

SUPPLY CHAIN RISK, DISRUPTION AND RESILIENCE; COMPARISON BY SIZE AND INDUSTRY TYPES

Arsalan Safari¹, Vanesa B. Al Ismail², Mahour M. Parast³, Ismail Golgeci⁴, and Shaligram Pokharel⁵

ABSTRACT

This study categorizes the types of the supply chain (SC) risk events and disruption and characterizes the plans for SC resilience by firm size and by industry in a holistic framework. We applied systematic literature review and analysis of high quality peer-reviewed journal articles published since January 2000. We collected these articles through three main global scientific databases using relevant keywords. The study maps the sources and antecedents of SC risks and disruption in a comprehensive framework for the six SC risk categories of demand, supply, organization, operations, environment, and network/control. Our findings suggest that the SC resilience plans developed by small and medium-sized enterprises (SMEs) are not necessarily the same as those of large enterprises. While collaboration and networking, and risk management are the most crucial resilience capabilities for all firms, applying lean and quality management principles and utilizing information technology are more crucial for SMEs. For large firms, knowledge management and contingency planning are more important. The resilience plans also vary by industry type as well. Based on our analysis, the authors identify theoretical inconsistencies and knowledge gaps in the literature on SC risks and SC resilience, leading to suggested directions for research in this field.

KEYWORDS

Supply Chain Disruption Risk, Supply Chain Resilience, Contingency Theory, Size, Industry

INTRODUCTION

Supply chain resilience is increasingly acknowledged as a critical capability to respond, recover, and adapt in the face of severe adversities and disruptions. Most of the research on SC resilience has focused primarily on various antecedents and consequences of SC resilience (Christopher and Peck, 2004; Jüttner, 2005; Blos et al., 2009; Cao and Zhang, 2011; Zhao et al., 2013; Bavarsad et al., 2014; Chen, 2018; Jajja et al., 2018). This research has underplayed two fundamental elements of SC resilience: the firm's size, and the firm's industry. To adapt to SC disruptions, firms have specific processes, organizational structures, and capacities that differ by the firms' size and industry; a firm's size and industry have been treated as peripheral factors

¹ Associate Professor, Center for Entrepreneurship & Organizational Excellence, College of Business & Economics, Qatar University, Doha, Qatar, asafari@qu.edu.qa, orcid.org/0000-0002-9324-3321

² Senior Researcher, College of Business & Economics, Qatar University, Doha, Qatar, vanesa.b@qu.edu.qa, orcid.org/0000-0003-4067-3886

³ Eminent Scholar, Arizona State University: Tempe, AZ, US, mahour.parast@asu.edu, orcid.org/0000-0001-6589-1076

⁴ Associate Professor, Aarhus University: Aarhus C, DK, i.golgeci@uea.ac.uk, orcid.org/0000-0002-6853-3255

⁵ Professor, College of Engineering, Qatar University, Doha, Qatar, shaligram@qu.edu.qa, orcid.org/0000-0002-7709-7803

by most empirical studies and not considered by the systematic literature reviews on SC resilience (e.g., Tukamuhabwa et al., 2015; Ali et al., 2017; Kochan and Nowicki, 2018). The research has typically not provided an in-depth analysis of the impact of firm size and industry type on SC resilience plans, and what has been discovered about the role of firm size and industry remains fragmented. This systematic review analyzes the academic literature to understand SC risk and resilience across different organizational sizes and industries (i.e., manufacturing and service sectors). The service sector includes all service-related businesses and construction. Our literature review and analysis of 224 articles published in a top peer-reviewed journal (at least A-ranked in the journal quality list provided by the Australian Business Deans Council (ABDC) within 2000-2021 - offer an in-depth quantitative and explorative analysis of SC resilience plans that are adopted separately by startups, small and medium-sized enterprises (SMEs), and large enterprises in different industries to mitigate disruptions and ensure business continuity.

Despite the extensive research on SC risk and resilience, understanding how firms' risk management approaches and responses to SC risks and disruptions differ across different firm sizes and industries remains somewhat shallow and fragmented. This systematic literature review analyzes the academic literature to understand SC risk and resilience across different organizational sizes and industries. Our systematic literature review shows that most studies have been conducted without paying enough attention to organizational size and industry. First, our analysis reveals that research on SC risk and resilience for SMEs and startups remains embryonic and needs further development. Second, we find that size is usually considered a control variable in operations and SC management research (Bode et al., 2011; Ambulkar et al., 2015; Bode and Wagner, 2015; Jajja et al., 2018; Azadegan et al., 2019; Parast, 2020). Limiting size and industry only to control variables means the research outcomes cannot easily be extrapolated to different organizational sizes and industries. SMEs and startups usually have capacities, limitations, and priorities that are different from those of large enterprises, emphasizing different practices (Hahn, 2020). For startups, access to funds is the key factor; thus, limited access to funds is a major factor in their SC resilience. For large organizations, access to funds is not critical; process innovation is more important and needs to be emphasized (Golgeci and Ponomarov, 2013; 2015; Parast, 2020). SMEs emphasize agility; large organizations put more emphasis on efficiency (Wieland and Wallenburg, 2013; Thun and Hoening, 2011).

This paper is organized as follows. We first present the theoretical framework of the study. Section 3 describes the methods used in this study. Section 4 discusses the results; we apply descriptive statistics and analyze the literature using various explorative approaches. Section 5 is the conclusion, including the theoretical and practical implications of this research.

RESEARCH METHODOLOGY

This review focuses only on the structural and systematic analysis of high-quality journal papers from January 2000 to June 2021 using manual screening process, assuming that any prior development in risk analysis would have been considered and updated in the recent papers. The sample was filtered using the inclusion/exclusion criteria shown in Table 1 which were adapted from Liao et al. (2017). This study targeted papers with empirical data or case study analysis. This study excluded conceptual, modeling, and review articles and other types of publications such as theses, books, reports, notes, and news. It is assumed that high-quality research presented in a thesis would have already been published in a high-quality journal.”.

Table 1: Inclusion and exclusion criteria for the systematic literature review

	Criteria	Criteria Explanation
Inclusion	Partially related	-The article does not explicitly mention the topic nor uses keywords, but it has the intersection of categories at least in a part/section of the article. - The research efforts of a paper are majorly and deeply dedicated to SC Risk and Resilience.
	Closely related	- The research efforts of the empirical paper are explicitly and specifically dedicated to SC risk and resilience.
Exclusion	Search engine reason	-The article is not written in English, or it was not published in a top peer-reviewed journal (at least A-ranked in the journal quality list provided by the Australian Business Deans Council (ABDC) within 2000-2021.
	Non-related	-The article is not academic (e.g., editorials, newspapers, theses, books, reports, or notes) -the article is a conceptual, modeling, or review article. -The article (topic and keywords) is not related to SC risk and resilience, but to another topic due to homonyms.

According to Podsakoff et al. (2005), papers in high-quality journals can be considered the main source to validate the concepts and impact the subject area. Therefore, this review focuses only on the structural and systematic analysis of high-quality journal papers for the period January 2000 to June 2021, assuming that any prior development on risk analysis would have been considered and updated in the recent papers. This review shows that most of the literature on SC risk and resilience has been developed and published recently. The sample was filtered using the inclusion/exclusion criteria that were adapted from Liao et al. (2017). This study targeted papers with empirical data or case-study analysis. This study excluded conceptual, modeling, and review articles and other types of publications such as theses, books, reports, notes, and news. It is assumed that high-quality research presented in a thesis would have already been published in a high-quality journal. Also, books and reports may have a time lag and are more prescriptive and descriptive; therefore, they are not considered in the review. The focus of the search was limited to ProQuest, ScienceDirect, and Google Scholar databases, as they capture most of the published literature. A correlation between the topic and the journal list mentioned above would help develop a comprehensive list of papers for review.

To search for the relevant literature in the database, publications from leading academic journals were scanned with keywords related to supply chain, risks, disruption, small and medium-sized enterprises, new ventures (startups), agility, and distribution network. Table 2 shows the combination of keywords used in the database search; the approach for selecting these keywords was taken from from Krippendorff (2018). Group A has terms related to resilience as keywords, and Group B has terms related to risk as keywords. Group C has terms related to the combination of resilience, risk, and size of the firm. The keyword search yielded an initial sample of 3,466 publications.

Table 2: Keywords used in the database search

Keywords		
Group A	Group B	Group C
-Supply chain resilience	-Supply chain risk	-Supply chain risk or resilience
-Supply resilience	-Supply risk	- Supply chain and resilience and risk
-Resilient supply chain	-Supply chain risk management	-Supply chain and resilience and risk and SMEs
-Supply chain resilience distribution networks	-Supply chain risk mitigation	-Supply chain and resilience and risk and large companies
-Supply chain resilience strategies	- Supply chain risk mitigation strategies	- Supply chain and resilience and risk and startups/new ventures

The collected literature was then reviewed for their coverage of supply chain resilience, risk, and disruption domains using Hohenstein et al.'s (2015) definition: “*Supply chain resilience is 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.*” This definition captures SC resilience regardless of firm size. Extracting and mapping resilience plans for all firm sizes would help us understand the focus of SC resilience and differences based on company size. For example, startups may have fewer employees and may be more vulnerable to disruptions.

The keyword search yielded an initial sample of 3,466 publications. The collected literature was then reviewed for their coverage of SC resilience, risk, and disruption domains using Hohenstein et al.’s (2015) definition of Supply Chain Resilience. Furthermore, the sample was filtered using the inclusion/exclusion criteria shown in Table 1 which were adapted from Liao et al. (2017). This study targeted papers with empirical data or case study analysis. This study excluded conceptual, modeling, and review articles and other types of publications such as theses, books, reports, notes, and news. From the initial sample of 3,466 publications, 224 (6.5%) publications satisfied all criteria for review. (Appendix A lists the authors of the 224 articles. Appendix B shows the resilience plan themes by firm size. Appendix C shows the frequency of resilience themes.) The theoretical foundations of this study are analyzed on three fundamental approaches: 1) the initial visualization, mapping, and analysis of the literature by size, time, journal, approach, theoretical framework, and variables; 2) exploring, synthesizing, and deeply analyzing the literature, and defining the capacity for resilience; and 3) identifying inconsistencies, gaps, and limitations of the literature and proposing potential research directions to address them.

RESULTS

The results section discusses the differences and similarities of resilience plans developed by startups, SMEs that are not necessarily the same as those of large enterprises, as they usually emphasize different sets of resilience capabilities. Our findings strongly support the value of SC resilience and provide substantial ground for understanding the significant elements of SC resilience across different sizes of firms in different industries. Various aspects of SC resilience have been explored in the literature. The collected literature shows that most of the papers on SC resilience are published in six journals, and only eight journals have published one or more papers from 2016 to 2021. Our data shows that from 2016 to 2021 there is a trend of increased interest in the analysis and assessment of SC resilience and SC risks.

Of the journals in which the 224 reviewed articles were published, 31 journals are identified as A-ranked journals by the Australian Business Deans Council (ABDC). The distribution of risk and resilience articles is highly skewed across journals and does not follow a certain path. About 58% of the publications are published in management journals, and 42% are published in management-related journals.

SUPPLY CHAIN RISKS AND SOURCES

An uncertain event leads to the existence of risk, which can be called a risk event (Manuj and Mentzer, 2008). Our review and analysis of 224 articles confirm that the root causes and antecedents of disruption risk events in an SC can be grouped into demand, supply, organizational, operational, environmental, and network/control risks that may interact; these categories are summarized and explained below. SC resilience is considered in all firm sizes (startups, SMEs, and large enterprises) and many service, construction and manufacturing industries. The service sector includes all service-related businesses and construction.

1. *Demand Risks*: Demand-related risks are mainly related to the concentration of the customer base, short product life cycles, loss of major accounts, volatility of demand, innovative competitors, forecasting errors, demand fluctuations, risks affecting customers, payment delays, inventory shortages, and technological changes leading to demand changes. Demand-related risks can be addressed through various proactive and reactive policies and solutions such as collaboration, coordination, information and communication technology, and top management support (Manuj and Mentzer, 2008; Christopher and Peck, 2004; Mishra et al., 2021).

2. *Supply Risks*: Supply risks refer to potential or actual disturbances to the inputs of production of goods or services upstream of the firm. Supply risks include dependence on crucial suppliers, consolidation in supply markets, quality and management issues arising from off-shore sourcing, potential second-tier level disruption, and length and variability of replenishment lead times. Also considered as supply risks are supply chain uncertainties, price and market problems, information asymmetry, and logistics-related issues. Some of the many solutions proposed by researchers are sourcing intermediaries (Vedel and Ellegaard, 2013), integrating external responsiveness and creating dynamic capabilities (Foerstl et al., 2010), and developing effective supplier relationship management (Blackhurst et al., 2011).

3. *Organizational Risks*: Issues related to the organization are also discussed in the literature. Examples of SC risk events from an organizational perspective are organizational changes, mechanistic systems, employee turnover, employee engagement issues, lack of dedicated resources and training for the SC in the organization, marketing and sales processes, organization finances, and inventory held and managed. Research shows the importance of organizational capability to adopt SC resilience-related measures; the measures could improve flexibility, agility, collaboration (e.g., Jajja et al., 2018; Yang and Hsu, 2018), or integration of digital solutions (e.g., Dubey et al., 2018; Hahn, 2020).

4. *Operational Risks*: Operational risks are about issues and disruptions in the end-to-end process of producing goods or providing services: receiving inputs; converting inputs to outputs using human resources, physical resources, and non-physical resources; and distributing outputs. The risks include quality-related issues (e.g., defects, errors, discrepancies, reworks, and returns), safety, lengthy set-up times and inflexible processes, manufacturing yield variability, equipment unreliability and breakdowns, limited capacity/bottlenecks, and outsourcing critical business processes. Firms need to be proactive and develop demand forecasting, operation planning, and resource allocation (Zhu et al., 2018).

5. *Environmental Risks*: Environmental risks include risk events associated with a firm's external environment (natural, political, legal, global, economic, demographic, technological, or socio-cultural) that may directly or indirectly impact the firm's SC networks, marketplace, and ecosystem. This includes natural disasters such as earthquakes, floods, hurricanes, tropical storms, weather changes, and wildfires occurring at any place in the supply chain. Supply chain risks can also be due to the wider level of natural risks such as global pandemics. A few research studies focus on COVID--19-related risks (e.g., Fatemi et al., 2021; El-Baz and Ruel, 2021; Spieske and Birkel, 2021; Pimenta et al., 2022). These papers suggest researching the impact of pandemics on every aspect of supply chains, including inventory management, supplier selection, and SC design.

6. *Network/Control Risks*: Global supply chains are riskier and more complicated than domestic supply chains because of a variety of links interconnecting a wider network of firms (Manuj and Mentzer, 2008). Ideally, a firm should have an effective awareness system for any potential or actual disturbances to the anticipated flow of product and information from within and between every node or link in its SC networks through which its value stream flows. This might be hard to achieve in practice, but firms should at least strive to familiarize themselves with the details and consequences of these risk events and be more proactive. Every

organization has its policies, rules, procedures, and systems that help it govern and control its business affairs and SC-related activities, such as asset management and control, transportation management, and safety stock. Control risk events arise from applying or misapplying these rules and systems (Christopher and Peck, 2004).

QUALITATIVE ANALYSIS

We provide our analysis concerning the two contingency dimensions (firm size and industry segment) examined in the previous sections.

1. Firm size and supply chain resilience

The review provides several important insights related to SC risks and resilience capabilities in startups, SMEs, and large corporations. Because there is only one study related to resilience capability in startups, we provide our assessment for SMEs and large corporations.

We start our evaluation by comparing the common themes in different industry sectors (manufacturing, services and construction) and different sizes (SMEs and large firms). In both groups of the industry size, “collaboration and networking” as well as “risk management” emerge as the most frequently cited resilience capabilities. In summary, in SMEs, collaboration and networking, quality management, risk management, flexibility, information systems/technology, innovation, and supply chain integration are the most highly cited resilience capabilities discussed in the literature in that order. For large corporations, risk management, and collaboration and networking are the most widely cited resilience capabilities, followed by flexibility, contingency planning, information systems/technology, responsiveness, and knowledge management and information sharing in that order. Thus, we see similarities and differences between SMEs and large corporations in terms of resilience capabilities that are emphasized in each group and extracted from the literature. Out of 12 resilience capabilities/themes listed for both SMEs and large firms, six themes are common between them. However, large organizations tend to be more rigid and hierarchical; they develop action plans and allocate resources for risk management initiatives. SMEs tend to be more organic, agile, and flexible, capitalizing on their organic structure to improve agility, innovation, quality and learning capacities.

2. Industry type and supply chain resilience

Our review of the studies in SC resilience based on the industry type reveals several important insights. First, collaboration-networking and risk management as the most important resilience practices across all industries, followed by a mix of resilience practices such as flexibility, information systems/technology, SC integration, and responsiveness in different orders.

The analysis provides more valuable nuances for developing an industry-specific resilience plan. While flexibility is regarded as an important resilience capability in the chemical industry, information systems are critical to improving resilience in the logistics industry. Agility is an important resilience practice in the manufacturing sector; contingency planning is mostly emphasized in the service industries. Our review suggests that while some general resilience practices are common across industries (e.g., collaboration and networking), the development of resilience capabilities should be based on the nature of the industry.

Regarding resilience capabilities, further analysis suggests a clear distinction between manufacturing industries and service industries. While collaboration and networking as well as risk management are important for both sectors, the manufacturing sector places more emphasis on flexibility and SC integration, and the service sector places more emphasis on knowledge management, information systems/technology, and responsiveness. For manufacturing firms, slack resources are highlighted as a resilience-enhancing capability; for service firms, there is not much discussion on the effectiveness of this capability.

3. Firm size and industry type combination

We previously examined the effect of firm size and type of industry on the development of resilience capabilities separately. It would be insightful for organizations to realize what type of resilience capabilities should be developed based on the overall impacts of these two dimensions of firm size and industry together. This requires a more detailed assessment of the literature to assess the combination of both contingency factors (firm size - industry).

To properly address the combination of size - industry, we identified SC resilience studies that clearly focused on firm size and industry type. We only reviewed articles where these two dimensions were clearly identified. Thus, we excluded studies that used a cross-sectional approach or studies in which firm size was a mix of large and SMEs or not specified. Using this procedure, we identified 96 articles that met our criteria. Table 3 below shows our practical assessment of the size-industry combination. We evaluated the articles based on two dimensions of size (i.e., large and SME) and two dimensions of industry (i.e., manufacturing and service).

Quadrant 1: Large Firms - Manufacturing: The most widely cited resilience practices for large manufacturing firms are risk management plans, collaboration and networking, and knowledge management. The development of resilience capability in large manufacturing firms entails the development of a risk management plan, which includes identifying, assessing, avoiding, mitigating, transferring, sharing, and accepting risk; this encompasses all activities of risk management. Overall, the literature suggests that large manufacturing firms are more involved in risk management plans than their service counterparts.

Quadrant 2: Large Firms – Services: The overall resilience capability practices for large service firms are collaboration and networking, risk management plans, and contingency planning. Large service organizations seem to have a much narrower focus on risk management practices: which consist of identifying steps to be taken if a disruption risk occurs (contingency planning). Such a distinction between risk management and contingency plans may suggest that large manufacturing organizations are exposed to more disruption risks.

Quadrant 3: SMEs - Manufacturing: Our review of the studies in this domain identified collaboration and networking, flexibility, and quality management (i.e., lean, and continuous improvement) as the main resilience capabilities of SMEs in the manufacturing space. The literature suggests that the more resilient manufacturing SMEs require assistance from sources other than banks and government loans and grants. They need to rely on collaborating firms such as large corporations and international financial institutions (Moore and Manring, 2009; Gunasekaran et al., 2011; Pal et al., 2014; Santoro et al., 2020). In addition, manufacturing SMEs should be more organic and flexible and use a significant number of external linkages that can help them become more resilient and more successful at the same time. Applying quality management practices, such as lean and continuous improvement approaches are highly recommended by the literature (Demmer et al., 2011; Pal et al., 2014) and they can help SMEs to be more effective and efficient, innovative and responsive to any changes and disruptions.

Quadrant 4: SMEs – Services: Our review of the studies in this domain identified risk management, information systems/technology, and collaboration and networking as the main resilience capabilities for service SMEs. Collaboration and networking capabilities have the same significance for service SMEs as they have for manufacturing SMEs. To establish resilience at the firm level and the supply chain level, SMEs must incorporate information systems and advanced IT infrastructure for effectively informed decision-making, information sharing, communication and organizational learning (Jayaram et al., 2014; Ali et al., 2017).

Table 3: Resilience capabilities for different size-industry configurations (by priority order)

Industry/Size	Large	SME
Manufacturing	<ul style="list-style-type: none"> - Risk management - Collaboration & networking - Knowledge management 	<ul style="list-style-type: none"> - Collaboration & networking - Flexibility - Quality Management (lean, continuous improvement)
Service (and Construction)	<ul style="list-style-type: none"> - Collaboration & networking - Risk management - Contingency planning 	<ul style="list-style-type: none"> - Risk management - Information systems/technology - Collaboration & networking

Table 3 summarizes the resilience capabilities based on the size and industry type. Since there was only one study related to resilience capabilities in startups, we cannot provide a discussion on resilience capabilities in the startup domain. The single study conducted in the startup space discussed the importance of data analytics and the platform economy (i.e., information systems/technology for digital business platforms) for improving SC operational efficiency and productivity (Hahn, 2020).

CONCLUSIONS AND IMPLICATIONS

Our attempt was to answer the research question of “How are SC risk and resilience applied and manifested across different organizational sizes and industries?”. The review of 224 articles shows that most SC risk and resilience studies have been conducted without paying enough attention to organizational size and industry. Both the size and the industry of firms are considered control variables in these studies. However, SMEs and startups usually have different capacities, limitations, and priorities from those of larger enterprises. Firms in different industries operate amid different realities and face different internal and external factors when devising their resilience plans and achieving SC resilience. Thus, firm size and industry are likely to have a profound influence on how SC risk and resilience are applied and manifested among organizations.

THEORETICAL IMPLICATIONS

This study contributes to the literature on SC risk and resilience in several ways. First, the study builds upon the relatively dispersed previous research into SC risk and resilience, and it maps the sources and antecedents of SC risks and disruption in a comprehensive framework of six categories of risk events: demand, supply, organization, operations, environment, and network/control.

Second, to the best of our knowledge, this study is the first theoretical assessment for startups, SMEs, and large organizations for understanding the SC risks and disruptions that may be caused by due to various factors discussed above. Our findings suggest that the SC resilience plans for startups and SMEs are not necessarily the same as those for large organizations. While risk management and SC resilience plans require allocating resources and developing an effective action plan, startups and SMEs usually suffer from a lack of sufficient resources. However, larger enterprises can better overcome SC risks and be more resilient. According to our literature review, there is only one study for startups: Hahn (2020) highlighted the importance of data analytics, information systems, and the platform economy (digital platform) for SC resilience in startups. For SMEs, in addition to information systems, collaboration and networking, quality management, risk management and flexibility are more important. Besides collaboration and networking, larger enterprises' risk management, flexibility, contingency planning, and information systems/technology are the most important capabilities for their SC resilience plans.

Our analysis highlighted the SC resilience differences by both size and industry type. According to our result (Table 3), collaboration and networking are the most crucial resilience capabilities for all firms. Firms can be more competitive in the market and more resilient by benefiting from the synergetic effects of collaborative relationships with their SC partners (Ali et al., 2017). These are some of the key suggestions: collaboration with customers (Liu and Lee, 2018); strategic collaborative learning (Hallikas et al., 2005); collaborative efforts to align information and find substitutive parts (Messina et al., 2020); and integrating both configuration and manufacturing flexibilities for better alliances with both new and current SC partners (Huang and Lu, 2020). According to our study, risk management is an effective and popular approach for large firms to be more resilient because of their capabilities and resources for risk management compared with startups and SMEs that face resource and skill shortages. As highlighted by various studies, firms need to be proactive and conduct an SC risk assessment and devise mitigation strategies before facing disruptions (e.g., Thun and Hoenig, 2011; Grötsch et al., 2013; Swierczek, 2016; Rezapour et al., 2017).

Another effective part of a SC resilience plan among large manufacturing enterprises is knowledge management: collecting, managing, and sharing SC knowledge, expertise, and information in organizations. Many SC scholars highlight it as an effective part of a resilience plan (e.g., Hendricks and Singhal, 2005; Essuman et al., 2020; Mishra et al., 2021). Continuity and contingency planning are also effective and most frequently appear in resilience plans for large service organizations that are highlighted in the literature (e.g., Norrman and Jansson, 2004; Davarzani et al., 2015; Lam and Bai, 2016; Islam et al., 2021).

For SMEs, in addition to collaboration and networking, flexibility (i.e., flexibility of operations, changing suppliers, rerouting and alternative shipping paths/methods, input substitutes, design flexibility, manufacturing flexibility, and flexibility in organizational structure) is the most important resilience solution in SME manufacturing sectors (e.g., Pal et al., 2014; Stranieri et al., 2017; Bode and Macdonald, 2017). This is followed by applying lean and other quality management solutions for the manufacturing SMEs (e.g., Demmer et al., 2011; Govindan et al., 2014; Pal et al., 2014). At its core, lean theory identifies eight types of waste, also known as "muda" in Japanese, which are defects, overproduction, waiting, non-utilized talent, transportation, inventory, motion, and excess processing (Liker, 2004). We all know that by applying lean principles to supply chain management, organizations can identify and eliminate waste in all aspects of the supply chain, from procurement and inventory management to production and delivery. This can lead to a more efficient and responsive supply chain, with reduced lead times, lower costs, and improved customer satisfaction. For SMEs in the service sector, in addition to applying effective risk management systems, information systems/technology, and effective collaboration and networking (e.g., Hahn, 2020; Belhadi et al., 2021) are important resilience solutions in that order.

PRACTICAL IMPLICATIONS

This study has some effective practical implications as well. First, SMEs and large organizations should become familiar with the main causes and antecedents of their SC risk events and improve their SC resilience by developing effective *ex-ante* and *ex-post* plans for dealing with disruptions. In addition to responsive efforts to minimize the impacts of disruptions, firms need to be proactive by implementing preventive measures to mitigate SC risks and become more resilient. Second, firms should recognize that their SC resilience plans are not necessarily the same for different industry sectors. Risk management, collaboration, networking, and knowledge management (in that order) are the most important resilience plans/themes in large manufacturing firms. Nonetheless, collaboration and networking, risk management, and contingency plans (in that order) are the most effective resilience plans/themes for large service firms. Both manufacturing firms and service firms need to focus

on effective collaboration and networking with their partners and key stakeholders, to mitigate the negative impact of SC disruptions.

Third, manufacturing operations place more importance on identifying, assessing, avoiding, mitigating, transferring, and sharing plans for risk events (i.e., risk management), quality management, and knowledge development and sharing. Manufacturing operations that are less flexible than service operations, which mainly focus on business continuity plans and effective information systems. The nature of manufacturing operations is different from the nature of service operations: manufacturing is a functional, mechanistic, production-oriented model; services are more organic, humanistic, and relationship-based models (Duncan and Moriarty, 1998; Truong and Hara, 2018). Therefore, we expect manufacturers to focus more on risk management and preventive measures compared to service organizations, which mainly focus on the steps to be taken if disruptions occur (contingency planning).

Fourth, business managers need to be aware of the types of SC risk events if they implement preventive measures or responses for those risk events. The likelihood of occurrence of those risk events, the consequences of the occurrence of those risk events, and effective *ex-ante* and *ex-post* resilience plans will vary with the firm size and firm industry. We have listed resilience plans/themes (prioritized by firm size) that businesses can consider in Appendix B.

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