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ORIGINAL ARTICLE

Risk management strategy for supply chain sustainability and resilience capability

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Abstract
Supply chain sustainability-related risks that have an undesirable environmental, social and economic impact result in global supply chain uncertainty and complexity. This paper investigates the relationships between supply chain sustainability risks, global uncertainty and mitigating strategies to attain supply chain resilience capability. The paper suggests the supply chain resilience capability and four fundamental risk-mitigating strategies to cope with supply chain sustainability risks. Data collected via survey were employed for structural equation modelling and moderation tests to explore appropriate mitigating strategies for differing sustainability risk environments. The results suggest a structural procedure for better supply chain resilience under diverse sustainability risks. Inspired by the literature gap, the study empirically examines how sustainability risks and global uncertainty influence supply chain resilience and provides the most effective risk management strategies among accept, avoid, control, share/transfer according to different sustainability risks. There is a lack of empirical research investigating how to address the supply chain sustainability risk through the provision of effective mitigating strategies for better supply chain resilience capability. The results provide insight for future research in supply chain resilience and sustainability studies.

Keywords Supply chain sustainability · Global supply chain uncertainty · Supply chain resilience · Risk management strategy · Structural equation modelling

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Introduction

Environmental, social and economic risks increase the global supply chain (GSC) uncertainty, complexity (Merschmann and Thonemann 2011) and business challenges (Tang and Musa 2011; Aven 2016). The GSC design has a significant impact on the environment (Mollenkopf et al. 2009; Heckmann et al. 2015). For example, geographical distance surges transportation, inventory volume and lead time in the supply chain (SC), incurring environmental risks such as excessive energy consumption and pollution (Levy 1995; Giannakis and Papadopoulos 2016). Also, differing cultures, working environments, political instability, health risks such as pandemics and frequent changes in the regulatory environment (Dornier et al. 1998) in the social account influence the complexity of business activities such as demand forecasting, supplier selection and material planning (Xu et al. 2019). Last, economic risks constantly exist, for example, the currency exchange rate, material price volatility and market competitiveness (Manuj and Mentzer 2008). Although the benefits of a sustainable SC enhance the firm's global reputation (Christmann 1998), cost reduction (Zhu et al. 2005) and better supplier options (Zhu et al. 2008), key challenges include suppliers' resistance, the lack of clear metrics for measuring sustainable practices, and the opportunity cost of losing key existing partners in a GSC (Mollenkopf et al. 2009). Outsourcing and supplier selection decisions by only considering the supplier's ability to meet the firm's quality, quantity, delivery, price, and service needs (Leenders et al. 2002) can change the GSC networks, which often leads the environmental and social issues, especially in a mass production environment (Foerstl et al. 2010). Offshore sourcing also delays lead time and more inventories which can have an undesirable impact on environmental issues (Christopher and Lee 2004). Sustainability-related environmental, social and economic risks, in turn, impose more complexity and uncertainty on the GSC.

The supply chain risk management research has moved from traditional risk of products and services to future capabilities to broader scope such as corporate sustainability and resilience capability (Bak 2017). Organisational sustainability requires acting with social responsibility and minimal environmental impact while maintaining financial viability (Rostamzadeh et al. 2018). The pursuit of SC sustainability is recognised as an effective strategy to cope with contemporary challenges (Giannakis and Papadopoulos 2016), generating moral capital for firms to mitigate the consequences of potential business risks in the supply chain (Godfrey et al. 2009). Appropriate mitigating strategies address the sustainability-related SC potential risks and prevent the negative impact of environmental, social and economic risks (i.e. triple-bottom line). Although the focus on a firm's social and environmental responsibility, such as its carbon footprint, often falls outside its core SC operations, such as purchasing, manufacturing and distribution, several social scandals in multinational companies (e.g. Apple and Tesco) demonstrate how sustainability-related SC risks can critically erode profit and reputation. Therefore, identification of sustainability-related supply chain risks, the assessment of their impact and the development of risk management tools are becoming critical roles for supply chain managers (Hoffman et al. 2014).

Building resilience is deemed an essential strategic and dynamic capability (Seville et al. 2015) that enables the supply chain to adapt, respond and recover promptly from unpredictable sustainability-related risk events (Ali et al. 2017). Resilience characterises an organisation or a social body that rebuilds itself after being substantially affected by an exogenous attack (Berkes et al. 2003). Thus, SC Resilience can be defined as "the ability of SC to return to normal operating performance, within an acceptable period, after being disturbed" (Peck 2005; Brandon et al. 2014). Similarly, supply chain resilience can be a dynamic capability (see Teece et al. 1977; Wieland and Durach 2021) to deal with supply chain sustainability risks and global uncertainty since it is a requisite adaptive capacity aiming for flexibility, velocity, visibility and collaboration (Jüttner and Maklan 2011). To lessen the impact of sustainability risks and achieve SC resilience capability, provision for effective mitigation strategies is also crucial. Therefore, a comprehensive understanding of the potential SC sustainability risks (Giannakis and Papadpoulos 2016) and SC resilience, together with an appropriate risk mitigation strategy, are critical prerequisites for better environmental, social and economic sustainability.

The primary objective of this study is to explore potential SC sustainability risks in the global environment and suggest the most effective mitigation strategies to achieve better SC resilience capability through empirical data analysis. The key research aims are to: (1) identify SC sustainability risk factors and potential mitigating strategies; (2) explore the relationships between potential sustainability-related SC risks (i.e. economic, environmental and social), global uncertainty and supply chain resilience capability; (3) investigate the most appropriate risk-mitigating strategies (i.e. accept, avoid, control, share, transfer) for enhancing SC resilience; (4) recommend managerial practices in how the organisation handle sustainability risks in a global context. The management of sustainability-related risk in the supply chain is receiving contemporary research attention in a changing and unpredictable global environment (Scholten et al. 2014; Pournader et al. 2020), for example, the pandemic as a social risk resulting in severe disruptions to SCs as well as a financial recession (Casselman 2020).

In answering the research aims, the study leads to several theoretical and managerial contributions. We apply SC resilience as a theoretical capability and risk management strategy as the practical tool in addressing how organisations cope with SC sustainability risks that incur uncertain GSC environments. First, the study expands the SC sustainability risk management view aligning with resilience capability and four key mitigating strategies. The majority of studies have investigated a typical sustainability-related risk (e.g. Teuscher et al. 2006; Tang and Musa 2011; Song et al. 2017; Kim et al. 2019), SC sustainability-related risk with limited mitigation strategies (e.g. Giannakis and Papadopoulos 2016; Sreedevi and Saranga 2017) or only SC resilience concept with potential SC risks (e.g. Brusset and Teller 2017; Macdonald et al. 2018). Instead, we employed four fundamental mitigation strategies and resilience capability simultaneously as key determinants to cope with SC sustainability risks and global SC uncertainty. Also, few studies have empirically investigated the role of different mitigating strategies as a proactive risk management activity for better SC resilience. Regarding the managerial perspective, we proposed risk-mitigating activities so that the research should fulfil the gap of practical insight (Scholten et al. 2014). Thus, the findings support the decision-making procedure to select the most effective mitigating strategies depending on the different sustainability risk environments.

Theoretical constructs and hypothesis development

The study emphasises SC sustainability risks, mainly stemming from environmental, social and economic perspectives, which can be managed by distinct mitigating strategies and SC resilience capability (Brusset and Teller 2017). Therefore, a conceptual framework represents the structural procedure on how SC sustainability risks (i.e. triple-bottom line) impact global uncertainty and SC resilience capability, and how different risk management strategies can be employed to enhance the relationship between SC sustainability risk and resilience capability. First, GSC uncertainty is a mediating factor that links the relationship between SC sustainability risk and resilience capability. Second, we explore the moderating role of the different risk-mitigating strategies for better SC resilience depending on three sustainability risks. Figure 1 depicts the research framework. Thus, the research model empirically examines the role of different risk management strategies to support organisations' resilience under sustainable SC risks. The structural relationships among factors are reviewed thoroughly, with supporting hypotheses.

Sustainability risks in global supply chain management

Sustainability can be regarded as the degree to which the current organisational decisions influence the future situation of the natural environment, society and business viability (Krysiak 2009). Thus, sustainability can be a key tool to achieve both

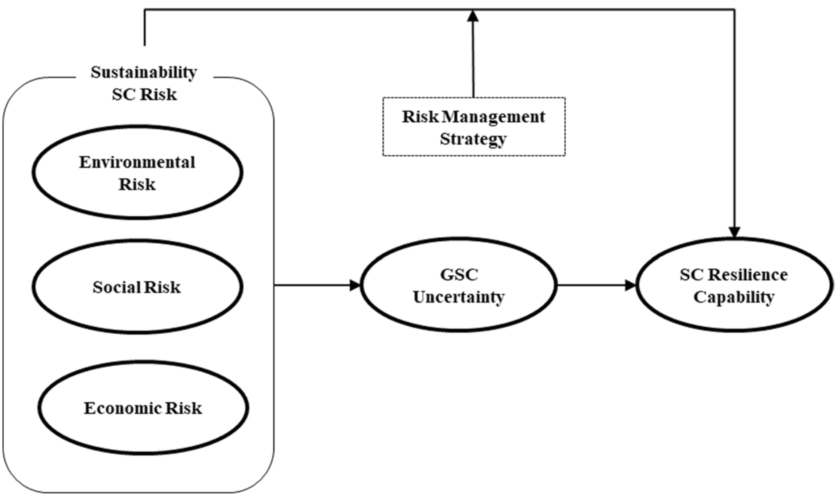

Fig. 1 Research framework

cost reduction and the long-term profitability of a firm (Wang and Sarkis 2013). Similarly, supply chain sustainability is regarded as the creation of coordinated supply chains through the integration of social, environmental and economic considerations to improve the resilience of the organisation over the long term, and increase profitability and competitiveness (Ahi and Searcy 2013).

Thus, the sustainability approach is externalised to the environmental, social and economic dimensions. SC risk can be categorised into two groups, internal and external (Olson and Wu 2010). Internal risks include operations and information system disruptions derived from supply, manufacturing and delivery, while external risks (i.e. sustainability risk) stem from nature, social, economic and market-related uncertainty. Brusset and Teller (2017) supported a similar distinction that internal SC risks involve information, suppliers, customers and organisational factors at an operational level, while external risks include social, political, environmental and economic aspects at a business level. Thus, we have targeted SC sustainability-related risks that are differentiated from internal supply chain risks (Tang 2006). In the environmental dimension, the risk principle is to satisfy the quality of a shared ecosystem, while the social account incorporates the acceptance of responsibility towards employees, customers, business partners, governments and society (Porter and Kramer 2006; Pullman et al. 2009). The economic dimension represents monetary risks derived from the economic environment, corporations and individuals' deceitful behaviour, and an endeavour for sustained economic growth (Jeucken 2004).

Thus, we defined three categories of SC sustainability risk: (1) environmental, (2) social and (3) economic, mainly supported by the triple-bottom line view of Elkington (1998)'s definition. At the item level, environmental risks involve environmental accidents, natural disasters, pollution, energy consumption, alternative energy, environmental degradation, product wastes, excessive packing and greenhouse gases (Olson and Wu 2010; Tummala and Schoenherr 2011; Waters 2011; Wiengaten et al. 2016; Giannakis and Papadopoulos 2016; Song et al. 2017; Rostamzadeh et al. 2018). Social risk incorporates working time, unfair wages, inhumane treatment, discrimination, health and safety, social instability, cultural/political, pandemic, demographic challenges and relationship risk (Tummala and Schoenherr 2011; Giannakis and Papadopoulos 2016; Song et al. 2017; Gouda and Saranga 2018; Rostamzadeh et al. 2018). Currency exchange rate, price volatility, competitive market moves, litigation, antitrust risk, corruption, tax avoidance and financial crisis are examples of economic risk (Dornier et al. 1998; Manuj and Mentzer 2008; Olson and Wu 2010; Tang and Musa 2011; Tummala and Schoenherr 2011; Song et al. 2017; Bak 2017). Researchers' growing interest in SC sustainability has revealed the significance of sustainable business practices and sustainability-related risk management with an appropriate risk-mitigating strategy (Anderson 2006).

Supply chain resilience capability

Supply chain resilience is defined as the capability to react to, cope with, adapt to or withstand unexpected events (Hohenstein et al. 2015; Nikookar and Yanadori

2022). Similarly, supply chain resilience can be defined as “the capacity for an enterprise or set of business entities to survive, adapt, and grow in the face of turbulent change” (Fiksel et al. 2015). As GSCs have increased in length and complexity (Blackhurst et al. 2005), sustainability risks such as natural catastrophes, pandemics, wars, strikes and economic upheavals severely impact SC performance (Chopra and Sodhi 2004; Wagner and Bode 2008). Thus, organisations must enhance SC resilience with specific tactics that help them develop such dynamic capabilities under global uncertainty (Hendricks 2005; Ponomarov and Holcomb 2009). Especially, sustainability risks are not simple to detect, assess or control, and are often impossible to predict. Although the occurrence of sustainability-related events is infrequent, the impact of disruptions such as natural disasters or a strike at a supplier’s plant (Gunasekaran et al. 2015) is significant. Today’s GSC environment is complex and more prone to disruption by unexpected natural and man-made events (Wagner and Bode 2008), so the capability to recover rapidly has become essential.

SC resilience capabilities include SC agility, collaboration, information sharing, sustainability, risk evaluation, trust, visibility, risk management culture, adaptive capability and structure (see Soni et al. 2014; Nikookar and Yanadori 2022). Similarly, Jain et al. (2017) extend SC resilience with 13 items: adaptive capability, collaboration among players, trust among players, SC sustainability, risk sharing, information sharing, SC structure, market sensitiveness, SC agility, SC visibility, risk management culture, minimising uncertainty and technological capabilities among partners. Brusset and Teller (2017) also supported the importance of resilience capability, suggesting four procedures to minimise the influence by evaluating process vulnerabilities, assessing the level of risks, deploying alternative plans for risk and increasing visibility over the whole SC.

Sustainability risk studies also highlighted the significance of understanding a firm’s capabilities and becoming proactively resilient (Brusset and Teller 2017; Negri et al. 2021) since supply chain resilience enables the firm to persist through the shocks or transform and then quickly recover when facing unexpected disruptions and risks (Wieland 2021). Thus, the high probability of sustainability risks can promote the prerequisite capability for SC resilience. For example, a healthy and collaborative work environment drives employees to perform better, reduces absenteeism and attrition, reduces the probability of a disruption event in the supply chain and leads to better supply chain resilience (Gouda and Saranga 2018). Also, companies with competitive markets, innovative products and unpredictable demand, require focusing more on the agile SC strategy (Stavrulaki and Davis 2010) rather than the lean SC strategy. Since resilience is a dynamic capability to be sustainable in the supply chain (Ivanov 2018), it is necessary to explore the interconnections between sustainability risks and resilience capability and provide prerequisite competencies for managers to design resilience solutions (He et al. 2021). Synthesising the classifications and claims made in previous studies, we propose the following hypotheses:

H1 Organisations facing high SC sustainability risks, including (a) environmental risk, (b) social, (c) economic risk, are required better SC resilience capability.

Global supply chain uncertainty

Risk is distinguished from uncertainty in the sense that it is measurable (Ho et al. 2015) by evaluating historical data or subjective assumptions. Among several SC management literature, SC uncertainty has been recognised (e.g. Davis 1993; Trkman and McCormack 2009; Flynn et al. 2016; Hasani and Khosrojerdi 2016). Flynn et al. (2016) suggested two types of supply chain uncertainty: micro and macro-levels. Similar to Sreedevi and Saranga's (2017) identification, micro-level uncertainty is based on the variability of inputs to the technical core of SC, corresponding to the uncertainty in the continuous processes of traditional operations, such as component damage, fabrication yields failure and shipment delay (Tan et al. 2014; Roh et al. 2014). Next, macro-level uncertainty is related to unclear and ambiguous situations faced by SC members in rapidly changing external environments at a business level (Flynn et al. 2016), such as when an organisation encounters a natural disaster, recession or cultural challenges (i.e. sustainability-related risks), competitive pressure, fast competitive moves and fast changes in customer need concern (Hasani and Khosrojerdi 2016). Especially, globalisation significantly boosts the improvement of supply chain surplus and, in turn, increases demand and supply chain uncertainty (Gereffi and Lee 2011) in a more competitive environment. Similarly, Cucchiella and Gastaldi (2006) categorised uncertainty as internal (i.e. micro) and external (i.e. macro) levels such as competitor action and changes in consumer need and demand.

Therefore, macro-level uncertainty occurs in a complex and dynamic global context that features externally unclear and ill-structured situations (Tan et al. 2014; Flynn et al. 2016). Changes in economic conditions, market turbulence, competitive intensity, technological turbulence, changes in customer needs and environmental challenges (Beckman et al. 2004; Germain et al. 2008) are examples of the primary sources of macro-level global uncertainty. These macro-level uncertainties are challenging to anticipate and understand and are influenced by SC sustainability risks profoundly. For example, low-probability and high-impact events (Hora and Klassen 2013) such as natural disasters, wars, political instability and accidents result in global-level uncertainty (Kauppi 2012). An increased volume of global trade has also generated strict abidance with environmental standards and compliance through national, international and self-regulation (Williams et al. 1993; Zeng and Eastin 2007). Other examples include unexpected shifts in customer demand (i.e. economic account) or when an organisation encounters excessive product waste (i.e. environmental account) or a pandemic (i.e. social account), which can lead more complex and unpredictable GSC environment. Frequent changes in production technology in a globally competitive environment increase the complexity of manufacturing and force technical modification at the supplier end, increasing supply chain resilience capability (Seedevi and Saranga 2017). Innovative and customised product offerings (i.e. buyer-driven chains) to mitigate economic and market risk can support firms in achieving sustainable competitive advantage. However, they also result in greater complexity in the manufacturing, procurement and delivery process, leading to higher global uncertainty throughout the entire supply chain (Randall and Ulrich 2001). Therefore, GSC uncertainty can be triggered by SC sustainability risks (Flynn et al. 2016) and encourages the firm to adapt to uncertainty through resilience capability. Building on these relationships, we propose the following hypotheses:

H2 The relationships between SC sustainability risks, including (a) environmental risk, (b) social, (c) economic risk and SC resilience, are mediated by GSC uncertainty.

The moderating role of risk management strategies

Risk management requires business entities to examine all possible outcomes and then weigh the potential returns against the potential risks (Ho et al. 2015; Fan and Stevenson 2018). Especially, since sustainability-related risks are highly unpredictable to detect, mitigating strategies to respond to the probability of unforeseen events are critical. Sustainability risk management can typically be grouped into four fundamental mitigating strategies (Giannakis and Papadopoulos 2016) including retain (i.e. accept), avoid, control (or mitigating) and share/transfer. First, the acceptance strategy involves the retainment of the potential negative impacts that would be incurred by a sustainability-related risk event, especially in a case where the actual cost of the other strategies would be higher than the total cost of the potential damage (Vose 2008; Hajmohammad and Vachon 2016). Acceptance can also be used if the probability of an event and/or the consequence of impact is relatively minor to ignore (Um and Han 2020). For example, a pandemic can be contained by adapting to a new reality, and boycotts can be accepted or ignored if penalties are low (Giannakis and Papadopoulos 2016).

Second, the avoidance strategy can be employed when the activity leads to severe risks that are contemplated unacceptable. This enables the probability of even to be zero by evading and guaranteeing that the risk is not present (Hajmohammad and Vachon 2016). For example, avoid polluting providers and using clean energy (Diesendorf 2007), locating the facility away from an urban area (Blackburn 2007), avoiding countries with a poor transparency record (Giannakis and Papadopoulos 2016), avoiding investment in unstable regions (Taylor 2009), avoiding outsourcing and offshoring (Tang and Musa 2011) and participating only in low economic uncertainty (Miller 1992).

Third, control involves the attempt to prevent risk by reducing the probability of an event occurring and actions to mitigate the consequences of related risks. Therefore, we regard the control strategy as a tool to curtail risks. Examples of reducing the probability of an event include a supplier development programme, utilising energy-efficient or eco-friendly technologies, employing certified staff, designing sustainable contracts and monitoring the conduct of third parties (Giannakis and Papadopoulos 2016) from the sustainability perspective. To minimise the probability of consequences, firms should respond rapidly to negative reports about sustainable practices by suppliers, ensure their liquidity, build a trustful relationship with the local community (Taylor 2009), build extra capacity, enforce safety instructions (Halldórsson et al. 2009), introduce waste-management training, train employees for new technologies (Last 2001), hedge against energy price variation and the currency exchange rate, monitor the CO_2 footprint across the SC (Anderson and Anderson 2009), reduce packaging and employ contingency plans for SC resilience (Giannakis and Papadopoulos 2016).

Last, unlike the control strategy, the share and transfer strategy focus on the distribution of risks to mitigate the consequences of related risks. For example, economic risks can be shared or transferred obligation through outsourcing, insurance (e.g. shipment and liquidated damage), collaboration and legal contracts with suppliers and customers (Macneil 1978; MacCormack et al. 1994; Manuj and Mentzer 2008). Further measures include insuring against potential catastrophes and disasters (Waters 2011), conducting sustainability audits with key suppliers, outsourcing legal services, taking out medical and health insurance for employees (Halldórsson et al. 2009; Giannakis and Papadopoulos 2016), multiple sourcing (Manuj and Mentzer 2008) and sharing regulatory information for sustainability law (Giannakis and Papadopoulos 2016). Mitigating strategies support the management of sustainability risks and enhance the SC resilience capability to respond to unexpected events proactively and reactively (Hajmohammad and Vachon 2016). Also, supply chain resilience is an enhancement to risk management through mitigating strategies, not a replacement for it (Pettit et al. 2019). Therefore, to investigate the effectiveness of SC sustainability risk management practices, we propose the following hypotheses:

H3 The relationship between environmental risk and supply chain resilience capability is strengthened when firms pursue risk mitigation strategies: (a) acceptance, (b) avoidance, (c) control, (d) share and/or transfer.

H4 The relationship between social risk and supply chain resilience capability is strengthened when firms pursue risk mitigation strategies: (a) acceptance, (b) avoidance, (c) control, (d) share and/or transfer.

H5 The relationship between economic risk and supply chain resilience capability is strengthened when firms pursue risk mitigation strategies: (a) acceptance, (b) avoidance, (c) control, (d) share and/or transfer.

Research methodology

Sample and data collection

A survey is employed to collect data from both the UK and South Korea. Based on the method of Douglas and Craig (2007), after a professional translated the original version of the questionnaire into Korean, another translator then translated it back into English. The two professionals then reach an agreement on a final version of the questionnaire. After conducting a pilot test based on interviews with three manufacturing firms, we analysed pre-data and feedback to confirm the clarity of the questionnaire. Using a database from the Korea Importers Association (KIA) and expert panels in the UK, we sent the finalised questionnaire to 900 manufacturing firms through an online platform in the UK ($n = 350$) and by telephone, email and face-to-face meetings in South Korea ($n = 550$). In total, we received 342 completed questionnaires from 159 companies in the UK and 183 firms in South Korea. This is an acceptable number of respondents ($n > 271$) with which to investigate relationships, including marginal effects at 0.8 statistical power, with a 0.05 significance level (Verma and Goodale 1995; Forza 2002). Respondent positions are CEOs or directors (42.7%), managers (44.3%) and others (13.0%). Based on the number of full-time employees ($n > 250$) 49.3% are large enterprises (LEs) and 49.7% of the firms are small and medium-sized enterprises (SMEs). Table 1 categorises the respondent firms by key product sector.

Regarding bias tests, first, to estimate potential late-response bias, we follow the procedure suggested by Armstrong and Overton (1977). *T* test indicates there is no difference at the 0.05 level between early and late respondents, revealing the response bias issue as minor. Second, to test for common method bias, Harman's one-factor test is conducted. A principal component factor analysis using all the items in the study shows distinct five factors with eigenvalues above 1 (i.e. accounting for 57.8% of the total variance, with the largest accounting for 14.8%). Since no single factor is apparent in the un-rotated factor structure, the common method variance issue is insignificant. Last, to ensure key structures of the model is cross-culturally stable since samples are collected from two countries, we conducted multi-group CFA estimation to cross-validate the model resulting in an acceptable fit to the data (χ^2/df = 1.58, RMSEA = 0.042, SRMR = 0.051, CIF = 0.904), suggesting that measurement invariance (i.e. configural invariance) is supported across the two countries, which implies those same items load on the same factors with similar loadings in the two countries.

Measurement

All items employed in each structure are adopted from the existing literature. Four items (GSU1-4) from Flynn et al. (2016) are selected to explain the structure of GSC uncertainty. SC sustainability risk is composed of three key areas, established on the

Table 1 Survey respondents

Manufacturing industry type	Total	Valid %
Food, beverage, tobacco	37	10.8
Wood, paper and furniture	40	11.7
Chemical materials and mineral products	33	9.7
Metal products	33	9.6
Electric parts and components	33	9.6
Electric machinery, computer and communication products	57	16.7
Clothing, textiles and leather	34	10.0
Machinery and transport equipment	38	11.1
Other	37	10.8
Total	342	100%

triple-bottom line, environmental (REN), social (RSO) and economic risk (REC). Six items (see Manuj and Mentzer 2008; Olson and Wu 2010; Tummala and Schoenherr 2011; Wiengaten et al. 2016; Gouda and Saranga 2018) for environmental risk, seven (see Dornier et al. 1998; Meixell and Gargeya 2005; Tummala and Schoenherr 2011; Brusset and Teller 2017; Song et al. 2017; Rostamzadeh et al. 2018) for social risk and six (see Dornier 1998; Tang and Musa 2011; Giannakis and Papadopoulos 2016; Brusset and Teller 2017; Bak 2017) for economic risk are employed to explain each SC sustainability risk structure. The SC resilience capability (SRC) construct concerns the ten enablers to reduce risk impact and enhance resilience and includes items from cross-validated articles (e.g. Soni et al. 2014; Jain et al. 2017; Brusset and Teller 2017; Rubbio et al. 2019; Han et al. 2020). Four key mitigating strategies are employed based on the definition from Giannakis and Papadopoulos (2016) and Hajmohammad and Vachon (2016).

As suggested by Thun and Hoenig (2011), we employed two dimensions to determine the accurate level of risk including the probability of the event and the consequence of the event. Respondents were asked to indicate the level of probability of each risk item and its impact on the company (1 = lowest and 5 = highest) separately. The level of agreement with each statement was measured on a five-point Likert scale for resilience capability and GSC uncertainty (1 = strongly disagree and 5 = strongly agree) and risk management strategies were rated based on performance (1 = poor and 5 = excellent) with supporting examples for each strategy.

Measurement validation

We tested a confirmatory factor analysis (CFA) to determine measurement composite reliability (CR), convergent validity through factor loading, average variance extracted (AVE) and discriminant validity. Structural equation modelling (SEM) is employed to test both the model and the hypothesis since SEM enables the examination of the bivariate relationships between single interacting variables as well as the overall causal fit and paths of a holistic model among several dependent variables (Worren et al. 2002; Mardani et al. 2017). The study first employed AMOS 25 for path analysis, then PROCESS under SPSS 25 to examine the conditional moderated effect, as suggested by Hayes (2013).

We decided the threshold of item loadings above 0.5 (Hair et al. 2010) from the list of dependent and independent variables for content and convergent validity, which include the two items (SRC2, 7 and 9) between factor loadings 0.5 and 0.6. Table 2 indicates the factor loadings, composite reliability (CR) and average variance extracted (AVE) with the fit indices. The measurement model indicated a satisfactory fit to the data (χ^2/df = 869.160/474 = 1.83, GFI = 0.866, SRMR = 0.060, RMSEA = 0.049, CFI = 0.932). CR confirmed acceptable internal consistency (> 0.807), while convergent validity was assured since all the loadings were similar to or greater than 0.5, with acceptable AVE values (> 0.502). In Table 3, there was no case where the square of the correlation between a pair of constructs was greater than the AVE of the constructs. Thus, discriminant validity was verified using the procedures suggested by Zait and Bertea (2011).

Table 2 Confirmatory factor analysis

Structure	Code	Abbreviated item statement	Factor loading	CR	AVE
Environmental risk (REN)	REN 1	Environmental accident	0.657	0.882	0.557
	REN 2	Natural disaster	0.702		
	REN 3	Pollution	0.812		
	REN 4	Energy consumption	0.724		
	REN 5	Product wastes	0.748		
	REN 6	Excessive packaging	0.618		
Social risk (RSO)	RSO 1	Working time (work–life imbalance)	0.736	0.929	0.652
	RSO 2	Unfair wages/rate	0.753		
	RSO 3	Discrimination	0.799		
	RSO 4	Health and safe working environment	0.753		
	RSO 5	Social instability	0.807		
	RSO 6	Cultural and political risk	0.811		
	RSO 7	Integration/relationship risk	0.751		
Economic risk (REC)	REC 1	Currency exchange rate	0.669	0.912	0.636
	REC 2	Material/product price volatility	0.762		
	REC 3	Market competitor/alternatives	0.762		
	REC 4	Financial/cost risk	0.813		
	REC 5	Country litigation risk	0.676		
	REC 6	Antitrust/dishonesty claim	0.619		
Global SC uncertainty (GSU)	GSU1	Our global competitive pressures are high	0.727	0.807	0.511
	GSU 2	Competitive moves in our market are fast, with short time gaps between different companies' reactions	0.717		
	GSU 3	The needs and wants of our customers are changing very fast	0.708		
	GSU 4	Our customers' needs and wants are difficult to ascertain	0.671		

Table 2 (continued)

Structure	Code	Abbreviated item statement	Factor loading	CR	AVE
SC resilience capability (SRC)	SRC 1	Ability to provide a quick response to supply chain disruption	0.617	0.909	0.502
	SRC 2	Ability to cope with changes brought by the supply chain disruption through collaboration with partners to minimise uncertainty	0.561		
	SRC 3	Ability to adapt to the supply chain disruption easily through information sharing	0.623		
	SRC 4	Ability to maintain high-risk awareness and evaluation at all times	0.624		
	SRC 5	Ability to maintain trust with partners to adapt to supply chain disruption	0.638		
	SRC 6	Supply chain allows increasing visibility over the supply chain	0.608		
	SRC 7	Ability to adapt to and cope with changes from the supply chain disruption through risk management culture in the organisation	0.533		
	SRC 8	Ability to deploy adaptive capability and alternative plans	0.640		
	SRC 9	Adaptive SC structure to cope with changes brought by the supply chain disruption	0.589		
	SRC 10	Ability to cope with changes brought by the supply chain disruption through technologies	0.608		

Composite reliability (CR) = $\left(\sum \text{standardised loading}\right)^2 / \{\left(\sum \text{standardised loading}\right)^2 + \sum \epsilon_i\}$

Average variance extracted (AVE) = $\sum (\text{standardised loading})^2 / (\sum (\text{standardised loading})^2 + \sum \epsilon_i)$

Fit indices: χ^2/df (chi square) = 869.160/474 = 1.83, GFI (goodness-of-fit index) = 0.866, SRMR (standardised root-mean-square residual) = 0.060, RMSEA (root-mean-squared error of approximation) = 0.049, CFI (comparative fit index) = 0.932

Table 3 Inter-construct correlation estimates and related AVEs

	REN	RSO	REC	GSU	SRC
REN	0.557$^+$				
RSO	0.687**	0.652$^+$			
REC	0.420**	0.435**	0.636$^+$		
GSU	0.114*	0.083	0.239**	0.511$^+$	
SRC	0.549**	0.584**	0.587**	0.289**	0.502$^+$
Mean	2.97	2.99	3.23	3.43	3.27
SD	0.712	0.731	0.606	0.756	0.497

$^+$Average variance extracted, * represents significant at the 0.05 level and ** 0.01 level

Results

SEM analysis

We performed SEM analysis for variables to examine the structural relationships among SC sustainability risks, global uncertainty and resilience capability. All model paths have high *t* values (≥ 2.095) and acceptable *p* values (< 0.05) except for the relationships between environmental, social risk and GSC uncertainty. The fit indices of GFI (≥ 0.870), CFI (≥ 0.935), RMSEA (≤ 0.057) and SRMR (≤ 0.048) imply an acceptable fit with the model.

All three SC sustainability risk classes impact SC resilience capability positively with accepted *p* values ($p \leq 0.036$). Social risk ($\beta = 0.353$) and economic risk ($\beta = 0.331$) exhibit significant direct impacts on SC resilience followed by environmental risk ($\beta = 0.183$), whilst environmental and social risk have an insignificant impact on global uncertainty ($p > 0.05$), which indicate the indirect mediation effect of global uncertainty only exists between economic risk and SC resilience capability (total effect = 0.400). Bootstrapping indirect impact analysis demonstrated the positive indirect impact ($\beta = 0.069$) among economic risk and SC resilience capability through GSC uncertainty. Thus, the results presented in Table 4 support hypotheses H1a, H1b, H1c and H2c. However, H2a (i.e. the link of environmental risk with GSC uncertainty) and H2b (i.e. the link of social risk with GSC uncertainty) are rejected.

Moderating effect of mitigating strategies

A moderation effect analysis was conducted using ‘Model 1’ in PROCESS to investigate whether the links between SC sustainability risks and SRC are dependent on different mitigating strategies (i.e. H3–H5). We accepted moderator hypotheses when the path coefficients between the interaction term and the dependent variable are statistically significant (Baron and Kenny 1986). The moderating effects of the acceptance strategy on SC resilience capability are significant under the environment of environmental risk (interaction $\beta = 0.182$,

Table 4 SEM Path analysis

Construct (Model)	Path Coefficient	*t* value	Significance	Total effect	Hypothesis
REN—SRC	0.183*	2.095	0.036	0.215*	Accepted
RSO—SRC	0.353***	4.018	0.000	0.317**	Accepted
REC—SRC	0.331***	5.149	0.000	0.400**	Accepted
REN—GSU	0.169	1.398	0.162	0.169	Rejected
RSO—GSU	− 0.174	− 1.489	0.136	− 0.174	Rejected
REC—GSU	0.339***	4.137	0.000	0.339***	Accepted
GSU—SRC	0.203**	3.739	0.001	0.203**	Accepted

Bootstrapping 5000 times for mediation effect

χ^2/df = 843.824/472 = 1.79, SRMR = 0.057, RMSEA = 0.048, GFI = 0.870, CFI = 0.935

*Represents significant at the 0.05 level, ** 0.01 level and *** 0.001 level

$p < 0.001$), social risk (interaction $\beta = 0.119$, $p < 0.05$) and economic risk (interaction $\beta = 0.193$, $p < 0.001$).

The avoidance strategy significantly moderates all relationships between three sustainability risks and SC resilience capability: environmental risk (interaction $\beta = 0.175$), social risk (interaction $\beta = 0.109$) and economic risk (interaction $\beta = 0.154$). Similarly, the control strategy moderates all relationships significantly between environmental risk (interaction $\beta = 0.201$), social risk (interaction $\beta = 0.136$) and economic risk (interaction $\beta = 0.193$) with SC resilience capability respectively. The moderating effect of the share/transfer strategy is significant for environmental risk (interaction $\beta = 0.128$) and economic risk (interaction $\beta = 0.097$), while not for social risk ($p > 0.1$) environment. Therefore, H3a, 4a, 5a (i.e. accept), H3b, 4b, 5b (i.e. avoid), H3c, 4c, 5c (i.e. control), H3d and 5d (i.e. share/transfer) are accepted; however, H4d is rejected.

We explored a conditional effect of sustainability risks on SC resilience capability moderated by each mitigating strategy to check the degree of the moderating effect under different strategic risk approaches. Thus, the study employed a bootstrap analysis on 10,000 resamples using the estimation of a bias-corrected 95 percentile confidence interval (CI). There are no CIs including the 0 between the upper limit confidence interval (ULCI) and the lower limit confidence interval (LLCI) (Hayes 2013; Chang et al. 2016), which is also confirmed by *p* values that are less than 0.05. Table 5 indicates the results of moderated relationships, their path coefficient, significance level and conditional effects (i.e. low, middle and high). The coefficients of low, medium and high clusters reveal an increasing moderation effect on resilience capability when a firm performs each mitigating strategy with more focus.

Discussion and conclusions

Discussion of major findings

We investigated how fundamental four mitigation strategies impact the relationships among SC sustainability risk, global uncertainty and SC resilience capability

Table 5 Moderated relationships

Construct	Path coefficient	*t* value	Significance	Conditional effect (Low/Middle/High)
REN—SRC				
Acceptance	0.182***	4.384	0.000	0.235/0.355/0.475
Avoidance	0.175***	4.436	0.000	0.232/0.348/0.465
Control	0.201***	5.012	0.000	0.217/0.351/0.486
Share/transfer	0.128*	3.137	0.019	0.262/0.369/0.476
RSO—SRC				
Acceptance	0.119*	3.165	0.017	0.281/0.360/0.438
Avoidance	0.109**	2.874	0.004	0.274/0.346/0.419
Control	0.136**	3.393	0.001	0.274/0.365/0.456
Share/transfer	0.044	1.163	0.246	-
REC—SRC				
Acceptance	0.193***	4.151	0.000	0.277/0.420/0.564
Avoidance	0.154**	3.442	0.001	0.321/0.424/0.528
Control	0.193***	3.958	0.000	0.293/0.423/0.553
Share/transfer	0.097*	2.446	0.015	0.366/0.447/0.528

Bootstrap resample = 10,000

Low (mean minus one standard deviation)/Middle (mean)/High (mean plus one standard deviation) at 95% CI

*Represents significant at the 0.05 level, ** 0.01 level and *** 0.001 level

through a survey. First, as key findings, the relationships between SC sustainability risks and resilience capability are reliant on different mitigating strategies through moderation analysis. Under environmental risks, the control strategy is the most effective approach to strengthen SC resilience capability, followed by acceptance, avoidance and share/transfer strategies. For example, close partnerships, safety training and co-development of an emergency plan with suppliers for an environmental accident, flexible supply chain structure and outsourcing for a natural disaster, clean alternative energy employment, sustainable supplier selection and locating the facility away from urban areas for pollution, sustainable products and production techniques for energy consumption (Gouda and Saranga 2018), disposal or recycling management for product waste, postponement and sustainable design of packaging for excessive packing should be considered to mitigate environmental risk. Similarly, under a social risk environment, the control strategy is the most significant approach, followed by acceptance and avoidance strategies, while the share/transfer approach does not reinforce the SC resilience capability. Examples include the establishment of a culture for a balanced life, a flexible working scheme for working time, engagement with industry bodies for a fair wage, provision of legal service for social equality, safety training and consulting and medical insurance for a healthy and safe working environment, close relationships with shareholders and monitoring government regulation for political risk, entering the market with a similar culture, vertical integration and cocreation for integration risk. For economic risk, both the control and acceptance strategies are most appropriate to improve the SC resilience capability, followed by the avoidance and share/transfer strategies. For instance, multiple sourcing and hedging for an exchange rate, industry collaboration and large volume purchasing for material price volatility, building extra capacity and brand loyalty for market competitiveness, economic audit and flexible payment for financial risk, review system for litigation risk and building community relationships for antitrust risk. Overall, a control strategy provides a more significant benefit in SC sustainability risks, while the share/transfer strategy is least effective, especially for social risk. Also, the avoidance strategy indicated a relatively weaker influence than the acceptance and control strategies. According to the comparison among conditional effects (i.e. low and high-performance conditions), the effectiveness of using mitigating strategies is higher in environmental (i.e. from 0.217 to 0.486) and economic risks (i.e. from 0.277 to 0.564) than in social risks. Table 6 in Appendix presents the sustainability risk factors, references, effective strategies that are statistically accepted and related activity examples.

Second, the SC sustainability risks induce better resilience capability, especially for social risks followed by economic and environmental risks. A firm faced with high social and economic risks, such as health, culture, currency exchange risk and high price volatility as well as high uncertainty, such as the fast movement in customer needs and competitive pressure from markets or competitors, results in a greater probability of achieving better SC resilience capability. Environmental risks that are challenging to detect and manage, such as natural accidents, pollution and fire (Wiengaten et al. 2016), reveal a minor improvement in SC resilience capability relatively.

Third, the results demonstrated that SC global uncertainty significantly mediates a relationship between economic risk and SC resilience capability. Instead, the direct impacts of environmental and social risks on SC resilience capability are more potent than the indirect impact through SC uncertainty. This reveals that SC resilience capability (i.e. agility, collaboration, information sharing, risk evaluation, trust, SC visibility, risk management culture, adaptive plan, adaptive SC structure and technological capability) can be achieved under different SC sustainability risks environments and through global uncertainty; therefore, employing the most appropriate and effective mitigating strategies is vital to formulate better SC resilience.

Implications and conclusion

There are several theoretical contributions to filling gaps in the SC sustainability literature and managerial implications providing practical direction and activities in addressing SC sustainability risks. First, the findings explain the structural procedure on how to achieve SC resilience capability by understanding the SC sustainability-related risks and exploring the role of key mitigating strategies depending on the types of risk. Also, the results provide comprehensive guidance on how and when an individual strategy improves SC resilience capability. Appropriate choice of the most effective mitigating approach under different SC sustainability risk environments is a vital step to ensuring better SC resilience capability. Second, the study demonstrated that all mitigating strategies and activities (see Appendix 1) strengthen SC resilience capability except for the relationship between social risk and resilience capability when the firm employs a share/transfer strategy. Although companies can employ mixed strategies in different circumstances, the companies should understand the benefits of each strategy in alignment with their business focus. Third, the GSC uncertainty (i.e. mediator) reveals the key management areas required for resilience, especially in an economic risk environment. Three sustainability-related risks (i.e. environmental, social and economic), global uncertainty and each mitigation strategy demonstrate different levels of influence on SC resilience capability; thus, the organisations should prioritise their approaches after evaluating the risks faced. Last, understanding the relationships among SC sustainability risks, global uncertainty, strategic benefits and resilience capability offers SC management practices for top management who are required to detect risk proactively and respond for better SC resilience.

Regarding the academic implications, first, the study suggests the theoretical lens on how to approach SC sustainability-related risks and resilience capability by fulfilling the gap from previous research. While previous studies explored SC resilience linked with SC internal risks (e.g. Brusset and Teller 2017; Song et al. 2017; Pettit et al. 2019) at the operations level or SC risk management approaches with SC sustainability-related risks (e.g. Govindan et al. 2014; Giannakis and Papadopoulos 2016; Sreedevi and Saranga 2017), this study explores inter-relationships of risk, uncertainty and resilience by stressing the role of four fundamental risk-mitigating strategies, which provide explicit explanations regarding the sustainable SC risk management processes from strategic perspectives. Second, the study contributes to extending the concept of the moderating role of mitigating strategies in evaluating the environmental, social and economic risk as well as the mediating role of GSC uncertainty, which provides clear theoretical procedures and steps to achieve SC resilience capability.

The study has several limitations. First, it does not reflect the cost of mitigating strategies in a high-risk and uncertain environment. The firm must consider the level of risk and its compensation for the cost and resource limitation incurred in handling SC sustainability-related risks using different mitigating strategies. Second, for better generalisation, we consolidated data from all manufacturing sectors; however, the results may differ in service industries, given their different SC structures and service flows. Third, in exploring effective strategies from the triple-bottom perspective, the study excluded internal or operational risk factors. Thus, the interaction between sustainability risk (e.g. strategic level) and operations challenges (i.e. business level) would be captured simultaneously in future research for a better explanation of the extensive benefits of SC resilience.

Appendix

See Table 6.

Table 6 Sustainability supply chain risks, mitigation strategies and practices

SC sustainability risks	Authors	Accepted mitigation strategies and practices (H3–H5)
Environmental risk		
Environmental accident	Olson and Wu (2010), Tummala and Schoenherr (2011), Wiengaten et al. (2016) Giannakis and Papadopoulos (2016), Brusset and Teller (2017), Gouda and Saranga, (2018)	Avoid: the suppliers/processes in the high risk Control: emergency plan/close supplier partnership/safety training Share/transfer: insurance against potential catastrophes
Natural disaster	Olson and Wu (2010), Tummala and Schoenherr (2011), Waters, (2011), Wiengaten et al. (2016) Giannakis and Papadopoulos (2016), Song et al. (2017), Rostamzadeh et al. (2018)	Avoid: the countries/markets in the high risk Control: contingency plan/SC resilience/SC flexibility Share/transfer: insurance against disaster/outsourcing/offshoring
Pollution	Diesendorf (2007), Blackburn, (2007), Giannakis and Papadopoulos (2016), Song et al. (2017), Gouda and Saranga, (2018), Rostamzadeh et al. (2018)	Avoid: locate facility away from an urban area/avoid polluting suppliers/clean energy use Control: waste and disposal management/clean energy investment/eco-friendly design/select sustainable suppliers/monitor CO_2 footprint Share/transfer: outsourcing to green 3PLs
Energy consumption	Diesendorf (2007), Giannakis and Papadopoulos (2016), Gouda and Saranga, (2018)	Avoid: use of new technology Control: invest in renewable energy/R&D for efficiency Share/transfer: insure the maintenance contract/conduct sustainability audit with key suppliers
Product waste and recycling	Last, (2001): Giannakis and Papadopoulos (2016), Song et al. (2017), Gouda and Saranga, (2018), Rostamzadeh et al. (2018)	Avoid: postponement and lean manufacturing Control: waste/disposal management/recycling/quality improvement/waste-management training/redesign SC structure/Make to Order (MTO) Share/transfer: waste and recycling contract
Excessive packaging	Blackburn, (2007), Giannakis and Papadopoulos (2016), Gouda and Saranga, (2018)	Avoid: product design considering packing Control: use only sustainable packing Share/transfer: supplier/customer involvement in the product design process
Social risk		

Table 6 (continued)

SC sustainability risks	Authors	Accepted mitigation strategies and practices (H3–H5)
Working time	Tang and Musa (2011), Giannakis and Papadopoulos (2016), Brusset and Teller (2017)	Avoid: additional working time Control: establish incentives/culture for balanced life/monitor productivity level/flexible working scheme/legal contract with employees
Unfair wages/rate	Manuj and Mentzer (2008), Giannakis and Papadopoulos (2016), Gouda and Saranga, (2018)	Avoid: apply a fair minimum wage/insourcing of HR function Control: engaged with industry bodies to monitor
Discrimination	Giannakis and Papadopoulos (2016), Song et al. (2017)	Avoid: automation and robotics Control: employ legal services to deal with equal opportunities/training and generate practice for equality
Health and safety	Olson and Wu (2010), Giannakis and Papadopoulos (2016)	Avoid: reengineering the process in risk Control: training programs and safety instruction/medical consulting and support
Social instability	Tummala and Schoenherr (2011), Giannakis and Papadopoulos (2016), Song et al. (2017), Gouda and Saranga, (2018), Rostamzadeh et al. (2018)	Avoid: the countries/markets in high risk Control: capacity plan for instability management/flexible working plan/adapt to new technology/multiple sourcing
Cultural and political risk	Dornier et al. (1998), Meixell and Gargeya, (2005), Olson and Wu (2010), Tang and Musa (2011), Tummala and Schoenherr (2011), Rostamzadeh et al. (2018), Xu et al. (2019)	Avoid: enter the market with a similar culture Control: a close relationship with shareholders/localisation/customisation/outsourcing/monitoring government regulation and labour disputes
Integration/relationship risk	Lewis (1999), Olson and Wu (2010), Tang and Musa (2011), Gouda and Saranga, (2018), Rostamzadeh et al. (2018)	Avoid: complex supply chain structure Control: vertical integration/building supplier and customer relationship/cocreation/customer voice management/cross training
Economic risks		
Currency exchange rate	Dornier et al. (1998), Manuj and Mentzer (2008), Olson and Wu (2010), Tang and Musa (2011), Tummala and Schoenherr (2011), Song et al. (2017)	Avoid: less profitable/stable markets Control: payment hedging/multiple sourcing/government engagements/joint support from financial institutions Share/transfer: risk sharing contract

Table 6 (continued)

SC sustainability risks	Authors	Accepted mitigation strategies and practices (H3–H5)
Material/product price volatility	Manuj and Mentzer (2008), Olson and Wu (2010), Tang and Musa (2011), Song et al. (2017)	Avoid: explore alternative materials Control: operational hedging/close industry collaboration/vertical integration/mass production/mass purchasing
Market competitor/moves/alternatives	Manuj and Mentzer (2008), Manuj and Mentzer, (2008), Olson and Wu (2010)	Avoid: competitive markets Control: improve partnership and alignment/customer loyalty/build extra capacity Share/transfer: partnerships/consortium
Financial/cost risk	Olson and Wu (2010), Tang and Musa (2011), Giannakis and Papadopoulos (2016), Brusset and Teller (2017), Bak (2017)	Avoid: uncertain countries/markets Control: ensure liquidity through insurance-like/improve economic audit/flexible payment Share/transfer: insurance/partnership contract
Country litigation risk (e.g. tax/customs policy)	Olson and Wu (2010), Tummala and Schoenherr (2011), Giannakis and Papadopoulos (2016), Bak (2017)	Avoid: avoid countries with poor transparency record Control: review system that evaluates litigation exposure/monitoring tax and customs policy Share/transfer: ensure the liquidity/share regulatory information
Antitrust claim/dishonesty claim	Taylor, (2009), Giannakis and Papadopoulos (2016)	Avoid: investment in trustful markets Control: a close relationship with local community/extra capacity provision for disruptions Share/transfer: long-term partnership/contract

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References

Ahi, P., and C. Searcy. 2013. A comparative literature analysis of definitions for green and sustainable supply chain management. *Journal of Cleaner Production* 52: 329–341.

Ali, A., A. Mahfouz, and A. Arisha. 2017. Analysing supply chain resilience: Integrating the constructs in a concept mapping framework via a systematic literature review. *Supply Chain Management: An International* 21: 16–39.

Anderson, D.R. 2006. The critical importance of sustainability risk management. *Risk Management* 53 (4): 66–74.

Anderson, D.R., and K.E. Anderson. 2009. Sustainability risk management. *Risk Management and Insurance Review* 12 (1): 25–38.

Armstrong, J.S., and T.S. Overton. 1977. Estimating nonresponse bias in mail survey. *Journal of Marketing Research* 14 (3): 396–402.

Aven, T. 2016. Risk assessment and risk management: Review of recent advances on their foundation. *European Journal of Operational Research* 253 (1): 1–13.

Bak, O. 2017. Supply chain risk management research agenda: From a literature review to a call for future research directions. *Business Process Management Journal* 24 (2): 567–588.

Baron, R.M., and D.A. Kenny. 1986. The moderator mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology* 51 (6): 1173–1182.

Beckman, C.M., P.R. Haunschild, and J. Damon. 2004. Friends or strangers? Firm-specific uncertainty, market uncertainty and network partner selection. *Organization Science* 15: 259–275.

Berkes, F., J. Colding, and C. Folke. 2003. *Navigating social-ecological systems: Building resilience for complexity and change*. Cambridge, NY: Cambridge University Press.

Blackburn, W.R. 2007. *The sustainability handbook: The complete management guide to achieving social, economic and environmental sustainability*. London: Environmental Law Institute.

Blackhurst, J., C.W. Craighead, D. Elkins, and R.B. Handfield. 2005. An empirically derived agenda of critical research issues for managing supply-chain disruptions. *International Journal of Production Research* 43 (19): 4067–4081.

Brandon, J.E., B. Squire, C. Autry, and K.J. Petersen. 2014. A contingent resource-based perspectives of supply chain resilience and robustness. *Journal of Supply Chain Management* 50 (3): 55–73.

Brusset, X., and C. Teller. 2017. Supply chain capability, risks and resilience. *International Journal of Production Economics* 184: 59–68.

Casselman, B. 2020. Will the coronavirus cause a recession? Keep your eye on the barbershops, *The New York Times*.

Chang, W.J., A.E. Ellinger, K. Kim, and G.R. Franke. 2016. Supply chain integration and firm financial performance: A meta-analysis of positional advantage mediation and moderation factors. *European Management Journal* 34 (3): 282–295.

Chopra, S., and M. Sodhi. 2004. Managing risk to Avoid supply chain breakdown. *MIT Sloan Management Review* 46 (1): 53–62.

Christmann, P. 1998. *Environmental strategies of multinational chemical companies: global integration or national responsiveness*. Los Angeles, CA: The Anderson School, University of California Los Angeles.

Christopher, M., and H. Lee. 2004. Mitigating supply chain risk through improved confidence. *International Journal of Physical Distribution and Logistics Management* 34 (5): 388–396.
Douglas, S.P., and C.S. Craig. 2007. Collaborative and iterative translation: An alternative approach to back translation. *Journal of International Marketing* 15: 30–43.
Cucchiella, F., and M. Gastaldi. 2006. Risk management in supply chain: A real option approach. *Journal of Manufacturing Technology Management* 17 (6): 700–720.
Davis, T. 1993. Effective supply chain management. *MIT Sloan Management Review* 34: 35–46.
Diesendorf, M. 2007. *Greenhouse solutions with sustainable energy*. Sydney: UNSW Press.
Dornier, P.P., R. Ernst, M. Fender, and P. Kouvelis. 1998. *Global operations and logistics: Text and cases*. New York: Wiley.
Elkington, J. 1998. *Cannibals with forks: The triple bottom line of 21st century business*. Oxford: Capstone.
Fan, Y., and M. Stevenson. 2018. A review of supply chain risk management: Definition, theory, and research agenda. *International Journal of Physical Distribution & Logistics Management* 48 (3): 205–230.
Fiksel, J., M. Polyviou, K.L. Croxton, and T.J. Pettit. 2015. From risk to resilience: Learning to deal with disruption. *MIT Sloan Management Review* 56 (2): 79–86.
Flynn, B.B., X. Kuufteros, and G. Lu. 2016. On theory in supply chain uncertainty and its implications for supply chain integration. *Journal of Supply Chain Management* 52 (3): 3–27.
Foerstl, K., C. Reuter, E. Hartmann, and C. Blome. 2010. Managing supplier sustainability risks in a dynamically changing environment—Sustainable supplier management in the chemical industry. *Journal of Purchasing and Supply Management* 16: 118–130.
Forza, C. 2002. Survey research in operations management: A process-based perspective. *International Journal of Operations and Production Management* 22 (2): 152–194.
Gereffi, G., and J. Lee. 2011. Why the world suddenly cares about global supply chain. *Journal of Supply Chain Management* 48 (3): 24–32.
Germain, R., C. Claycomb, and C. Droge. 2008. Supply chain variability, organisation structure and performance: The moderating effect of demand unpredictability. *Journal of Operations Management* 26: 557–570.
Giannakis, M., and T. Papadopoulos. 2016. Supply chain sustainability: A risk management approach. *International Journal of Production Economics* 171: 455–470.
Godfrey, P.C., C.B. Merrill, and J.M. Hansen. 2009. The relationship between corporate social responsibility and shareholder value: An empirical test of the risk management hypothesis. *Strategy Management Journal* 30 (4): 425–445.
Govindan, K., S.G. Azevedo, H. Carvalho, and V. Cruz-Machado. 2014. Impact of supply chain management practices on sustainability. *Journal of Cleaner Production* 85: 212–225.
Gouda, S.K., and H. Saranga. 2018. Sustainable supply chains for supply chain sustainability: Impact of sustainability efforts on supply chain risk. *International Journal of Production Research* 56: 5820–5835.
Gunasekaran, A., N. Subramanian, and S. Rahman. 2015. Supply chain resilience: Role of complexities and strategies. *International Journal of Production Research* 53 (22): 6809–6819.
Hair, F.J., W.C. Black, B.J. Babin, and R.E. Anderson. 2010. *Multivariate data analysis: A global perspective*. New Jersey: Pearson Education.
Hajmohammad, S., and S. Vachon. 2016. Mitigation, avoidance, or acceptance? Managing supplier sustainability risk. *Journal of Supply Chain Management* 52 (2): 48–65.
Halldórsson, A., H. Kotzab, and T. Skjøtt-Larsen. 2009. Supply chain management on the crossroad to sustainability: A blessing or a curse? *Logistics Research* 1: 83–94.
Han, Y., W.-K. Chong, and D. Li. 2020. A systematic literature review of the capabilities and performance metrics of supply chain resilience. *International Journal of Production Research* 58 (15): 4541–4566.
Hasani, A., and A. Khosrojerdi. 2016. Robust global supply chain network design under disruption and uncertainty considering resilience strategies: A parallel memetic algorithm for a real-life case study. *Transportation Research Part E* 87: 20–52.
Hayes, A.F. 2013. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York: The Guilford Press.
He, L., Z. Wu, W. Xiang, M. Goh, Z. Xu, W. Song, X. Ming, and X. Wu. 2021. A novel Kano-QFD-DEMATEL approach to optimise the risk resilience solution for sustainable supply chain. *International Journal of Production Research* 59: 1714–1735.

Heckmann, I., T. Comes, and S. Nickel. 2015. A critical review on supply chain risk—Definition measure and modeling. *Omega* 52: 119–132.

Hendricks, K. 2005. Association between supply chain glitches and operating performance. *Management Science* 51 (5): 695–711.

Ho, W., T. Zheng, H. Yildiz, and S. Talluri. 2015. Supply chain risk management: A literature review. *International Journal of Production Research* 53 (16): 5031–5069.

Hoffman, H., C. Busse, C. Bode, and M. Henke. 2014. Sustainability-related supply chain risks: Conceptualisation and management. *Business Strategy Environment* 23: 160–172.

Hohenstein, N.O., E. Feisel, E. Hartmann, and L. Giunipero. 2015. Research on the phenomenon of supply chain resilience: A systematic review and paths for further investigation. *International Journal of Physical Distribution and Logistics Management* 45 (1/2): 90–117.

Hora, M., and R.D. Klassen. 2013. Learning from others' misfortune: Factors influencing knowledge acquisition to reduce operational risk. *Journal of Operations Management* 31 (1–2): 52–61.

Ivanov, D. 2018. Revealing interfaces of supply chain resilience and sustainability: A simulation study. *International Journal of Production Research* 56 (10): 3507–3523.

Jain, V., S. Kumar, U. Soni, and C. Chandra. 2017. Supply chain resilience: Model development and empirical analysis. *International Journal of Production Research* 55 (22): 6779–6800.

Jeucken, M. 2004. *Sustainability in finance: Banking on the planet*. Delft: Eburon Academic Publishers.

Jüttner, U., and S. Maklan. 2011. Supply chain resilience in the global financial crisis: An empirical study. *Supply Chain Management: An International Journal* 16 (4): 246–259.

Kauppi, K. 2012. Extending the use of institutional theory in operations and supply chain management research: Review and suggestions. *International Journal of Operations and Production Management* 33 (10): 1318–1345.

Kim, S., S.M. Wagner, and C. Colicchia. 2019. The impact of supplier sustainability risk on shareholder value. *Journal of Supply Chain Management* 55 (1): 71–87.

Krysiak, F. 2009. Risk management as a tool for sustainability. *Journal of Business Ethics* 85: 483–492.

Last, J. 2001. *A dictionary of epidemiology*, 4th ed. Oxford: Oxford University Press.

Leenders, M.R., H.E. Fearon, A.E. Flynn, and P.F. Johnson. 2002. *Purchasing and supply management*, 12th ed. Boston, MA: McGraw-Hill Irwin.

Lewis, L. 1999. CPFR: One giant business plan. *Progressive Grocer* 78 (4): 69–72.

Levy, D. 1995. The environmental practices and performance of transnational corporations. *Transnational Corporations* 41: 44–67.

Macdonald, J.R., C.W. Zobel, S.A. Melnyk, and S.E. Griffis. 2018. Supply chain risk and resilience: Theory building through structured experiments and simulation. *International Journal of Production Research* 56 (12): 4337–4355.

Mardani, A., D. Streimikiene, E.K. Zavadskas, F. Cavallaro, M. Nilashi, A. Jusoh, and H. Zare. 2017. Application of structural equation modeling (SEM) to solve environmental sustainability problems: A comprehensive review and meta-analysis. *Sustainability* 9: 1814–1869.

MacCormack, A., L. Newmann, and D. Rosenfield. 1994. The new dynamics of global manufacturing site location. *Sloan Management Review* 35: 69–80.

Macneil, I. 1978. Contracts: Adjustment of long-term economic relations under classical, neoclassical, and relational contract law. *Northwestern University Law Review* 72 (6): 854–902.

Manuj, I., and J.T. Mentzer. 2008. Global Supply Chain risk management. *Journal of Business Logistics* 29 (1): 133–154.

Meixell, M., and V.B. Gargeya. 2005. Global supply chain design: A literature review and critique. *Transportation Research Part E* 41: 531–550.

Merschmann, U., and U.W. Thonemann. 2011. Supplychain flexibility, uncertainty and firm performance: anempirical analysis of German manufacturing firms.*International Journal of Production Economics* 130 (1): 43–53.

Miller, K.D. 1992. A framework for integrated risk management in international business. *Journal of International Business Studies* 23 (2): 311–331.

Mollenkopf, D., H. Stolze, W.L. Tate, and M. Ueltschy. 2009. Green, lean, and global supply chains. *International Journal of Phyiscal Distribution and Logistics Management* 10 (1/2): 14–41.

Negri, M., E. Cagno, C. Colicchia, and J. Sarkis. 2021. Integrating sustainability and resilience in the supply chain: A systematic literature review and a research agenda. *Business Strategy and the Environment* 30 (7): 2858–2886.

Nikookar, E., and Y. Yanadori. 2022. Preparing supply chain for the next disruption beyond COVID-19: Managerial antecedents of supply chain resilience. *International Journal of Operations and Production Management* 42 (1): 59–90.

Olson, D.L., and D.D. Wu. 2010. A review of enterprise risk management in supply chain. *Kybernetes* 39 (5): 694–706.

Peck, H. 2005. Drivers of supply chain vulnerability: An integrated framework. *International Journal of Physical Distribution and Logistics Management* 35 (4): 210–232.

Pettit, T.J., K.L. Croxton, and J. Fiksel. 2019. The evolution of resilience in supply chain management: A retrospective on ensuring supply chain resilience. *Journal of Business Logistics* 40: 56–65.

Porter, M.E., and M.R. Kramer. 2006. Strategy and society: The link between competitive advantage and corporate social responsibility. *Harvard Business Review* 84: 78–92.

Ponomarov, S.Y., and M.C. Holcomb. 2009. Understanding the concept of supply chain resilience. *International Journal of Logistics Management* 20: 124–143.

Pournader, M., A. Kach, and S. Talluri. 2020. A review of the existing and emerging topics in supply chain risk management literature. *Decision Sciences* 51 (4): 867–919.

Pullman, M.E., M.J. Maloni, and C.G. Carter. 2009. Food for thought: Social versus environmental sustainability programs and performance outcomes. *Journal of Supply Chain Management* 45 (4): 38–54.

Randall, T., and K. Ulrich. 2001. Product variety, supply chain structure, and firm performance: Analysis of the US bicycle industry. *Management Science* 47 (12): 1588–1640.

Roh, J., P. Hong, and H. Min. 2014. Implementation of a response supply chain strategy in global complexity: The case of manufacturing firms. *International Journal of Production Economics* 147: 198–210.

Rostamzadeh, R., M.K. Ghorabaee, K. Govindan, A. Esmaeili, and H.G.K. Nobar. 2018. Evaluation of sustainable supply chain risk management using an integrated fuzzy TOPSIS-CRITIC approach. *Journal of Cleaner Production* 175: 651–669.

Rubbio, I., M. Bruccoleri, A. Pietrosi, and B. Ragonese. 2019. Digital health technology enhances resilience behaviour: Evidence from the ward. *International Journal of Operations and Production Management* 40 (1): 33–67.

Scholten, K., P. Sharkey-Scott, and B. Fynes. 2014. Mitigation processes—Antecedents for building supply chain resilience. *Supply Chain Management: An International Journal* 19 (2): 211–228.

Seville, E., V.D. Opstal, and J. Vargo. 2015. A Primer in resiliency: Seven principles for managing the unexpected. *Global Business and Organizational Excellence* 34: 6–18.

Soni, U., V. Jain, and S. Kumar. 2014. Measuring supply chain resilience using a deterministic modelling approach. *Computers and Industrial Engineering* 74: 11–25.

Song, W., X. Ming, and H.C. Liu. 2017. Identifying critical risk factors of sustainable supply chain management: A rough strength-relation analysis method. *Journal of Cleaner Production* 143: 100–115.

Sreedevi, R., and H. Saranga. 2017. Uncertainty and supply chain risk: The moderating role of supply chain flexibility in risk mitigation. *International Journal of Production Economics* 193: 332–342.

Stavrulaki, E., and M. Davis. 2010. Aligning products with supply chain processes and strategy. *International Journal of Logistics Management* 21 (1): 127–151.

Tang, C.S. 2006. Perspectives in supply chain risk management. *International Journal of Production Economics* 103 (2): 451–488.

Tang, O., and S.N. Musa. 2011. Identifying risk issues and research advancements in supply chain risk management. *International Journal of Production Economics* 133: 25–34.

Tan, K.H., Y.K. Tse, and J. Chen. 2014. Quality risk in the global supply network. In *Global supply chain quality management: Product recalls and their impact*, ed. B.B. Flynn and X. Zhao. Boca Raton, FL: Taylor and Francis.

Taylor, M. 2009. *International competition law a new dimension for the WTO?* Cambridge University Press.

Teece, D., G. Isano, and A. Shuen. 1977. Dynamic capabilities and strategic management. *Strategy Management Journal* 18 (7): 509–533.

Teuscher, P., B. Grüninger, and N. Ferdinand. 2006. Risk management in sustainable supply chain management: Lessons learnt from the case of GMO-free soybeans. *Corporate Social Responsibility and Environment Management* 13 (1): 1–10.

Thun, J., and D. Hoenig. 2011. An empirical analysis of supply chain risk management in the German automotive industry. *International Journal of Production Economics* 131: 242–249.

Trkman, P., and K. McCormack. 2009. Supply chain risk in turbulent environments—a conceptual model for managing supply chain network risk. *International Journal of Production Economics* 119 (2): 247–258.
Tummala, R., and T. Schoenherr. 2011. Assessing and managing risks using the supply chain risk management process. *Supply Chain Management: An International Journal* 16 (6): 474–483.
Um, J., and N. Han. 2020. Understanding the relationships between global supply chain risk and supply chain resilience: The role of mitigating strategy. *Supply Chain Management: An International* 26 (2): 240–255.
Verma, R., and J.C. Goodale. 1995. Statistical power in operations management research. *Journal of Operations Management* 13 (2): 139–152.
Vose, D. 2008. *Risk analysis: A quantitative guide*, 3rd ed. Chichester: Wiley.
Wagner, S.M., and C. Bode. 2008. An empirical examination of supply chain performance along several dimensions of risk. *Journal of Business Logistics* 29 (1): 307–325.
Wang, Z., and J. Sarkis. 2013. Investigating the relationship of sustainable supply chain management with a corporate financial performance. *International Journal of Productivity and Performance Management* 62 (8): 871–888.
Waters, D. 2011. *Supply chain risk management: Vulnerability and resilience in logistics*. London: Kogan Page.
Wieland, A. 2021. Dancing the supply chain: Toward transformative supply chain management. *Journal of Supply Chain Management* 57 (1): 58–73.
Wieland, A., and C.F. Durach. 2021. Two perspectives on supply chain resilience. *Journal of Business Logistics* 42: 315–322.
Wiengaten, F., P. Humphreys, C. Gimmenez, and R. Mcivor. 2016. Risk, risk management practice, and the success of supply chain integration. *International Journal of Production Economics* 171: 361–370.
Williams, H., J. Medhurst, and K. Drew. 1993. Corporate strategies for a sustainable future. In *environmental strategies for industry*, ed. D.C. Washington, 117–146. Island Press.
Worren, N., K. Moore, and P. Cardona. 2002. Modularity, strategic flexibility and firm performance: A study of the home appliance industry. *Strategic Management Journal* 23 (12): 1123–1140.
Xu, M., Y. Cui, M. Hu, X. Xu, Z. Zhang, S. Liang, and S. Qu. 2019. Supply chain sustainability risk and assessment. *Journal of Cleaner Production* 225: 857–867.
Zait, A., and P.S.P.E. Bertea. 2011. Methods for testing discriminant validity. *Management & Marketing Journal* 9: 217–224.
Zeng, K., and J. Eastin. 2007. International economic integration and environmental protection: The case of China. *International Studies Quarterly* 51 (4): 971–995.
Zhu, Q., J. Sarkis, and Y. Geng. 2005. Green supply chain management in China: Pressures, practices and performance. *International Journal of Operations and Production Management* 25 (5): 449–468.
Zhu, Q., J. Sarkis, J.J. Cordeiro, and K.H. Lai. 2008. Firm-level correlates of emergent green supply chain management practices in the Chinese context. *Omega* 36 (4): 577–591.

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