Quaddus (2017), Han, Chong, and Li (2020), and Parast (2022). Other SCRES enhancers mentioned by the interviewees that are not specific to facing supply or demand risks are contingency and recovery plans, digitalization, automation of processes, and a tendency towards vertical and horizontal collaborations.

Table 4 summarizes the SCRES enhancers that have proven crucial in the agri-food industry to mitigate supply and demand risks during the Covid-19 pandemic and Russia-Ukraine conflict, addressing our first research question. SCRES enhancers 11 to 17 have been particularly effective in mitigating both supply and demand risks; we call them horizontal SCRES enhancers.

Table 4. SCRES enhancers to mitigate demand and supply risks in the agri-food industry

Supply risk	Demand Risk
1. Upstream integration	7. Distribution channels/target markets diversification
2. Strategic supplier management	8. Flexible contracts with customers
3. Integrated inbound logistics	9. Buffer inventory
4. Diversification of supply sources/markets	10. Capillary distribution
5. Flexible contracts with suppliers	
6. Energy efficiency	
11. Automation	
12. Digitalization	
13. Collaboration	
14. Human Resource Management	
15. Contingency and recovery plans	
16. Financial solidity/liquidity management	
17. Brand positioning/company's age	

Our second research question investigates the reconfiguration of supply chain structures and operations following recent disruptions with the objective of improving SCRES. The evidence gleaned from our sample firms indicates that companies have enhanced existing decisions and strategies deemed crucial for SCRES, while simultaneously investing in new processes and occasionally redesigning their supply chains. Specifically, all sample companies persisted in their

investments to diversify their distribution channels and target markets, which, in turn, increased flexibility. The Orsero Group, a leading company in the exotic fruit trade, has undertaken several mergers and acquisitions operations to complete the diversification of its product portfolio, procurement sources, and sales channels. Certain firms in the sample expanded their buffer inventory to increase redundancy, whereas for others, this decision was inconvenient. It is the case of Barilla: according to the company's International Durum Wheat Purchasing Manager "*whit the extreme volatility of durum wheat's price, maintaining high levels of inventory has become risky; when prices decline, having substantial stock purchased at elevated prices can abruptly lead to losses on the product*".

Simultaneously, a prevalent trend among companies was to invest in more advanced planning and forecasting instruments to increase visibility, often accelerating the digitalization of supply chain operations and bolster coordination and information sharing across functions, triangulating procurement, production, and sales departments. For instance, Lactalis invested in more sophisticated planning and forecasting tools. This shift has led to a change in the sourcing strategy, with raw materials now received daily, based on the production requirements for the following day. Consequently, this approach has been integrated with suppliers, thereby increasing coordination among the entire supply chain. Barilla implemented market analysis and market intelligence tools to manage the durum wheat supply chain, along with software that automatically manages shelves and warehouse inventories based on daily sales. Instead Orsero Group completed the transition to an ERP system for inventory control with the objective of obtaining timely information on product management. Additionally, the company invested in artificial intelligence to generate predictive insights into product flows along the supply chain.

In response to supply shortages, product and process innovations have been implemented to reduce reliance on critical and scarce raw materials, and process automation has been adopted to decrease dependence on personnel. In particular, two companies, Fattorie Garofalo and Lactalis, have expanded the use of frozen raw materials to address the limitations associated with the limited shelf life of their products. Furthermore, investments have been directed towards centralizing raw materials and critical components sourcing, while also integrating upstream processes within the value chain. For example, La Linea Verde launched a project to centralize high-value materials purchasing at a European level that led to the establishment of a dedicated central purchasing department and has resulted in cost efficiency improvements; similarly, Fattorie Garofalo developed new centralized processes for milk purchasing.

Finally, investments in HRM, such as new training programs, revised compensation structures, job rotation initiatives, and the introduction of new professional roles aligned with evolving business ecosystems, have also emerged as SCRES enhancers pursued by several sample firms after the crisis. These observations align with the research of Hohenstein et al. (2015), who assert that effective HRM can bolster resilience by enhancing managers' capacity to interpret diverse information, exploit opportunities, and detect threats. This is exemplified by La Linea Verde's

actions, which introduced new professional roles, including function coordinators who report directly to the CEO. These roles aim to improve communication between production facilities, standardize best practices, and streamline decision-making processes to enhance organizational agility. Additionally, a new position has been established in the company to oversee the commercialization of surplus goods acquired from members of the Producer Organization (PO).

Table 5 summarizes our findings, presenting SCRES enhancers that are crucial for addressing supply risk (n° 1-9), demand risk (n° 10-14), or both (n° 15-22). More in detail, "X" denotes SCRES enhancers existing before, and "O" denotes SCRES enhancers developed after the analyzed disruptions. "XO" identifies SCRES that were present before the crises and further developed after.

Table 5. SCRES enhancers available before and developed after recent disruptions

	Orsero	La Linea Verde	Berlucchi	Barilla	Lactalis	Fattorie Garofalo
1. Upstream integration	O	X	X	X		X
2. Strategic supplier management	X	XO	X	X	XO	X
3. Integrated inbound logistics	X					
4. Division dedicated logistics hub					O	
5. Diversification of supply sources/markets	XO	X		O	O	X
6. Flexible contracts with suppliers	X					
7. Product innovation to decrease dependence from critical raw materials				O	O	O
8. Energy efficiency	O		X			X
9. Centralized sourcing of raw materials/components		O				O
10. Distribution channels/target markets diversification	XO	X	XO	X	X	X

11. Flexible contracts with customers	X					
12. Advancements in planning & forecasting				O	O	O
13. Buffer inventory			XO	X		
14. Capillary distribution					X	
15. Automation		XO		X O		
16. Digitalization	O	X	X	X	X	O
17. Collaboration		O	X		O	
18. Information sharing	O	O		O	O	
19. Human Resource Management	XO	O		XO	O	
20. Contingency and recovery plans	O				XO	
21. Financial solidity/liquidity management	X	X	X	X	X	X
22. Brand positioning and company's longevity	X	X	X	X	X	X

Figures 2 and 3 illustrate the findings of this study within the context of the reference framework adopted. Specifically, Figure 2 presents SCRES enhancers that address supply risk, whereas Figure 3 displays SCRES enhancers aimed at mitigating demand risk within the agri-food industry. In both figures, each element categorized as an SCRES enhancer is labelled with either a "+" or a "-" symbol: "+" denotes a solely positive impact, whereas "-" indicates that due to varying characteristics of the supply chain, the element may have a negative effect.

Figure 2. SCRES enhancers to face supply risk in the agri-food industry

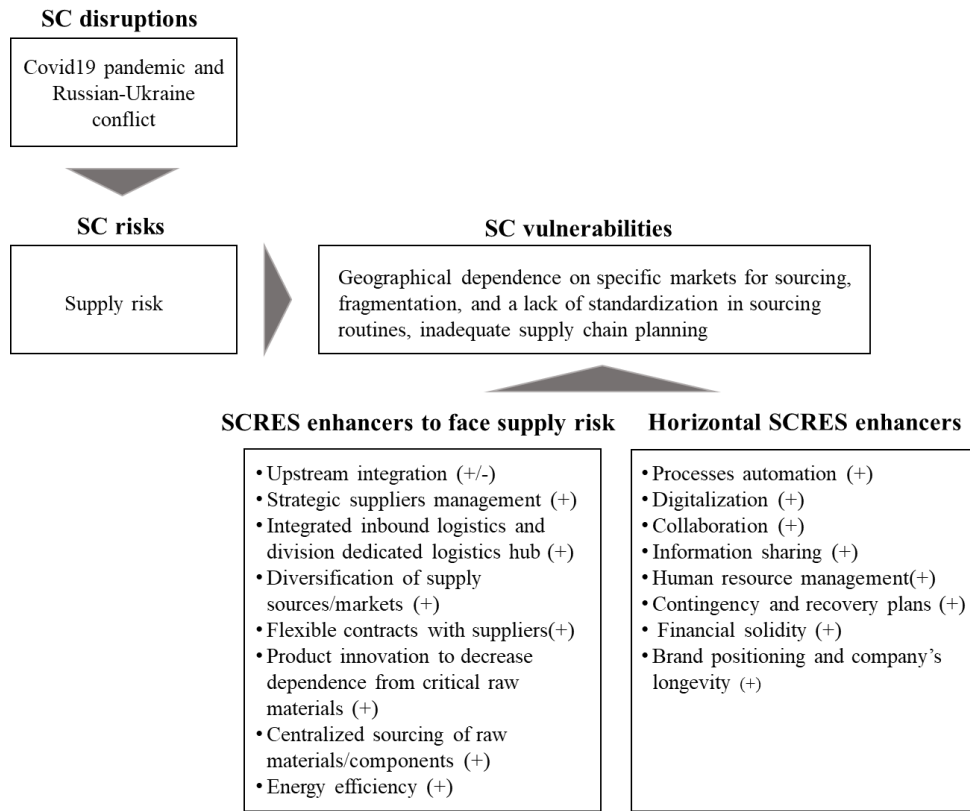
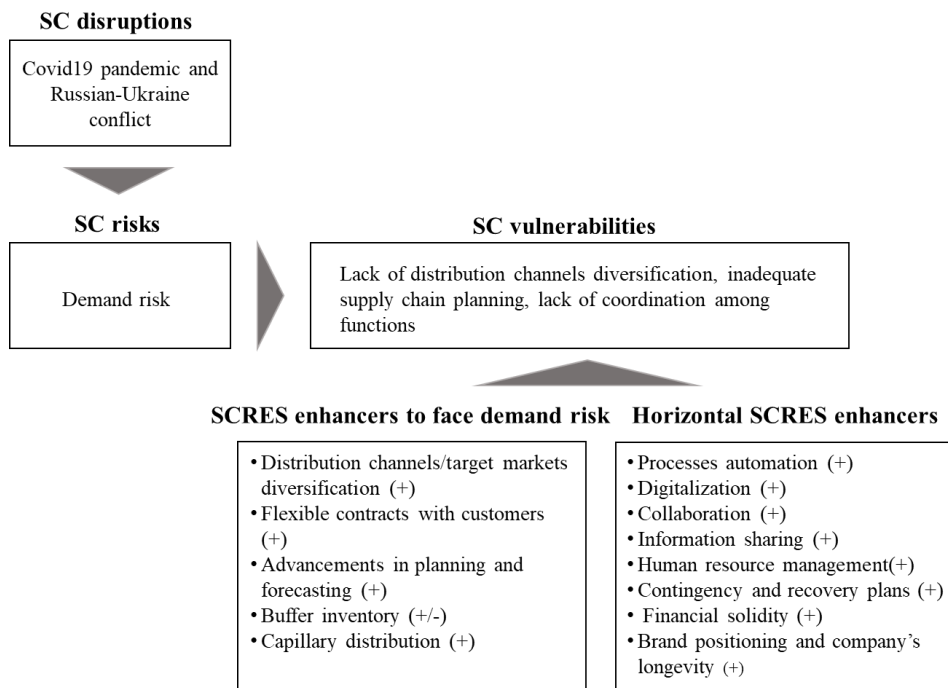


Figure 3. SCRES enhancers to face demand risk in the agri-food industry



5. Discussion

This paper begins by emphasizing the need to understand which SCRES enhancers are truly necessary to address supply and demand risk, adopting a contingency perspective on SCRES (Parast, 2022), and exploring which SCRES enhancers organizations invested in following the Covid-19 pandemic and the Russia-Ukraine conflict. Based on semi-structured interviews with key respondents representing six distinct supply chains in the agri-food industry, this study demonstrated that no universal set of SCRES enhancers is applicable across all companies and industries. Instead, firms must prioritize specific SCRES enhancers based on their unique business characteristics. Within the agri-food sector, key differentiating factors include product shelf life, emphasis on commodity versus specialty goods, and the structure of sourcing markets. Consequently, while this study identifies a core set of SCRES enhancers relevant to face supply and demand risks, these factors suggest that certain strategies may benefit one company while being impractical or proving less effective for another. For instance, buffer inventory may negatively impact companies dealing with products prone to high price volatility or limited shelf life. Similarly, upstream integration is not always feasible.

It is also noteworthy that not all companies in the sample possessed every SCRES enhancer prior to the crisis analyzed; however, this did not necessarily correlate with severe disruption impacts. This finding may be attributed to pre-existing levels of supply chain vulnerability. For example, an IGP-certified producer like Berlucci, characterized by upstream integration, low outsourcing, and a relatively straightforward supply chain, was characterized by few vulnerabilities and, in turn, experienced a less severe impact from the Covid-19 pandemic and the Russia-Ukraine war compared to companies with a more complex and international supplier base, such as the Orsero Group or Barilla.

Additionally, this research aligns with Weick and Sutcliffe's (2011, p. 1) assertion that "*unexpected events often audit resilience*". Many forward-thinking firms are leveraging challenges as opportunities to reassess their processes and become more resilient instead of simply returning to their former state. Indeed, recent disruptions have hastened the need for global supply chains to evolve in changing environments, speeding up the digitization and automation of various supply chains, and propelling the transition towards more sustainable production methods (Ivanov and Dolgui, 2020).

In particular, this study highlights that, in response to recent disruptions, companies are increasingly adopting strategies characterized by a focus on adaptability through supply chain approaches that prioritize flexibility through supply sources, markets, and distribution channel diversification, combined with the implementation of advanced planning and forecasting tools to enhance visibility and traceability. Product innovation has become another focal point, with efforts directed at reducing dependence on critical materials or markets while also committing resources to enhance energy efficiency. Firms also prioritize improved information-sharing mechanisms and

investment in human resource management, including the addition of new professional roles tailored to resilience needs. A notable transformation occurs within organizational cultures across these companies, emphasizing improved interdepartmental communication as a foundation for resilience. Simultaneously, investments in automation are rising, thereby reducing reliance on human labor, which is particularly beneficial in mitigating the impact of health-related disruptions, such as pandemics.

In summary, by embracing the inevitability of uncertainty and volatility, companies are designing and managing their operations with a strong emphasis on resilience, innovation, and sustainability, thereby enhancing their preparedness for future unforeseen crises.

6. Conclusion

This study contributes to the literature on supply chain risk management and SCRES by aiming to identify which SCRES enhancers have been most effective in addressing supply and demand risks during the recent crises associated with the Covid-19 and Russia-Ukraine conflict. To the best of the authors' knowledge, previous research on SCRES has largely focused on identifying capabilities that enhance a firm's ability to respond to disruptions. As a result, the capability perspective has dominated the understanding of SCRES (Wang, Yan, Jia, Chen, 2023). Moreover, while the literature has extensively examined and categorized SCRES enhancers, a gap remains in connecting specific SCRES enhancers to particular supply chain risks, which is crucial, given that organizations must allocate resources in alignment with their specific priorities to avoid overinvestment in resilience.

This study addresses this gap by adopting the contingency perspective of SCRES, which argues that there is no universal set of SCRES enhancers; instead, these elements must be evaluated in relation to specific organizational and contextual factors (Parast, 2022). In this context, this study examines which SCRES enhancers were most effective in mitigating the impacts of the aforementioned crises, focusing on a sample of six distinct supply chains within the agri-food industry, including durum wheat, dairy, fruit and vegetables, meat and cold cuts, and wine. The selection of cases followed a theoretical sampling approach (Eisenhardt and Graebner, 2007): companies were deliberately chosen to capture a broad range of perspectives and significant variation across key dimensions, such as initial operational and supply chain configurations, as well as the specific disruptions they experienced. Additionally, the study examined the reconfiguration of supply chains and modifications in daily practices that were implemented in direct response to the vulnerabilities exposed by these crises, with the aim of enhancing resilience.

The study findings reveal a common set of SCRES enhancers prevalent within the agri-food industry, including upstream integration, strategic supplier management, diversification of supply

sources and markets, flexible contracts with suppliers/customers, integrated inbound logistics, diversification of distribution channels and markets, capillary distribution, digitalization, collaboration, HRM, contingency and recovery plans, financial solidity, brand positioning, and company longevity. These results corroborate the findings of Shekarian and Parast (2021), who assert that flexibility, collaboration, agility, and redundancy are essential for mitigating supply and demand risks. Simultaneously, the study identifies that not all SCRES enhancers are universally beneficial across all types of businesses within the industry: while buffer inventory may be natural for businesses such as wine production, it can entail financial risks for those dealing with commodities subject to high volatility or may prove impractical for products with limited shelf life. Similarly, upstream integration may only be a viable option for businesses in which primary agricultural production is both economically advantageous and feasible. In different situations, strategic supplier management, centralized sourcing of critical materials and components, and direct involvement in suppliers' companies may represent a more prudent course of action.

In the realm of operational strategies and supply chain reconfiguration aimed at enhancing SCRES, which constituted our second research question, our investigation delineates four prominent trends observed among the analyzed companies: i) diversification of supply sources, markets, and distribution channels; ii) adoption of advanced planning and forecasting tools to enhance visibility and traceability; iii) enhancement of information sharing mechanisms; and iv) investments in HRM and new professional figures. Moreover, almost all companies in the sample have undertaken substantial efforts to transform their organizational culture, focusing on enhancing interdepartmental communication and improving HRM.

From a scholarly perspective, this study enriches the existing literature on SCRES by enhancing the comprehension of SCM strategies and practices that effectively mitigate supply and demand risks. Moreover, it deepens insights into the agri-food sector, which holds notable importance in resilience research owing to its pivotal role in ensuring food security and grappling with the escalating complexity and vulnerability of supply chains. From a practical viewpoint, this study contributes to an enhanced comprehension of essential strategies and capabilities for navigating challenges related to global sourcing, outsourcing, and demand management, particularly during periods of uncertainty.

The limitations inherent in this study pertain to the sample size and qualitative nature of the gathered data. Specifically, future research endeavors may aim to increase the number of cases analyzed and investigate our research questions through a theory-building approach (Eisenhardt, 1989). At the same time, Parast (2022) highlights that case-based research on SCRES is valuable for uncovering contingencies that may be overlooked in existing literature. This type of research also offers additional insights that contribute to theory development, and can inform further theory testing through subsequent survey-based studies.

Furthermore, future studies could delve into the intricate interplay between SCRES enhancers and other supply chain risks, such as process- and control-related risks. Finally, the findings of this study could be extended and validated across various industries to enhance the generalizability of the results and elucidate discrepancies among different sectors.

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Appendix 1

Barilla

Barilla is an Italian company specializing in the production of pasta, baked goods, and related food products. This diversification has strengthened its position as a leading global food producer. The firm sources its raw materials, including durum wheat, soft wheat, rye, tomatoes, basil, and vegetable oils from various regions across the globe, prioritizing local supply chains and sustainability. While most suppliers are based in Italy and Europe, a smaller proportion come from the Americas and Asia. For durum wheat, as for other strategic product categories, Barilla adopts an integrated supply chain management approach with extensive information sharing during the planning phase and direct control over all stages. To reduce environmental impact, the company prioritizes rail transport for materials and products. Barilla also forms partnerships and pursues certifications to uphold high ethical and environmental standards, particularly when sourcing materials such as cocoa and sugarcane from regions with social risk factors.

La Linea Verde

La Linea Verde is one of Italy's largest producers of prepackaged salads, fresh plant-based ready meals, and fresh beverages. The company primarily sources its IV gamma salad ingredients from Southern Italy, particularly the Piana del Sele region, while also considering other regions and countries based on market conditions and quality. Its supply chain integrates over 70 horticultural partners and covers 2,000 hectares of cultivation. Specifically, the company sources approximately 60% of its products from OP Sole e Rugiada, a consortium that brings together its associated farmers, while the remaining 40% is supplied by independent farmers and raw material traders. Downstream, the company distributes its products to distribution centers or directly to large retailers, primarily through third-party logistics providers. This short, traceable supply chain ensures consistent year-round quality. This process includes rigorous field control, precise washing, and drying of raw materials, followed by careful packaging and refrigerated transport.

Berlucchi

Guido Berlucchi S.p.A., based in Borgonato, primarily relies on grapes as the key raw material. The company's procurement strategy includes 115 hectares of company-managed vineyards and 450 hectares of partner vineyards. This supply chain is highly integrated, with all field operations overseen by Berlucchi's personnel, except for grape harvest, which is outsourced. Suppliers are required to comply with the Berlucchi Sustainable Viticulture Protocol (PBVS) and maintain organic certification. Once hand-harvested, the grapes are transported to the winery for pressing and fermentation to produce Franciacorta wine. Berlucchi's sales network spans Italy and 30 international markets and leverages a multichannel approach that includes Ho.Re.Ca, large

retailers, and online platforms. Logistics operations are outsourced to third-party carriers, who handle product distribution from a central warehouse.

The Orsero Group

The Orsero Group is the leading distributor of fruits and vegetables in Mediterranean Europe, handling and distributing over 800,000 tons of produce annually. The company manages the entire supply chain from sourcing and importing to quality control, storage, ripening, processing, marketing, and distribution. It operates with approximately 2,000 suppliers across more than 70 countries. The product range includes two key categories: multi-origin, multi-sourced fruit (covering most types of fruit), and year-round core products such as bananas and pineapples, which form the heart of its business. Orsero's import logistics involves transport by sea and air. The company operates 25 storage facilities, 22 ripening centers, and 4 fresh-cut processing centers in Italy. Quality control and monitoring extend not only to agricultural practices and cultivation standards but also to social and environmental compliance. In terms of commercialization and distribution, Orsero operates 37 wholesale fruit and vegetable market stands and generates 50% of its sales through large retailers channel.

Fattorie Garofalo

Fattorie Garofalo is the leading producer of Mozzarella di Bufala Campana and other buffalo milk products including cheese, ricotta, butter, and mascarpone. The company operates seven farms housing 12,000 buffaloes across approximately 3,000 hectares. These farms produce a significant portion of the feed for livestock, with approximately 75% of the feed sourced internally. The remainder, primarily soy, is purchased from international markets. The company runs three industrial facilities that handle 38 million liters of milk annually and produces 10 million kilograms of milk each year.

The logistics are fully outsourced. Approximately half of the company's products are sold in the Italian market, while the other half are exported to both EU and non-EU countries. The company's sales channels are diverse, with 85% of its products distributed through large retailers and the remaining through food service and industrial supply.

Lactalis (Meat and Cold Cuts Division)

The Lactalis Group specializes in the production of a wide range of dairy products, including milk, butter, cream, cheese, and dairy desserts. The company adapts its product range to local consumption patterns to meet diverse customer needs. It exports over 17,000 containers, including globally recognized brands such as Président and Galbani, as well as regional brands such as Pride and Laicran, to more than 100 countries. The Meat and Cold Cuts Division, which is the focus of the interview, sources fresh raw materials primarily from foreign suppliers (Italy and the EU),

while other consumables are obtained from around the world. Processing is carried out at the main plant in Melzo (Italy), although certain product categories are purchased directly from third parties. The finished products are distributed across various sales channels in Italy (large retailers, Ho. Re. Ca. and traditional trade), as well as internationally.

Appendix 2

Areas of investigation	Questions
Impact of disruptions and identified vulnerabilities	1.A Describe the impact that recent crises caused by Covid-19 and the Russia-Ukraine war have had on the company.
	1.B In light of the above, what vulnerabilities contributed to these impacts?
Supply chain and operations structure before disruptions	2.A What was the design of the supply chain and operations at the time of these disruptions?
	2.B What strategies, containment measures, technologies (e.g., horizontal/vertical collaborations, traceability systems, safety stocks, multiple suppliers) proved crucial in mitigating the specific disruptions faced by the company?
Changes and decisions made post-disruptions to make the supply chain more resilient	3.A How has the company redesigned its supply chain and operations, if at all, to enhance SCRES?
	3.B What is the objective of the decisions made (e.g., becoming more flexible, gaining more visibility, etc.)?

RP3: The impact of supply chain resilience on sustainability and financial performance: the mediating role of investments in sustainability

Abstract

Introduction - This study explores the relationship between supply chain resilience (SCRES) and sustainability. More specifically, it analyzes the impact of SCRES on firms' sustainability and financial performance, evaluating the mediating role of investments in sustainability (e.g., investments in renewable energy, electric vehicles, or employee well-being).

Methods - This study is based on a survey of responses from 713 Italian firms regarding the impacts of recent disruptions, resilience, and sustainability. A structural equation modeling (SEM) approach using partial least squares (PLS) was adopted to test the model.

Findings - This study reveals that SCRES exerts a direct and positive influence on firms' sustainability and financial performance. The analysis indicates that SCRES has a more substantial impact on environmental and social sustainability than on economic sustainability. Moreover, the model highlights the mediating role of sustainability investment in the relationship between resilience and sustainability. These findings indicate that resilient supply chains are more likely to adopt sustainable practices, supporting the alignment of resilience and sustainability.

Originality/Value - This study significantly contributes to theory by empirically testing the relationship between SCRES and sustainability, addressing a critical gap in the literature. To the best of the author's knowledge, this is also the first study to separately analyze economic sustainability and evaluate the mediating effect of sustainability investments using an SEM model.

1. Introduction

In recent times, global supply chains have faced significant challenges. The Covid-19 pandemic and its aftermath, conflicts between Russia and Ukraine, and Israel and Palestine, along with the pressures from climate change and a globalized economy, have all played a role (Qin, Su, Umar, Lobonç, and Manta, 2023; Henrich, Li, Mazuera, and Perez, 2022). The consequences of the aforementioned crises -such as logistics disruptions and the closure of supply markets and distribution channels- have led to several trends, including a push toward protectionism and the relocation of companies' sourcing markets and production sites (Gölgeci, Gligor, Bayraktar, and Delen, 2023). At the same time, increasing awareness of climate change and its effects, coupled with pressure from civil society and efforts to meet international commitments like the Paris Agreement, are pushing legislators to implement stricter environmental regulations (Ahmed, Ahmad, Rjoub, Kalugina, and Hussain, 2022). Concurrently, these tensions have accelerated the rate of change within companies, particularly the speed of the sustainability transition (mainly driven by the energy transition), as well as the digitization and automation of various supply chains (Ivanov and Dolgui, 2020).

These developments indicate that recovery from disruptions, and even decisions to proactively anticipate the consequences of disruptions, can resemble an acceleration of existing trajectories of change rather than merely creating a new normal, more akin to pre-existing conditions. These considerations underscore the critical importance of sustainability and resilience in supply chains (Fahimnia and Jabbarzadeh, 2016), as they are intertwined and form the core of contemporary discussions surrounding supply chain viability (Ivanov, 2022). Indeed, supply chains are increasingly required to enhance their sustainability performance across the triple bottom line (Ahi & Searcy, 2013) while simultaneously proactively addressing rising vulnerability and uncertainty (Ali, Mahfouz, & Arisha, 2017) through the development of resilient capabilities such as flexibility, redundancy and agility.

In the literature, many authors have endeavored to relate supply chain resilience (SCRES) and sustainability, arriving at different conclusions concerning the relationship between these two concepts (Marchese, Reynolds, Bates, Morgan, Clark, and Linkov, 2018). Some authors support the hypothesis that sustainability and its practices enhance SCRES, whereas others suggest that resilience is a component of sustainability, which is the ultimate objective. Additionally, some researchers argue that it is impossible to combine these concepts, as there is no hierarchical relationship between them. So, despite the apparent connection between resilience and sustainability, a clear correlation remains elusive, necessitating further detailed investigation (Ivanov, 2018; Negri, Cagno, Colicchia, and Sarkis, 2021).

To address this gap, this study investigates the relationship between SCRES and sustainability, focusing on the overarching research question (RQ):

- RQ: *What is the impact of SCRES on sustainability?*

Notably, sustainability is a multifaceted concept typically categorized into three dimensions: social, environmental, and economic sustainability (Ahi & Searcy, 2013). While previous literature has established a significantly positive correlation between SCRES and operational performance (Alkhatib and Momani, 2023; Belhadi, Kamble, Jabbour, Gunasekaran, Ndubisi, and Venkatesh, 2021; Chowdhury, Hossan, Quaddus, and Agarwal, 2019), research on the relationship between SCRES and other performance outcomes, such as sustainability, remains limited. This study, therefore, tests a model in which SCRES is posited to positively influence sustainability performance, examining sustainability through its three key components: environmental, social, and economic. Additionally, the study evaluates the mediating role of sustainability investments in the relationship between SCRES and sustainability performance. To test this model, a structural equation modeling (SEM) approach using partial least squares (PLS) was adopted, based on survey data from 713 Italian firms regarding the impacts of recent disruptions, resilience, and sustainability.

The remainder of this paper is organized as follows. Section 2, provides a theoretical background and develops the model's hypothesis. Section 3 presents the research methodology. Sections 4 and 5 present and discuss the major findings of this study, respectively. Finally, in Section 6, conclusions, limitations, and directions for future research are outlined.

2. Theoretical model and hypotheses development

2.1 The relationship between SCRES and sustainability

SCRES is "*the adaptive capability of a supply chain 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 plans to transcend the disturbance and restore the supply chain to a robust state of operations*" (Kamalahmadi and Parast, 2016, p.121) at an acceptable cost and time (Ribeiro and Barbosa-Povoa A., 2018). Many researchers have endeavored to identify and catalog the antecedents of SCRES through both qualitative and quantitative studies (Hohenstein, Feisel, Hartmann, and Giunipero, 2015; Ali et al., 2017; Al Naimi, Faisal, Sobh, and Bin Sabir, 2022), leading to a body of literature that examines capabilities, technologies, practices, and organizational traits associated with resilience.

Among the factors identified in previous studies as enhancers (i.e., antecedents or elements) of SCRES, sustainability stands out (Eggert, and Hartmann, 2023; Negri et al., 2021; Silva, Pereira, and Hendry, 2023). According to the most globally accepted definition from the World Commission on Environment and Development, sustainability is widely recognized as the practice of utilizing resources to fulfill the needs of the present generation without compromising the capacity of future generations to meet their own needs (WCED, 1987). This definition emphasizes the importance of preserving natural resources and ensuring their availability for future use, thereby promoting the long-term viability of human society and the environment. However, the concept of sustainability is broader and encompasses not only environmental sustainability, but

also social and economic sustainability. Integrating these dimensions, sustainability ensures that economic growth does not occur at the expense of environmental and social well-being. This multifaceted approach to sustainability is critical for building resilient supply chains capable of withstanding disruptions and adapting to changing environmental conditions.

From this perspective, SCRES is the ultimate objective of the system, and practices developed to increase sustainability have been proposed as contributing factors to it (Ahi and Searcy, 2013; Bansal and DesJardine, 2014; Cherrafi, Chiarini, Belhadi, El Baz, and Benabdellah, 2022; Closs, Speier, and Meacham, 2011). For instance, Ahi and Searcy (2013) found that a supply chain with a diversified economic portfolio is more sustainable from an economic point of view and less vulnerable to location-specific downturns, and a supply chain that adheres to environmental sustainability by utilizing non-toxic chemicals would incur fewer losses from a chemical spill. Furthermore, they demonstrated that high-quality healthcare provided to a company's employees is less likely to result in workforce capacity loss during a disease outbreak. Similarly, Cherrafi et al. (2022) found that specific sustainable practices, such as the circular economy, together with digital technology adoption, can be positively associated with resilience.

However, a second stream of literature posits that there is no hierarchical relationship between the concepts of sustainability and resilience. Di Paola, Cosimato, and Vona (2023) demonstrated that the connections between these two concepts are complex and can yield paradoxical outcomes, where sustainability may both decrease and increase after a company implements actions to enhance resilience and vice versa. Thus, SCRES can both increase and decrease as a consequence of investments in sustainability. For example, working exclusively with suppliers who adhere to sustainability practices can make it more challenging for a company to switch suppliers during disruptions. Additionally, rationalizing resource use along the supply chain may lead to reduced stock levels by eliminating unnecessary redundancies, which can limit the supply chain's ability to respond to disruptions (Levalle and Nof, 2015). According to Ivanov (2018), establishing long-term strategic relationships with suppliers and securing stable employment relations in supply regions can conflict with the flexibility required in the supply base to mitigate the ripple effect through multiple sourcing and backup facilities. Other practices that enhance sustainability, such as cost efficiency and waste minimization, can negatively affect resilience by reducing inventories throughout the supply chain. However, investments in supply chain visibility through traceability systems or process automation can positively affect both SCRES and sustainability.

According to Marchese et al. (2018), there is a third perspective that integrates resilience and sustainability, suggesting that SCRES is a component of sustainability and not the opposite. The Resilience Alliance, an international research organization, has significantly promoted this view among academic institutions and government agencies. Supporters of this framework argue that sustainability defines the global objectives of the system, whereas SCRES participates in the process of meeting these objectives (Anderies, Folke, Walker, and Ostrom, 2013) giving the supply chain the ability to withstand unexpected crises while maintaining control over functions and structures.

Several quantitative studies support this finding. For example, Walker, Pearson, Harris, Maler, Li, Biggs, and Baynes (2010) explores the consequences of changes in a system's resilience on the sustainability of resource allocation decisions, as measured by Inclusive Wealth using probabilistic risk analysis with sustainability defined as non-decreasing social welfare over time. Their findings indicated that resilience is an essential component of any comprehensive measure of sustainable development, echoing the conclusions of Maler (2008). Instead, Saunders and Becker (2015) identified risk management as an element that enhances SCRES, which in turn contributes significantly to sustainability performance. They used this framework to examine risks in communities that are highly exposed to earthquakes in New Zealand and concluded that reducing risk enhances both resilience and sustainability. Another study presented resilience as one of the four perspectives on sustainability, alongside security, reliability, and renewal. Within this spectrum, sustainability ranges from a secure or static state (preserving the status quo) to a state of renewal that facilitates rapid change and comprehensive reorganization (Seager, 2008). These insights collectively emphasize that both risk management and resilience are integral to sustainable development. By reducing vulnerabilities and enhancing adaptive capacities, communities and supply chains can achieve a balance that supports enduring social, economic, and environmental wellbeing.

Following this line of argument, we propose our overarching hypothesis, which is later divided into two sub-hypotheses:

Hp1: SCRES has a positive influence on sustainability

Considering the multiplicity of meanings and interpretations of sustainability due to the abundance of sustainability indices and assessment frameworks (e.g., Böhringer and Jochem, 2007; Singh, Murty, Gupta, and Dikshit, 2012), a clear definition of sustainability performance is lacking. Drawing inspiration from Büyükoçkan and Karabulut (2018), we define sustainability performance as *“the overall net outcome of a company's economic, environmental, and social impacts, measured against a defined baseline.”* However, in this study, when using the term “sustainability performance,” we refer specifically to a company's environmental and social sustainability, while the term “financial performance” address its economic sustainability.

The reason for this decision is that the relationship between SCRES and financial performance may differ, as investments to enhance SCRES can be costly. For instance, the well-known trade-off between redundancy and efficiency highlights that, while redundancy reduces vulnerabilities in a supply chain, it can also be an expensive strategy with negative impacts on financial performance (Sajjad, 2021). Concurrently, some studies support the notion that SCRES positively influences a firm's financial performance. For example, Li, X., Wu, Q., Holsapple, C. W., & Goldsby, T. (2017) argue that SCRES, characterized by supply chain alertness, preparedness, and agility, is not merely a cost of doing business. Rather, the attention, effort, and resources dedicated to resilience-driven practices can result in significant financial outcomes. Li et al. (2017) found that among the three resilience dimensions, supply chain preparedness is the strongest forecaster for a firm's financial performance. Similarly, Ruel and El Baz (2023) demonstrated the positive

impact of SCRES on financial performance through an analysis of data collected from 398 French firms.

To capture the relationship between SCRES and economic sustainability separately from the impact of SCRES on environmental and social sustainability, we propose the following two hypotheses.

Hp1a: SCRES positively affects sustainability performance

Hp1b: SCRES positively affects financial performance

2.2 The relationship between investments in sustainability and sustainability and financial performance

A stream of research examines the relationship between investments in sustainability, sustainability, and financial performance. For example, using a SEM approach, Indriastuti and Chariri (2021) demonstrated that green and corporate social responsibility (CSR) investments positively impact both financial performance and sustainability performance. The findings of this study align with previous research, such as Saxena and Khandelwal (2012), which demonstrated that green investments positively affect sustainability performance.

Moreover, numerous studies provide evidence supporting a positive relationship between ESG scores and firms' financial performance (Friede, Busch, and Bassen, 2015). For instance, some researchers have found that companies adopting robust sustainability practices and policies significantly reduce both the cost of debt and equity (Bhojraj and Sengupta, 2003; Schauten and van Dijk, 2011). Additionally, several studies have demonstrated a positive correlation between sustainability initiatives and firms' stock prices (Aktas, de Bodt, Cousin, 2011; Bebcuk, Cohen and Ferrell, 2009). Other scholars have examined the broader positive impact of sustainable practices on financial performance. For example, Darnall, Henriques, and Sadorsky (2008) showed that firms adopting comprehensive environmental practices that leverage their complementary resources and capabilities experience improved overall business performance. Moreover, other researchers assert that responsible behavior and a firm's environmental efficiency are key determinants of better market performance and profitability (Derwall, Guenster, Bauer and Koedijk, 2005; Karpoff, Lott and Werly, 2005). Moreover, evidence supports a positive relationship between firms' investments in social sustainability and their financial performance. Huselid (1995) demonstrated that investments in high-performance work practices, such as performance management systems, incentive compensation, and employee involvement, are associated with lower employee turnover, increased productivity, and improved corporate financial performance. Similarly, Faleye and Trahan (2011) find that announcements of workplace-friendly practices lead to a significant increase in ROA.

Following this reasoning, we propose our second hypothesis, which is split into Hypotheses 2a and 2b.

Hp2a: Investments in sustainability positively influence sustainability performance

Hp2b: Investments in sustainability positively influence financial performance

2.3 The mediating role of sustainability investments

Recent research has increasingly linked the concepts of SCRES and sustainability, giving rise to the notion of a "resiliently sustainable" supply chain that integrates the socio-ecological perspective of resilience (Fahimnia and Jabbarzadeh, 2016; Negri et al., 2021). From a socio-ecological perspective, a resilient system does not attempt to revert to its original state after disruptions but instead evolves toward more efficient and adaptable states (Folke et al., 2021). This perspective has been crucial in shaping the connection between resilience and sustainability, particularly as globalization has added layers of complexity and vulnerabilities to production systems, forcing supply chains to dynamically adapt to variability and pursue more sustainable trajectories (Nyström et al., 2019).

From this perspective, resilience serves as a driver of sustainability rather than vice versa. Effective SCRES strategies ensure supply chain continuity by adapting to market fluctuations and thereby securing economic returns. Simultaneously, these strategies foster social justice through job creation or retention, and promote environmental sustainability by facilitating the transition from traditional to alternative material sources (Carter et al., 2019). For instance, after the Covid-19 pandemic several opportunities for more sustainable development have been revealed, showing that resilience in response to crises can align with sustainability goals (Sarkis et al., 2020).

Moreover, the alignment of SCRES and sustainability is reinforced by the idea that the same strategies that enhance resilience, such as green initiatives and CSR activities, also contribute to superior sustainability performance. These early investments in sustainability not only improve environmental outcomes, but are also linked to better financial performance, demonstrating the dual benefit of integrating resilience with sustainability goals (Indriastuti and Chariri, 2021). Building on this framework, we examine the mediating role of sustainability investments in the relationship between SCRES and both sustainability, and financial performance. Accordingly, we present the following hypothesis.

Hp3a: SCRES positively influences sustainable performance through the mediating effect of sustainable investments

Hp3b: SCRES positively influences financial performance through the mediating effect of sustainable investments

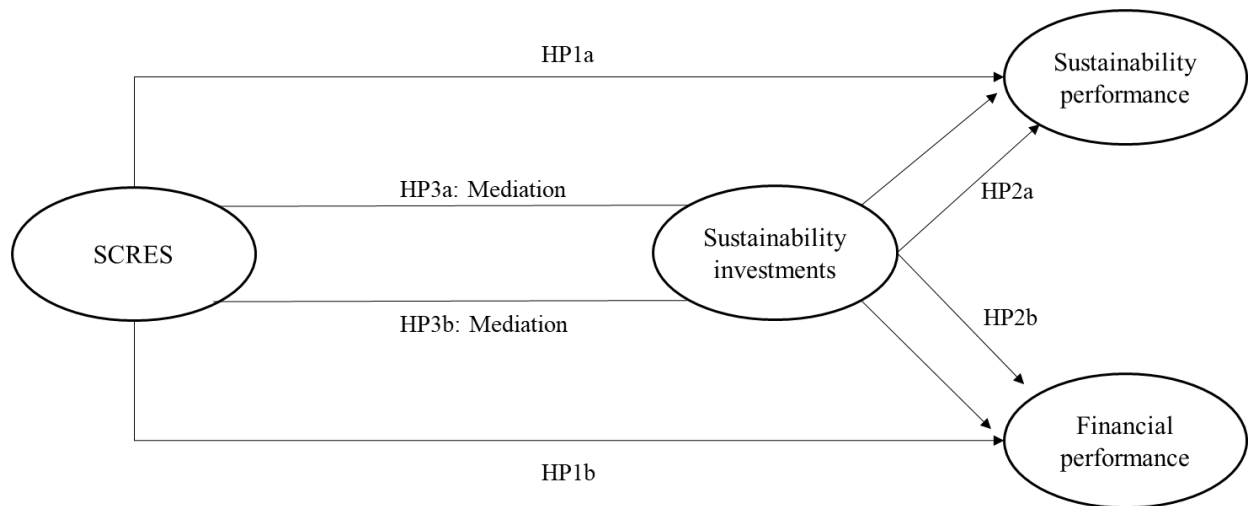
In summary, we hypothesized that there is a direct link between SCRES and sustainability, encompassing environmental, social, and economic dimensions. Specifically, we decided to test economic sustainability separately from social and environmental sustainability and measure the

former through financial performance and the latter through sustainability performance. Furthermore, we propose that this relationship is mediated by investments in sustainability initiatives, such as investments to improve energy efficiency, circular economy practices, and employee well-being (e.g., improvements in services for work-life balance, offer of supplementary insurance services, and donations for the development of local territories and communities).

Figure 1 presents a conceptual path diagram that highlights all the hypotheses, which have been elaborated upon in previous sections. The list of hypotheses represented in the following figure is:

- HP1a: SCRES → Sustainability performance
- HP1b: SCRES → Financial performance
- HP2a: Sustainability investments → Sustainability performance
- HP2b: Sustainability investments → Financial performance
- HP3a: SCRES → Sustainability investments → Sustainability performance
- HP3b: SCRES → Sustainability investments → Financial performance

Figure 1. Theoretical framework



3. Methodology

To evaluate our model, we employed SEM using the PLS approach, relying on the SEMinR software package (Ray, Danks, and Calero Valdez, 2021). As highlighted by Hair, Hult, Ringle, Sarstedt, Danks, and Ray (2021), SEM facilitates the simultaneous estimation of multiple regression equations by considering the relationships between observed variables and their underlying constructs. The application of the PLS approach in studies on SCRES is well-

established, with several research papers employing it in recent years (Birkie, Trucco, and Fernandez Campos, 2017; Juan, Li, and Hung, 2022).

According to Hair, Black, Babin, and Anderson (2019), there are two primary approaches to estimate relationships in a structural equation model: covariance-based SEM (CB-SEM) and PLS-SEM. We selected PLS-SEM over CB-SEM because the former is preferable under the following circumstances (Hair et al., 2021, pp. 3-23.), which represents the case study.

- The structural model is complex and includes numerous constructs, indicators, and model relationships.
- The aim of this research is to deepen the understanding of growing complexity by conducting exploratory research for theory development. PLS-SEM estimates path model relationships with the aim of maximizing the R^2 values of the endogenous constructs. This characteristic fulfills the in-sample prediction goal of PLS-SEM (Hair & Sarstedt, 2021), making it the preferred method when the research objective is theory development and variance explanation.
- The research relies on secondary data that may not have robust support from measurement theory. PLS-SEM can easily handle reflective and formative measurement models as well as single-item constructs, with no identification problems.
- The sample size is large, considering that PLS-SEM achieves high levels of statistical power with small sample sizes, but larger sample sizes increase the consistency of the PLS-SEM estimations. Statistical power implies that PLS-SEM is more likely to detect a significant relationship when it exists in the population. The same applies when comparing it with regression using sum score data, which also exhibits lower statistical power than PLS-SEM (Hair, Hollingsworth, Randolph, and Chong, 2017).

3.1 Data collection and sample description

The study is based on secondary data collected through a survey conducted as part of the Growing Resilient, Inclusive, and Sustainable (GRINS) project between January and February 2024. The GRINS project is an extended partnership funded by the Italian National Recovery and Resilience Plan (PNRR), under Mission 4 (Education and Research), Component 2 (From Research to Business), Investment 1.3 (Extended Partnerships), and Thematic Area 9 (Economic and Financial Sustainability of Systems and Territories). The project's primary focus is on fostering sustainability and resilience in economic and financial systems to bridge the gap between research and industry. More specifically, the survey, developed by several universities, including Bocconi University, the University of Padua, and the University of Rome Tor Vergata, aimed to understand how Italian companies react to disruptions and build resilience. This study targeted Italian companies operating in various sectors and at different stages of the supply chain. The survey was conducted by SWG, a company specializing in market research and sector analysis. Over approximately three months, SWG utilized a computer-assisted telephone interview (CATI) methodology to gather

data. The survey involved telephone interviews with senior managers to ensure collection of accurate and relevant information. Each interview lasted approximately 30 minutes and provided a detailed understanding of the companies' strategies and responses to the recent crisis. The final database, comprising responses from 1,025 companies, represents a substantial sample of small, medium, and large firms in the manufacturing, communication services, construction, retail, and other sectors. To isolate companies with similar characteristics and impacts on environmental sustainability, the database was filtered, excluding service providers who were not directly involved in manufacturing and supply chain processes. (e.g., accommodation and catering service activities, information, and communication services). This decision is supported among the other things by the commonly accepted notion that the manufacturing sector produces more air, land, and water pollution than service facilities (Stead and Stead, 2000). Furthermore, service companies have been affected by recent crises in diverse ways, with sectors such as travel and hospitality experiencing a significant drop in demand, whereas sectors such as e-commerce and healthcare have seen an exponential increase in demand. Consequently, the final sample comprised 713 firms. The majority of this sample (90%) consisted of small- or medium-sized enterprises (fewer than 250 employees), and nearly half were engaged in manufacturing activities. A detailed description of the samples is provided in Table 1.

Table 1. Dataset description

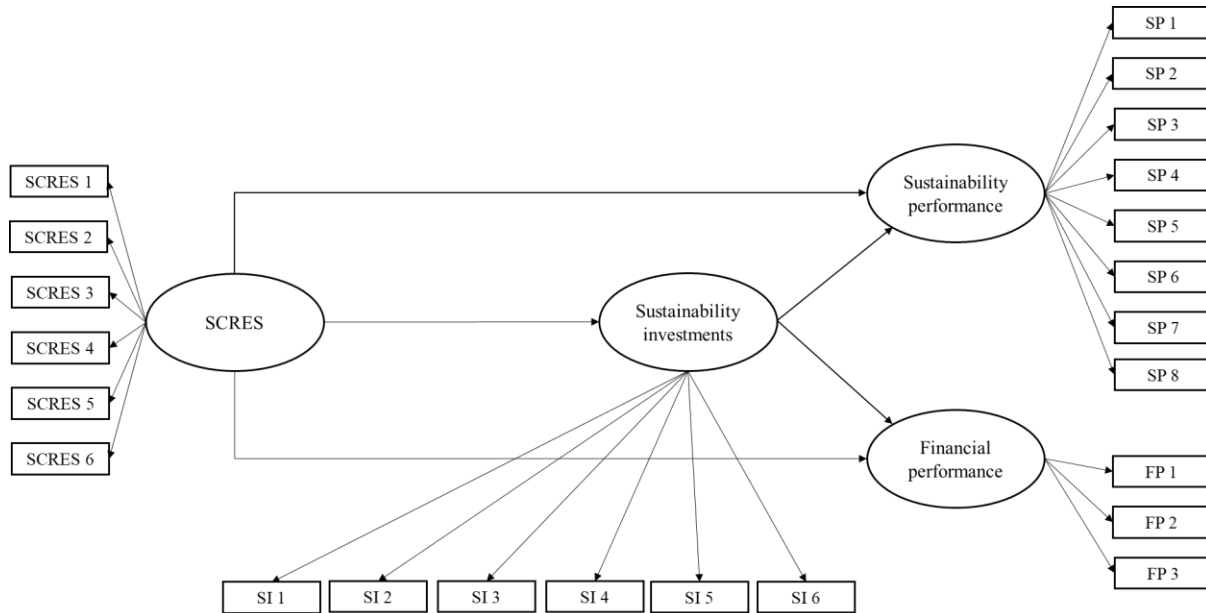
Industry	Frequency	Number of employees	Frequency
Manufacturing activities	49%	From 10 to 49	59%
Wholesale and retail trade, repair of motor vehicles and motorcycles	32%	From 50 to 249	32%
Construction	11%	250 or more	10%
Water supply, sewerage, waste management, and remediation activities	4%		
Transportation and storage	4%		
Electricity, gas, steam, and air conditioning supply	1%		

3.2 Data encoding

Four constructs measured through reflective measurement were included in the model (Figure 2):

1. SCRES, measured through SCRES1, SCRES2, SCRES3, SCRES4, SCRES5, and SCRES6;
2. Sustainability Performance, measured through SP1, SP2, SP3, SP4, SP5, SP6, SP7, and SP8;
3. Sustainability Investments, measured through SI1, SI2, SI3, SI4, SI5, and SI6;
4. Financial Performance, measured through FP1, FP2, FP3.

Figure 2. Reflective measurement model



The primary variables in this study can be conceptualized as second-order constructs. Previous research has treated these concepts as consisting of several dimensions that can be aggregated into multiple subconstructs. For instance, Brandon-Jones et al. (2014) and Gölgeci and Ponomarov (2015) identified aspects such as the supply chain's ability to quickly restore its original state and product flow, maintain structural and functional stability, and absorb the financial consequences of disruptions as components of SCRES. Financial performance can be described using subconstructs such as revenues, gross margins, or ROI (Delen, Kuzey, and Uyar, 2013). Instead, sustainability metrics typically comprise environmental, economic, and social dimensions, making them interdisciplinary composite measurements (Brink, Hengeveld, and Tobi, 2020). Ding (2005) considered energy conservation, environmental impact, and social benefits as sub-constructs that are useful for measuring sustainability performance.

The following tables illustrate the first-order constructs for SCRES (Table 2), sustainability investments (Table 3), sustainability performance (Table 4), and financial performance (Table 5), which serve as the latent variables in our model. These constructs, presented in the form of Likert-type scales in the survey, are consistent with those used and validated in the literature, as illustrated above.

Table 2. Measures of SCRES

SCRES1	We trust in our ability to find viable solutions using the resources we already have.
SCRES2	We are capable of responding to adversities and crises while maintaining our role in the sector.

SCRES3	We can reorganize in the face of adversity and still deliver value to the customer.
SCRES4	Our company can easily manage new vulnerabilities as soon as they are identified.
SCRES5	When facing specific threats, we develop responses at the organizational level.
SCRES6	Our organization quickly restores performance after a crisis or adversity.

Table 3. Measures of sustainability investments

SI1	Use of eco-friendly materials to reduce the environmental impact of the product/service over the past two years
SI2	Adoption of product/service design and development practices aimed at reducing its environmental impact throughout the entire lifecycle over the past two years
SI3	Development of circular economy initiatives over the past two years
SI4	Investments in renewable energies over the past two years
SI5	Investments to convert corporate fleets to hybrid or electric vehicles over the past two years
SI6	Collaboration with non-profit organizations over the past two years

Table 4. Measures of sustainability performance

SP1	Reduction of CO2 emissions over the past two years
SP2	Reduction of energy consumption over the past two years
SP3	Reduction of water consumption over the past two years
SP4	Achievement of gender parity over the past two years
SP5	Reduction of the number of workplace accidents and injuries over the past two years
SP6	Improvements of services for work-life balance over the past two years
SP7	Offer of supplementary insurance services dedicated to employee health over the past two years
SP8	Donations for the development of local territories and communities over the past two years

Table 5. Measures of financial performance

FP1	Trend in revenues during systemic crises
FP2	ROI during systemic crises, compared to competitors
FP3	Gross margin during systemic crises, compared to competitors

3.3 Evaluation of the reflective measurements model

As anticipated, we estimated the relationship between the construct and each indicator using a reflective measurement model. The descriptive statistics of the different indicators are illustrated in Table 6.

Table 6. Descriptive statistics of the reflective measurement model

	No.	Missing	Mean	Median	Min	Max	Std.Dev.	Kurtosis	Skewness
SP1	1	0	3.10	3	1	5	1.06	2.47	-0.29
SP2	2	0	3.30	3	1	5	0.98	2.85	-0.35
SP3	3	0	2.95	3	1	5	1.07	2.42	-0.14
SP4	4	0	2.96	3	1	5	1.11	2.44	0.02
SP5	5	0	3.53	4	1	5	1.03	2.84	-0.48
SP6	6	0	2.95	3	1	5	1.02	2.50	-0.06
SP7	7	0	2.94	3	1	5	1.06	2.43	-0.12
SP8	8	0	2.61	3	1	5	1.14	2.11	0.11
SI1	9	0	3.04	3	1	5	1.12	2.39	-0.32
SI2	10	0	2.91	3	1	5	1.12	2.31	-0.21
SI3	11	0	2.76	3	1	5	1.16	2.04	-0.15
SI4	12	0	2.83	3	1	5	1.19	2.12	0.03
SI5	13	0	2.32	2	1	5	1.12	2.09	0.33
SI6	14	0	2.29	2	1	5	1.17	1.89	0.35
SCRES1	15	0	3.55	4	1	5	0.90	2.73	-0.14
SCRES2	16	0	3.47	3	1	5	0.82	3.05	-0.19
SCRES3	17	0	3.54	4	1	5	0.82	2.87	-0.05
SCRES4	18	0	3.30	3	1	5	0.81	3.11	-0.13
SCRES5	19	0	3.43	3	1	5	0.82	2.74	-0.03
SCRES6	20	0	3.27	3	1	5	0.87	3.06	-0.20
FP1	21	0	6.69	7	1	8	1.10	5.07	-1.31
FP2	22	0	3.28	3	1	5	0.90	2.96	-0.33
FP3	23	0	3.24	3	1	5	0.88	3.07	-0.25

Reflective measurement models are assessed based on indicator reliability, internal consistency reliability, convergent validity, and discriminant validity (Hair, Ringle, and Sarstedt, 2011).

3.3.1 Indicator reliability

The initial step in assessing a reflective measurement model involves evaluating the extent to which each indicator's variance is accounted for by its corresponding construct, as this reflects the indicator reliability. According to the literature, indicator loadings greater than 0.708 are recommended because they indicate that the construct explains more than 50 percent of the indicator's variance. Instead, indicators with loadings below 0.40 should always be excluded from the measurement model (Hair, Hult, Ringle, & Sarstedt, 2022). As shown in Table 7, none of the indicators had loadings lower than 0.40. Indicators with loadings between 0.40 and 0.708 should be removed only if the decision increases internal consistency reliability or convergent validity. At the same time, content validity, which refers to the degree to which a measure captures all aspects of a given construct, is often preserved while maintaining all indicators. Consequently,

considering that we relied on secondary data, indicators in this range were retained to preserve content validity.

Table 7: Factor Loadings matrix

	SCRES	Sustainable investments	Sustainable performance	Financial performance
SP1	0.00	0.00	0.78	
SP2	0.00	0.00	0.72	
SP3	0.00	0.00	0.77	0.00
SP4	0.00	0.00	0.65	0.00
SP5	0.00	0.00	0.62	0.00
SP6	0.00	0.00	0.75	0.00
SP7	0.00	0.00	0.69	0.00
SP8	0.00	0.00	0.71	0.00
SI1	0.00	0.77	0.00	0.00
SI2	0.00	0.85	0.00	0.00
SI3	0.00	0.86	0.00	0.00
SI4	0.00	0.57	0.00	0.00
SI5	0.00	0.48	0.00	0.00
SI6	0.00	0.70	0.00	0.00
SCRES1	0.67	0.00	0.00	0.00
SCRES2	0.76	0.00	0.00	0.00
SCRES3	0.75	0.00	0.00	0.00
SCRES4	0.77	0.00	0.00	0.00
SCRES5	0.75	0.00	0.00	0.00
SCRES6	0.75	0.00	0.00	0.00
FP1	0.00	0.00	0.00	0.50
FP2	0.00	0.00	0.00	0.89
FP3	0.00	0.00	0.00	0.90

3.3.2 Internal consistency reliability and convergent validity

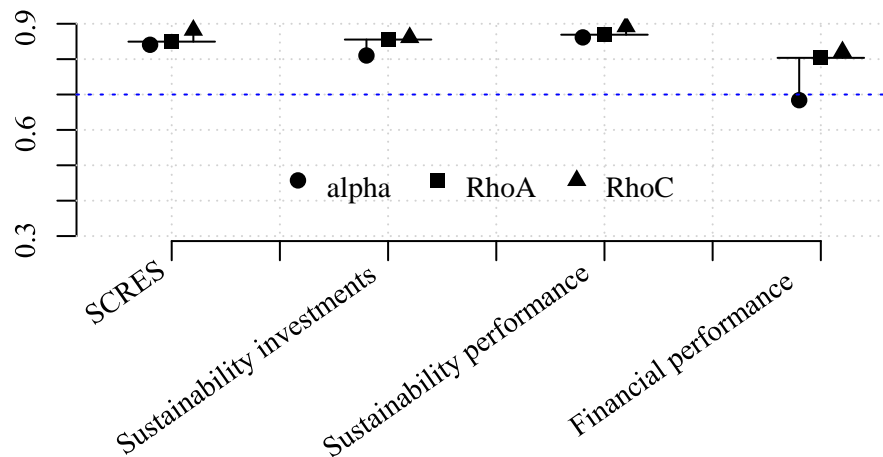
Internal consistency reliability was assessed to determine the extent to which indicators measuring the same construct were associated with each other. Three metrics were used to evaluate internal consistency reliability:

- Cronbach's Alpha
- Exact (or Consistent) Reliability (rhoA)
- Composite Reliability (rhoC)

Alpha, rhoA, and rhoC should exceed 0.70, with ideal values between 0.80 and 0.90, a minimum threshold of 0.70, and a maximum threshold of 0.95 (Hair et al., 2021, pp. 77). As shown in the table below (Table 8), the results meet the required thresholds, except for Cronbach’s alpha for the Financial Performance construct, which is 0.68. However, considering that this coefficient tends to increase with the number of items in the scale, the value for Financial Performance is satisfactory for a construct measured using a few items (Cortina, 1993; Field, 2005). Furthermore, it is important to note that among the three metrics used to assess internal consistency reliability, Cronbach’s alpha is the most conservative (Hair et al., 2021, pp. 78). Lastly, there appears to be no redundancy in the item measurements, as the indicators do not exceed the 0.95 threshold (Diamantopoulos, Sarstedt, Fuchs, Wilczynski, and Kaiser, 2012).

A graphical comparison of the metrics is reported here below:

Figure 3. A comparison of Cronbach’s Alpha, RhoA, RhoC



Convergent validity refers to the degree to which a construct effectively explains the variance in its indicators. The metric used to evaluate a construct’s convergent validity was the average variance extracted (AVE) for all indicators within each construct. This measure should exceed 0.5 (Hair et al., 2021, pp. 78). As shown in the table below, the AVE in our analysis is higher than 0.5 for all constructs.

Table 8. Internal consistency reliability and convergent validity

	alpha	rhoA	rhoC	AVE
SCRES	0.84	0.85	0.88	0.56
Sustainability Investments (SI)	0.81	0.86	0.86	0.52
Sustainability Performance (SP)	0.86	0.87	0.89	0.51
Financial performance (FP)	0.68	0.80	0.82	0.62

3.3.3 Discriminant validity

Discriminant validity was used to understand the potential overlap among constructs. The heterotrait-monotrait ratio (HTMT) of correlations was employed for this purpose (Henseler, Ringle, and Sarstedt, 2015). In general, HTMT values should not exceed 0.9 for constructs that are very similar, but when constructs are conceptually more distinct, a more conservative threshold value is suggested, such as 0.85 (Henseler et al., 2015). Because all the constructs in our model are distinct, the HTMT values align with the model's setup. Table 9 presents these results.

Table 9. HTMT ratio to measure discriminant validity

	SCRES	Sustainability investments	Sustainability performance	Financial performance
SCRES	NA	NA	NA	NA
SI	0.39	NA	NA	NA
SP	0.56	0.77	NA	NA
FP	0.48	0.35	0.42	NA

In addition, bootstrap confidence intervals were implemented to test whether the HTMT is significantly different from 1, 0.9, and 0.85, with the results reported hereafter at a 95% confidence level (Table 10). Since none of the bootstrap intervals contains these values, we can reject the null hypothesis that the HTMT for each construct is equal to 0.9 or 0.85.

Table 10. Bootstrap confidence intervals

	Original Est.	Bootstrap Mean	Bootstrap SD	T Stat.	2.5% CI	97.5% CI
SCRES → SI	0.39	0.39	0.03	11.68	0.33	0.45
SCRES → SP	0.56	0.56	0.04	15.16	0.48	0.63
SCRES → FP	0.48	0.48	0.05	9.75	0.39	0.58
SI → SP	0.77	0.77	0.03	28.02	0.71	0.82
SI → FP	0.35	0.35	0.05	7.38	0.27	0.45
SP → FP	0.42	0.43	0.05	8.33	0.33	0.53

4. Findings

4.1 Evaluation of the structural model

To assess the model's explanatory power, we examined the coefficient of determination (R^2), which represents the variance explained in each endogenous construct (Shmueli & Koppius, 2011).

Generally, R^2 values of 0.75, 0.50, and 0.25 are considered substantial, moderate, and weak, respectively, in many social science disciplines (Hair, Ringle, and Sarstedt, 2011). However, acceptable R^2 values depend on the research context; for example, for studies predicting stock returns, an R^2 value as low as 0.10 is deemed satisfactory (e.g., Raithel, Sarstedt, Scharf, & Schwaiger, 2012). In our model, reflecting the constructs we aim to explain, these indices range from moderately moderate to moderately low (see Table 11 for details), with some exceptions, such as the high R^2 (0.57) for the relationship between sustainable investments and sustainable performance, which is quite expected.

Table 11. Model's explanatory power

	Sustainability performance	Sustainability investments	Financial performance
R²	0.52	0.12	0.19
AdjR²	0.51	0.12	0.18
SCRES	0.28	0.35	0.33
Sustainability investments	0.57	NA	0.19

Similar to the discussion of R^2 values, the f^2 values (Table 12) indicate that SCRES has a positive but moderately low effect on Sustainability Investments (0.14), Sustainability Performance (0.14), and Financial Performance (0.11). Conversely, Sustainability Investments exert a strong effect on Sustainability Performance but have a very low effect on Financial Performance.

Table 12. Evaluation of the f^2 effect size

	SCRES	Sustainability investments	Sustainability performance	Financial performance
SCRES	0	0.14	0.14	0.11
Sustainability investments	0	0.00	0.58	0.04
Sustainability performance	0	0.00	0.00	0.00
Financial performance	0	0.00	0.00	0.00

4.2 Significance and relevance of the structural model relationships

In line with Streukens and Leroi-Werelds (2016) recommendations to assess the significance and relevance of the relationships in the fitted model, we performed bootstrapping with 1,000 samples to compute 95% confidence intervals for each path coefficient. PLS-SEM processes standardized data, and the path coefficients reflect changes in an endogenous construct's values corresponding to standard deviation unit changes in a specific predictor construct while holding all other predictor constructs constant. As shown in Table 13, all the coefficients are statistically significant. This is demonstrated by comparing the T-statistics with the 1.96 threshold and verifying that none of the 95% confidence intervals include zero, thereby rejecting the null hypothesis that the specific coefficients are equal to zero in the population.

Path coefficients typically range between -1 and +1, with lower values indicating strong negative associations and higher values indicating strong positive relationships. Values below -1 or above +1 may occur when collinearity is extremely high, necessitating multicollinearity reduction strategies (Hair et al., 2021, pp. 118). In our model, each coefficient demonstrated a positive impact on the corresponding endogenous construct, supporting all our hypotheses. More specifically, SCRES has a positive impact on Sustainability Investments, Sustainability Performance, and Financial Performance, with magnitudes of 0.35, 0.28, and 0.33, respectively. Sustainability Investments has a positive impact on Sustainability Performance and Financial Performance with magnitudes of 0.57 and 0.19, respectively.

Table 13. Evaluation of direct effects

	Original Est.	Bootstrap Mean	Bootstrap SD	T Stat.	2.5% CI	97.5% CI
SCRES → SI	0.35	0.36	0.03	10.63	0.29	0.42
SCRES → SP	0.28	0.28	0.03	9.15	0.22	0.34
SCRES → FP	0.33	0.33	0.04	8.16	0.25	0.40
SI → SP	0.57	0.57	0.03	18.52	0.51	0.63
SI → FP	0.19	0.19	0.04	5.01	0.12	0.26

Table 14 presents an examination of the total effects between the constructs, encompassing both direct and indirect effects. This analysis provides a more comprehensive picture of structural model relationships (Nitzl, Roldán, & Cepeda Carrión, 2016). In our model, the total effect of SCRES on Sustainability Performance is 0.48, while the total effect of SCRES on Financial Performance is 0.39. This signifies that SCRES has a positive impact on sustainability, with a greater impact on environmental and social aspects.

Table 14. Evaluation of total effects

	Original Est.	Bootstrap Mean	Bootstrap SD	T Stat.	2.5% CI	97.5% CI
SCRES → SI	0.35	0.36	0.03	10.63	0.29	0.42
SCRES → SP	0.48	0.48	0.03	15.43	0.42	0.55
SCRES → FP	0.39	0.40	0.04	10.37	0.32	0.47
SI → SP	0.57	0.57	0.03	18.52	0.51	0.63
SI → FP	0.19	0.19	0.04	5.01	0.12	0.26

As PLS-SEM lacks an established global goodness-of-fit measure, no analysis has been conducted with this objective. Recent efforts to introduce common goodness-of-fit metrics within a PLS-SEM framework (Schuberth, Henseler, & Dijkstra, 2018) have achieved limited success. The notion of model fit, as defined in CB-SEM, is not applicable to PLS-SEM because of the different principles underlying these methods (Hair, Sarstedt, & Ringle, 2019).

4.3 Mediation analysis

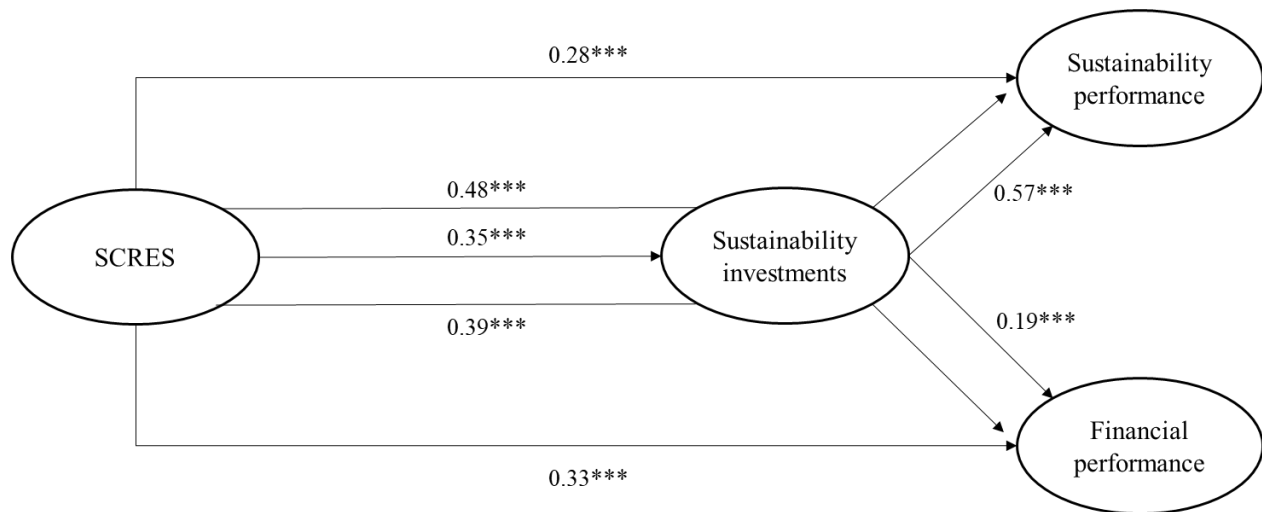
According to Preacher and Hayes (2004), researchers should bootstrap the sampling distribution of the indirect effect to perform a mediation analysis. In our study, this method was used to assess the significance of the mediation effect of sustainable investments in the relationships between SCRES and sustainability performance, as well as between SCRES and financial performance. The results presented below (Table 15) show that both mediation effects are significant, as evidenced by the bootstrap confidence intervals, supporting Hypotheses 3a and 3b. Since both the indirect and direct effects in our model are significant and point in the same direction, we observe complementary (or partial) mediation (Zhao, Lynch, and Chen, 2010; Baron and Kenny, 1986).

Table 15. Mediation analysis

	HP 3a	HP 3b
Original Est.	0.20	0.07
Bootstrap Mean	0.20	0.07
Bootstrap SD	0.02	0.01
T Stat.	9.95	4.67
2.5% CI	0.16	0.04
97.5% CI	0.24	0.10

Figure 4 presents the SEM results including direct and indirect effects.

Figure 4. SEM model results³



5. Discussion

Resilience and sustainability are two critical and sometimes conflicting objectives for contemporary supply chains. On the one hand, the growing emphasis on sustainability compliance necessitates fundamental rethinking of production systems, with the adoption of sustainable practices becoming increasingly urgent. On the other hand, the complexity and interconnectedness of global supply chains demand the capacity to minimize the likelihood and contain the spread of unexpected crises and recover through prompt and effective reactive strategies. This study begins by underscoring the importance of evaluating the impact of SCRES on sustainability. Specifically, we formalize the following research question: “*What is the impact of SCRES on sustainability?*”.

Employing a SEM approach with PLS and drawing on survey data from 713 Italian companies, this study empirically demonstrates that resilience exerts a direct and positive influence on firm sustainability. More specifically, the analysis indicates that SCRES has a more substantial impact on environmental and social sustainability than on economic sustainability, which is evaluated through financial performance indicators. Furthermore, our model highlights the mediating role of sustainability investments in the relationship between resilience and sustainability.

Specifically, as expected, sustainability investments such as those aimed at reducing the environmental impact of products and services, investing in renewable energy or electric vehicles, and engaging in partnerships with non-profit organizations significantly enhance sustainability performance measured through environmental and social impact indicators. Instead, the direct effect of sustainability investments on financial performance, although well supported by the existing literature (Darnall et al., 2008; Derwall et al., 2005; Karpoff et al., 2005), is comparatively

³ Although the 95% confidence intervals are reported in the table, significance was assessed by testing bootstrap intervals at the 99% and 99.9% levels, with each relationship remaining significant within these ranges.

less pronounced. This can be attributed to the financial performance metrics used in the survey, which prioritize measures such as revenue, margins, and ROI rather than incorporating broader indicators, such as stock prices, that capture market reactions to a company's sustainability initiatives (e.g., investments in energy efficiency and employee well-being) and its overall reputation.

It is important to note that the explanatory power of our model, as assessed by the coefficient of determination (R^2), ranges from moderate to low. Although we have established a positive and significant impact of SCRES on sustainability, it does not account for the entirety of the construct. These results align with the core concepts of this study because resilience alone cannot fully account for a company's financial and sustainability performance. Economic, social, and environmental sustainability are influenced by myriad factors, including market dynamics, regulatory environments, technological advancements, and competitive strategies beyond resilience. This is particularly true for financial performance, which can be improved through sustainable investments and as a result of the company's general focus on sustainability. However, financial performance is also more directly affected by variables such as demand, prices, and operational costs.

Overall, our findings suggest that the connection between resilience and sustainability lies in the ability to anticipate and recover from disruptions, which are the two core components of resilience. Regarding anticipation, a proactive approach is essential not only to address unexpected crises but also to respond to ongoing changes driven by two key factors: increasingly stringent sustainability regulations and the rapid evolution of technology. Firms that develop this anticipatory capability tend to place greater emphasis on sustainable development. For example, efforts to reduce energy consumption and investments in the circular economy, recognized in the literature as enhancers of SCRES, are strategies to enhance sustainability. In terms of the ability to withstand disruptions, resilient supply chains, characterized by flexibility, visibility, agility, redundancy, and collaborative capabilities, are better positioned to manage disruptions. This, in turn, positively influences firms' proactivity and long-term orientation, encouraging them to prioritize sustainability as a strategic objective. Such prioritization leads to increased investments in sustainability initiatives, which further support the achievement of key sustainability goals, including reduced emissions, lower energy consumption, greater attention to employee well-being, positive impacts on local communities, and improved economic performance.

These results are consistent with those of previous studies. According to Negri et al. (2021), companies that adopt a holistic and comprehensive view of resilience and incorporate a socio-ecological perspective are better positioned to achieve long-term economic, environmental, and social sustainability. Jüttner and Maklan (2011) argued that although building SCRES often involves costly strategies, its implementation enables supply chains to thrive amid political, social, and market changes, thereby enhancing sustainability and continuity. Wieland and Durach (2021) asserted that the drivers of engineering and socio-ecological resilience are synergistic, contributing

jointly to the short-term functioning and long-term survival of supply chains, including their sustainability. Moreover, Shen and Sun (2023) emphasize that SCRES capabilities, such as flexibility and collaboration, are crucial for a firm's social sustainability efforts, thereby enhancing overall sustainability.

6. Conclusion

Sustainability and resilience are two key concepts in supply chain management literature. Traditionally, these concepts have been independently studied. However, in light of recent disruptions and the subsequent discourse concerning supply chain viability in a crisis-prone era, as well as the increasing awareness of an urgent sustainable transition, these two topics have been increasingly examined in relation to each other. Recent investigations by various authors have yielded diverse conclusions on the relationship between sustainability and resilience (Marchese et al., 2018). Some scholars suggest that resilience is a component of sustainability, whereas others support the opposite view. Moreover, some researchers have argued that there is no hierarchical relationship between the two concepts. Despite the apparent connection between resilience and sustainability, a clear correlation remains elusive (Ivanov, 2018; Negri et al., 2021).

In this study, we tested a model using PLS-SEM methodology, positing SCRES as a component of firms' sustainability rather than vice versa. We analyzed sustainability by separately considering environmental and social sustainability (measured through the "sustainability performance" construct) from economic sustainability (measured through the "financial performance" construct). This distinction is based on the premise that the relationship between SCRES and economic sustainability may differ because investments to enhance SCRES can be costly and negatively impact firms' financial performance. Furthermore, we tested the mediating effect of sustainability investments on the relationship between SCRES and sustainability performance as well as between SCRES and financial performance.

Our model results support all our hypotheses, with each coefficient demonstrating a positive impact on the corresponding endogenous construct. Specifically, SCRES has a positive impact on sustainability investments, sustainability performance, and financial performance with magnitudes of 0.35, 0.28, and 0.33, respectively. Sustainability investments positively impacts sustainability performance and financial performance, with magnitudes of 0.57 and 0.19, respectively. Mediation analysis revealed that the total effect of SCRES on sustainability performance was 0.48, while the total effect of SCRES on Financial Performance was 0.39. These findings indicate that SCRES positively impacts sustainability, with a more pronounced effect on environmental and social aspects.

6.1 Theoretical and practical implications

This study makes significant contributions to both theory and practice. First, it addresses a critical gap in the literature by empirically testing the relationship between resilience and sustainability. To the best of our knowledge, this is the first study to separately analyze economic sustainability from the other two constructs (social and environmental sustainability) and to evaluate the mediating effect of sustainability investments within an SEM model.

Furthermore, our findings prove that the concepts of resilience and sustainability are not inherently conflicting. Consequently, investments in resilience strategies can align with the socio-ecological perspective of company growth and change, wherein a robust and resilient supply chain not only withstands disruptions but also prioritizes environmental impacts, invests in employee well-being, and achieves positive financial returns.

Recent disruptions, particularly the Covid-19 pandemic, have highlighted the potential of fostering more sustainable development as a resilient response to crises (Sarkis, 2020). In line with this perspective, this study underscores the importance of integrating resilience and sustainability strategies to ensure immediate operational continuity and long-term growth.

6.2 Limitations and future research directions

Despite the contributions made in this paper, it is essential to acknowledge some limitations. First, it relies on secondary data, meaning that some constructs are derived from available survey questions, which may not fully capture the intended variables. Second, this study focuses on Italian companies, which may be influenced by specific market dynamics and peculiarities, suggesting that the findings could be expanded to other geographical contexts. Additionally, we considered manufacturing firms and logistics operators together, while excluding a set of service providers from the survey. This study lays the groundwork for further exploration of the multifaceted relationship between resilience and sustainability across various industries and contexts. For example, starting from these results, future studies can deepen and compare the relationship between SCRES and sustainability by focusing on specific players such as tech companies, traditional manufacturing firms, and logistics operators.

Regarding the model results, the moderate to low R^2 values indicate that while SCRES is a crucial determinant, it interacts with other variables and contextual factors to shape firms' overall financial and sustainability performance. This complexity underscores the need for a multifaceted approach when analyzing the drivers of sustainability and financial performance. Therefore, future research should consider additional variables and potential moderating or mediating factors that could further elucidate the relationship between SCRES and sustainability. Moreover, more items could be selected to measure each construct in our model. For example, sustainability investments can be further detailed and sustainability performance can be evaluated using more comprehensive measures from previously validated scales. Finally, future research endeavors can focus on model

testing by adopting different methodologies such as CB-SEM or multiple regression analysis, including control variables such as firm size, firm age, and industry type.

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