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Sustainable supply chains for supply chain sustainability: impact of sustainability efforts on supply chain risk

Sirish Kumar Gouda[a] and Haritha Saranga[b*]

[a] *Operations Management and Quantitative Techniques Area, Indian Institute of Management Tiruchirappalli, Tiruchirappalli, India;* [b] *Production and Operations Management Area, Indian Institute of Management Bangalore, Bangalore, India*

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Supply chain managers across the globe are finding it difficult to manage the increasingly complex supply chains despite adopting a variety of risk mitigation strategies. Firms on the other hand have also been adopting various kinds of environmental and social sustainability practices in recent times to reduce carbon footprint and improve their image on the social front. However, very few studies in the extant literature have examined the impact of sustainability practices on supply chain risk. We address this important gap in literature by empirically testing this relationship, using primary data from six manufacturing sectors and 21 different countries including developed as well as emerging markets across the globe. Our findings indicate that risk mitigation strategies do not always reduce the actual supply chain risk experienced by firms, whereas sustainability efforts help reduce supply chain risk, especially in emerging market contexts. In addition, we find that, while reactive risk mitigation strategies on their own fail to reduce supply chain risk, they are effective when used in conjunction with sustainability efforts. We also find that preventive risk mitigation efforts are only effective in mature supply chains such as the OECD countries.

Keywords: sustainability; sustainable supply chain; supply chain risk management; supply chain collaboration; preventive risk mitigation; reactive risk mitigation

1. Introduction

Customers everywhere in the world expect seamless service from their suppliers. With the growing complexity and competition in the global arena, managers, however, are finding it increasingly difficult to ensure that their supply chains are free from disruptions (Kleindorfer and Saad 2005; Bode et al. 2011). Given the omnipresence of supply chain vulnerabilities and the severity of disruptions, operations management practitioners as well as researchers have begun to explore the various facets of supply chain risk management (SCRM). A recent survey by the Business Continuity Institute in 2016 revealed that 73% of firms reported having risk management solutions for their supply chains (BCI 2016), which is an indication of the significant amount of resources that firms have to invest in tackling these risks.

Supply chain disruptions are generally caused by various external events such as strikes, legal disputes and natural disasters as well as internal events such as accidents, theft, contamination and sabotage (Speier et al. 2011; Ivanov et al. 2017). These disruptions have detrimental effects not only on the firm's reputation and customer goodwill but also on its financial health (Hendricks and Singhal 2003). For example, In 2015, explosions from hazardous chemicals at Beijing's Maritime Gateway affected many Fortune 500 companies.[1] Ericsson lost around $ 400 million due to a fire accident in one of its supplier's (Philips) plant caused by lightning (Chopra and Sodhi 2004). Maruti Suzuki India Ltd., a prominent automaker in India, reportedly lost around $110 million due to a labour strike at their Manesar plant.[2] The increasing occurrence of such disruptions with high impact potential has led firms to adopt various preventive and reactive risk mitigation strategies. Some of the commonly adopted supply chain risk mitigation strategies include postponement, maintaining strategic stock, flexible supply base, make and buy strategies, flexible transportation, revenue management, dynamic pricing, assortment planning and silent product roll-over (Ho et al. 2015).

Practitioners on the other hand have long acknowledged the importance of sustainability efforts in managing supply chain risk. For example, German logistics giant DHL has recently launched a software (Resilience360) to track supply chain risks, and it detects supply chain disruptions by monitoring various categories of risk involving environmental damages and labour disputes.[3] Many global firms such as Starbucks, Walmart and Apple have also implemented environmental and social sustainability practices primarily to mitigate risks. Walmart for example has consciously made investments in environmental and social sustainability practices in order to reduce supply disruptions from its 50,000 suppliers based in China (Denend and Plambeck 2007). Recognising sustainable sourcing as one of the most important ways to ensure disruption-free supply

*Corresponding author. Email: harithas@iimb.ernet.in

chains, many manufacturing firms began to sensitise their suppliers about sustainable practices through regular audits and workshops. Anecdotal evidences from other parts of the world also suggest that firms find synergies in jointly developing sustainability practices along the supply chain, ultimately benefiting all the partners in the supply chain by reducing the risk of disruption (Foerstl et al. 2010). We posit on similar lines that one of the so-called *expected unexpected side benefits* (Corbett and Klassen 2006) of sustainable supply chains, as evidenced in practice, is reduction of supply chain risk (Carter and Rogers 2008; Hofmann et al. 2014; Taylor and Vachon 2018). However, very few research studies have explored the impact of sustainability practices on risk management (Foerstl et al. 2010; Klassen and Vereecke 2012; Hofmann et al. 2014). Even the few studies that examine supply chain risk management under the lens of sustainability are either case study based or conceptual in nature. To our knowledge, there is no academic study that empirically establishes linkages between sustainability practices and supply chain risk.

Our work makes several noteworthy contributions. First, we fill the gap in the literature by empirically studying the direct impact of firm's sustainability practices on supply chain risk. Towards this end, using resource-based view (RBV), we establish an empirical relationship between supply chain risk perception, various risk mitigation strategies, effort in sustainability initiatives and actual risk experienced by the firm, using primary data collected across several sectors of manufacturing firms. Second, we study the moderating effect of social and environmental sustainability practices on supply chain risk, in conjunction with different types of risk mitigation strategies. Finally, our study compares and contrasts the linkages between various supply chain risk management strategies and sustainability practices, and their impact on actual risk, in a variety of geographical contexts that include developed as well as emerging markets. Our study results provide many useful insights for supply chain managers and senior managers in multinational firms that face significant challenges due to the global nature of their supply chains.

2. Literature review and hypotheses development

In this section, we provide a brief overview of extant literature in supply chain risk management and sustainable supply chains, and develop conceptual linkages between the two areas and postulate our hypotheses using well-established theories and existing literature in SCRM.

2.1 *Supply chain risk*

Various definitions for supply chain risk have come about using terminology borrowed from literature on Enterprise Risk Management, financial and operational risk. Christopher and Peck (2004) define supply chain vulnerability as an exposure to shocks arising from within and outside the supply chain. Kumar, Tiwari, and Babiceanu (2010) define supply chain risks as *the potential deviations from the initial overall objective that, consequently, trigger the decrease of value-added activities at different levels* (3717). While some researchers have defined supply chain risk conceptually, others have used a more quantitative approach to define it. Manuj and Mentzer (2008) have defined supply chain risk in terms of the probability of occurrence of a risk event and the impact of such an event on the supply chain performance.

$$Supply\ chain\ risk = Probability(Risk\ event) \times Impact(Risk\ event)$$

Even though vulnerabilities, risk and disruption have been used interchangeably in general, recent works (Kleindorfer and Saad 2005; Kern et al. 2012) have classified risk into two categories; *operational ris*k arising from inadequate or failed processes leading to a supply–demand mismatch and *disruption risk* arising from man-made or natural disasters. While operational risks can be worked upon, disruption risks are less controllable. Jüttner, Peck, and Christopher (2003) on the other hand propose the following categories of risks; *internal risks* arising within the organisation, *supply-chain risks* internal to the supply chain but external to the organisation and *external supply chain risks* arising from the environment. We adopted the classification of supply chain risks provided by Kumar, Tiwari, and Babiceanu (2010) as follows:

(i) *Inbound risk (Supply risk)* emanating from disruptions at supplier's end.
(ii) *Process risk* resulting from disruptions or failures within the firm, and
(iii) *Shipment risk* based on disruptions in shipping or distributional logistics.

2.2 *Supply chain risk assessment and mitigation*

After the identification of the various categories of risks that a firm is exposed to, the next important step in SCRM is the assessment of risk followed by appropriate mitigation strategies. The process of risk assessment includes evaluating the likelihood of occurrence of a risk event and the impact of such a risk event (Yates and Stone 1992; Kleindorfer and Saad

2005; Manuj and Mentzer 2008; Kern et al. 2012). Risk mitigation efforts can only be effective, when risk assessment is done diligently by understanding the type of risk, various parameters affecting it and its possible impact on the supply chain (Kern et al. 2012). Thus, based on the categories of identified risks and assessment of their probability and impact, firms invest in a wide variety of risk mitigation strategies. Some of the well-known strategies include maintaining safety stock, multiple sources of supply, multiple transportation modes, supplier certification, dynamic pricing, task forces for managing disruptions, contingency plans and assortment planning (Ho et al. 2015; Ivanov et al. 2017). Bode et al. (2011) categorise these strategies into *buffering* actions, which are firm level internal measures to minimise the risk occurring from supply chain partners, and *bridging* actions, which span the boundaries of the firm to include supply chain partners in reducing the risk. Thun, Drüke, and Hoenig (2011) have classified various risk mitigation strategies into *preventive* and *reactive* risk mitigation strategies. Preventive risk mitigation efforts aim to reduce the probability of occurrence of a risk event, whereas reactive risk mitigation efforts try to reduce the negative impact of the risk event. While both preventive and reactive risk mitigation strategies are devised before a risk event occurs, preventive risk mitigation strategies tend to provide benefits before the risk event occurs and reactive risk mitigation strategies are likely to have an impact after the risk event occurs (Thun, Drüke, and Hoenig 2011). We too classify risk mitigation strategies into preventive and reactive strategies in our study.

Risk assessment therefore is an important aspect of supply chain risk management as it helps in devising the right type of risk mitigation strategies, and has a positive impact on the risk mitigation strategies (Kern et al. 2012). In our study, risk assessment is measured in terms of the probability and occurrence of inbound, process and shipment risk events. While some firms invest in more preventive risk mitigation strategies, other firms tend to have makeshift arrangements to react to risk events. With increasing levels of risk magnitude and likelihood, firms tend to invest more in being prepared to tackle disruptions in their supply chains. All these programs are aimed at either preventing the chance of occurrence of a risk event or mitigating the impact of such an event if and when it happens. And hence, we posit the following:

> **Hypothesis 1a:** *Firms with higher risk assessment invest in significantly higher levels of preventive risk mitigation efforts.*
> **Hypothesis 1b:** *Firms with higher risk assessment invest in significantly higher levels of reactive risk mitigation efforts.*

According to RBV, firms sustain competitive advantage through acquiring or by possessing valuable, rare, inimitable and non-substitutable (VRIN) resources and capabilities (Barney 1991). RBV suggests that resources that firms accumulate are difficult to imitate especially when they are path dependent, causally ambiguous or socially complex (Barney 1991). Capabilities are actions through which firms use bundles of resources to accomplish their objectives (Branco and Rodrigues 2006). A few of these resources and capabilities are used by firms to develop and implement strategies to reduce supply chain risk. Thus, we use resource-based view as the theoretical anchor in order to investigate the relationship between risk mitigation efforts, sustainability practices and supply chain risk.

While perceptions regarding risk are formed on basis of various parameters such as past experiences, risk preferences and infrastructural robustness, mitigation efforts are aimed at reducing actual supply chain risk. Therefore, apart from assessing the probability and magnitude of potential risk, firms also need to track the actual supply chain risk. As discussed above, while preventive risk mitigation strategies are supposed to reduce risk experienced by firms by reducing the chance of occurrence of a risk event, reactive risk mitigation strategies are expected to mitigate risk by reducing the impact of a risk event. Typical preventive strategies include selection of a reliable supplier upfront, employing preventive maintenance for equipment, inspecting and tracking both internal processes and the processes at the suppliers end.

Suppliers form an important part of supply chains. For example, around 37% of the respondents in Deloitte survey (Deloitte 2013) believed that Tier-1 suppliers or third parties are responsible for the most costly risk events, whereas 27% of respondents felt that Tier-2 suppliers are responsible for the most damage. While selecting a reliable supplier who can satisfy the needs of the firm through on-time delivery of quality products is an obvious choice for firms to avoid disruptions of any sort, it is relatively difficult to find an economical choice of such a supplier. To avoid disruptions, some firms resort to regular inspections and monitoring of suppliers, thus reducing the chance of occurrence of a risk event. For example, Cisco claims that it has multiple suppliers and it keeps a check on the costs by constantly monitoring and benchmarking suppliers (Chopra and Sodhi 2004). For internal process risks, reliability engineers suggest planned preventive and scheduled maintenance as an effective solution to avoid disruptions (Kleindorfer and Saad 2005). Design safety engineers promote clear safety procedures to avoid any mishaps in the production environment, which could affect customer deliveries (Christopher et al. 2011). In global supply chains, customers and suppliers are dispersed across the globe and transportation plays a key role in matching supply with demand. Glitches in logistics can result in long lead times and affect customer deliveries severely. Technologies such as Global Positioning System (GPS), which are easily available for most private and public logistics providers, can aid firms to make necessary arrangements in case of a disruption.

Despite the best efforts by firms to prevent disruptions from taking place, through adoption of preventive risk mitigation strategies discussed so far, disruptions do take place and firms need to be ready to react with backup plans, if and when they occur (Ivanov et al. 2017). Some of the common reactive risk mitigation strategies include maintaining extra capacity, flexible transportation modes, multiple sourcing options or backup suppliers. One popular example that clearly demonstrates the benefits of having backup suppliers is the case of Nokia and Ericsson. Both these firms were sourcing semiconductor chips from Philips, whose plant in Albuquerque, New Mexico had a fire accident that damaged millions of chips and had to be shut down for almost six weeks. While Nokia mitigated the damage of this accident through backup suppliers, Ericsson lost millions of dollars as they did not have any contingency plan in place for such disruptions (Yoon et al. 2017).

In order to tackle internal process risks, firms implement a host of risk mitigation strategies. Even though there is a high emphasis on lean management, firms do resort to maintaining safety inventory, extra capacity subcontracting options to handle any internal disruptions (Bode et al. 2011). United States government, for example, maintains a large reserve of petroleum as a hedge against disruptions (Chopra and Sodhi 2004). These measures help organisations avoid any delays in fulfilling the customer orders. To avoid losses due to distributional disruptions, firms also use multiple transportation modes for their deliveries (Vilko and Hallikas 2012). Dell Inc., for example, uses a combination of inventory and multi-modal transportation to avoid supplier-delay risks. They use low-cost shipment options for less expensive components within the US (apart from maintaining some inventory) and air transportation to ship components from Asian suppliers as and when needed (Chopra and Sodhi 2004). Therefore, cumulatively based on these arguments and anecdotal evidences, we hypothesise the following.

Hypothesis 2a: *Firms with higher levels of preventive risk mitigation efforts experience significantly lower levels of supply chain risk.*

Hypothesis 2b: *Firms with higher levels of reactive risk mitigation efforts experience significantly lower levels of supply chain risk.*

2.3 *Sustainable supply chains and supply chain risk*

With growing pressure from stakeholders, firms all over the world are focusing on their triple bottom line: economic, social and environmental performance (Elkington 1998). Analytical and empirical research in sustainable operations has looked at issues such as remanufacturing, technology selection, supply chain design, new product design, reverse supply chains and inventory management. However, very few researchers (Foerstl et al. 2010; Cruz 2013; Hofmann et al. 2014; Taylor and Vachon 2018) have investigated the relationship between sustainable practices in supply chains and supply chain risk. This is surprising, especially since one of the definitions of supply chain risk management in fact is *the ability of a firm to understand and manage its economic, environmental, and social risks in the supply chain* (Carter and Rogers 2008, 366).

Extant literature in finance and strategy has, however, discussed the relationship between Corporate Social Responsibility (CSR) and firm risk (measured in terms of stock market performance). Orlitzky and Benjamin (2001) found that CSR activities reduce firm level risk. Jo and Na (2012) for example found that a firm's risk levels increase when customers perceive its CSR efforts as window dressing. In similar lines, there is a widespread recognition that the gap in the literature of sustainable supply chains and supply chain risk management needs to be explored. Hofmann et al. (2014) and Taylor and Vachon (2018) discussed the importance of sustainability-related aspects in managing supply chain risks and urged researchers to carry out further research in these areas. To the best of our knowledge, ours is the first empirical work that tests the relationship between sustainable supply chains and supply chain risk.

2.3.1 *Environmental sustainability and SCRM*

The natural resource-based view (NRBV) is an extension of RBV, which emphasises on the dependency of firms on natural resources and environment in maintaining competitive advantage. Three strategies, namely, pollution prevention, product stewardship and sustainable development, have been discussed at length in this context (Hart 1995). While pollution prevention and product stewardship provide competitive advantage to the firm through reduced emissions and minimising the life-cycle cost of the product, sustainable development is aimed at a future position of advantage by meeting unmet demand of the needy. In addition, several researchers have used NRBV to explain the relationship between sustainability efforts and superior financial, cost and market performance (Vachon and Klassen 2008; Wong et al. 2012; Golicic and Smith 2013). When firms invest in sustainability efforts, one of the ways they achieve superior firm performance is through risk reduction. Christmann (2000), for instance, argues that manufacturing firms which invest in environmental management activities develop complementary capabilities which allow them to excel in other areas of competitiveness. Investments in environmentally sustainable products and production techniques, for example, induce firms to reduce/eliminate use of hazardous material, which otherwise have the potential to cause disruptions across various stages of supply chain. In another study, Wong et al. (2012) argue that product stewardship enables electronic manufacturers to reduce pollution and better control over accidental polluting/hazardous substance releases, which can cause supply chain disruptions.

Pollution prevention strategies as opposed to pollution control strategies require complex technical knowledge as any change in the process might affect the overall productivity of the firm. Hence, key employees and tacit knowledge developed through continuous improvement methods illustrate the causally ambiguous resources and capabilities that a firm which invests in environmental sustainability practices possesses (Vachon and Klassen 2008). These in turn help in reducing environment-related risks such as disruption due to chemical and waste leakages, and disruptions due to bad press. For product stewardship strategy to be successful, a firm has to gather socially complex resources and involve in internal and external coordination with its stakeholders. The resources and capabilities that firms gather through pollution prevention and product stewardship strategies possess certain qualities that help provide competitive advantage to firms by avoiding disruptions due to environmental risks and also disruptions due to negative publicity. Based on the theoretical foundations of RBV and NRBV, Branco and Rodrigues (2006) suggest that a firm enjoys internal and external benefits through investment in pollution prevention and product stewardship strategies, which also form the backbone of environmental sustainability practices, in our context. By leading environmental innovation, firms can influence environmental regulations, rather than playing catch-up with the regulations, which can potentially cause disruptions to their supply chains. Externally, these strategies reduce the disruptions in a firm's supply chains by avoiding environmental risks and reputational risks. For example, Primark a fast-fashion retailer in Europe had disruptions due to reputational risk as Greenpeace found toxic elements in its children wear.[4] Other examples include firms such as Walmart, Bosch and Starbucks, who have implemented environmental sustainability practices not only to achieve cost advantages but also to reduce the supply chain risk. While Hart (1995) argues that firms achieve competitive advantage through these strategies by reducing costs, increasing reputation and legitimacy, and discovering new markets, we extend the argument by linking environmental sustainability strategies with supply chain risk mitigation.

2.3.2 *Social sustainability and SCRM*

Employees are one of the key resources that help firms achieve competitive advantage. This argument is exemplified by a recent survey by PwC and MIT Forum for Supply Chain Innovation, which revealed that supply chain operations are most sensitive to reliance of skill set and expertise of the workforce (PwC and MIT 2013). Using a thematic analysis of literature, Sodhi and Tang (2018) study the impact of partnerships and pressure on firms' investments in social sustainability practices which in turn have an impact on the firm performance. Branco and Rodrigues (2006) discussed the impact of corporate social responsibility, which includes employee health, safety and motivation, on firm performance using RBV lens. Extending their arguments, we propose that supply chain disruptions can be avoided or reduced through best practices in human resource management such as better health and safety and work-life balance policies, which are part of a firm's social sustainability practices. A healthy and conducive work environment drives employees to perform better, reduces absenteeism and attrition, which in turn reduce the impact as well as the probability of occurrence of a disruption event in the supply chain. Apart from these social sustainability initiatives, social certifications such as OHSAS 18001 and SA 8000 help reduce cost of regulatory fines and disruptions due to social liabilities. Similar to environmental management systems, social certifications signal to the external stakeholders such as customers, media, non-governmental organisations and regulatory agencies about their sound social sustainability initiatives, thus preventing disruptions in the firm due to reputational risks.

2.3.3 *Supplier sustainability and SCRM*

To ensure that suppliers follow sustainable practices, firms invest in activities such as identifying various sustainability-related risks at the suppliers end, assessing them and developing capabilities of suppliers in sustainability-related practices. These activities over a period of time help increase awareness and improve sustainability practices at the supplier's end, ultimately enabling them to deliver high quality goods that meet all regulatory requirements on time. This is an important requirement for customers, as evidence suggests that suppliers who use polluting chemicals, carcinogenic substances and high carbon emission processes in their production and distribution activities can not only damage the reputation of their customers but also create potential operational disruptions and product recalls (Wong et al. 2012; Wu et al. 2017), which consequently increase supply chain risk. Knowledge generated in developing suppliers sustainability processes would also help firms improve the reliability and robustness of their own internal and external processes, thus reducing the firm's overall supply chain risk. A lower supply chain risk is necessary for firms to achieve sustainable competitive advantage, as any disruption to business continuity can have severe impact on firm's performance (Hendricks and Singhal 2003). Through supplier integration, firms not only enable seamless communication and coordination between the two organisations but also support dynamically changing regulatory requirements in firm's sustainability measures, which require changes in firm's own processes as well as the supplier's processes (Foerstl et al. 2010). Hence, we conjecture that supplier sustainability development helps reduce supply chain risk.

Based on the above arguments, we hypothesise the following.

Hypothesis 3a: *Firms with higher levels of sustainability efforts experience significantly lower levels of supply chain risk.*

Traditional supply chain risk mitigation strategies (preventive or reactive) on the other hand are aimed at addressing the risks related to the three fundamental operational attributes: quality, cost and delivery. For example, reactive risk mitigation strategies, such as maintaining excess capacity, excess inventory and flexible transportation modes, are aimed at addressing delivery-related supply chain risks. Preventive risk mitigation strategies, such as selection of a reliable supplier, supplier monitoring, preventive maintenance and clear safety procedures, help prevent cost, quality and delivery- related risks. We argued earlier that sustainability efforts reduce various supply chain risks including environmental and social risks. To achieve supply chain risk reduction through sustainability initiatives, firm engage in continuous improvement programs which hone the employee skill set as well as increase their motivation levels. While it is accepted that safe working conditions and better work-life balance policies increase employee motivation, anecdotal evidence suggests that environmentally hygienic work conditions (with less pollution and wastage) also increase employee morale (Shrivastava 1995). Increased employee motivation and safe working conditions lead to better efficiency and productivity levels, thus reducing disruptions due to cost, quality and delivery-related problems. Apart from these, by developing supplier sustainability processes, firms also improve their own processes through tacit learning and thus reduce disruptions within and outside the firm.

Since the traditional risk mitigation strategies and sustainability efforts address supply chain risks with little overlap, we propose that a firm which invests in sustainability efforts along with preventive and reactive risk mitigation strategies is likely to experience significantly lower levels of supply chain risk. Also, note that, while traditional risk mitigation strategies result in short- to medium-term benefits, sustainability efforts are aimed at long-term benefits. On the basis of this synergistic relationship between preventive and reactive risk mitigation strategies, and sustainability efforts, we hypothesise the following.

Hypothesis 3b: *The relationship between preventive risk mitigation efforts and supply chain risk is positively moderated by sustainability efforts.*

Hypothesis 3c: *The relationship between reactive risk mitigation efforts and supply chain risk is positively moderated by sustainability efforts.*

3. Research methodology

3.1 *Sampling and data collection*

The data used in this study was collected from various manufacturing firms all over the world as a part of the sixth edition of the International Manufacturing Strategy Survey (IMSS) in 2013. IMSS is a global network of researchers with a common interest in understanding and analyzing the practices, strategies and performance of manufacturing firms all over the world. These data comprise inputs from manufacturing firms across 21 countries and data from each country is shared by the corresponding partner. The firms which participated in this survey belonged to one of the six industrial categories represented by ISIC codes between 25 and 30. In India, for example, 500 companies were randomly chosen from the PROWESS database in the six industrial categories, and these firms were contacted via mail and telephone. Surveys were administered only to those companies with an employee strength greater than 50. Out of these 500 companies, 121 (24.2% *Response Rate*) agreed and survey responses were collected. A brief snapshot of data from Indian manufacturing firms is provided in Table 1.

The questionnaire was designed in such a way that common method variance (which commonly occurs in single respondent surveys) is minimised. The robustness of the indicators used to measure various phenomenon is established by the fact that this is the sixth edition of the survey and the data from these surveys has been used in research published in top journals in the operations management area (Wiengarten et al. 2014; Adebanjo, Teh, and Ahmed 2017; Wiengarten, Bhakoo, and Gimenez 2015). While the basic structure of the questionnaire is consistent with the previous editions, new questions were added by the design team in alignment with the research goals of partners. Typical profiles of main respondents who filled in the questionnaires were Director of Production/Operations/Manufacturing or in a senior executive in higher position (Vice President/Managing Director). Apart from the main respondents, specific sections in the survey were answered by other functional heads such as the Head of R&D/Engineering, Head of purchasing and sales departments and Head of HR. The respondents were assured of complete anonymity and confidentiality. Common method variance was also checked ex-post using the Harman's single-factor method, and our results indicate that data loads onto eight different factors. For this study, we use data collected from India, China and OECD countries.

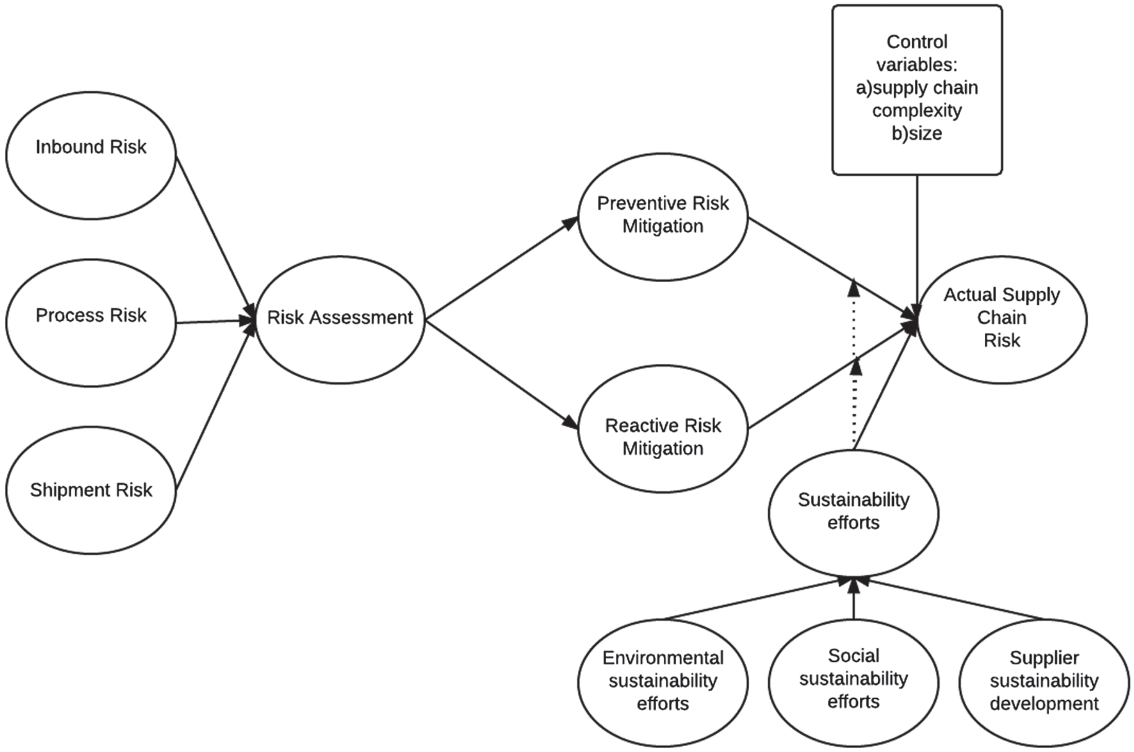

Figure 1. Conceptual model.

Table 1. Sample overview.

ISIC Code	Industry	Frequency	Number of employees	Frequency
25	Fabricated metal products, except machinery and equipment	16	50–250	47
26	Computer, electronic and optical products	34	Between 251 and 1000	55
27	Electrical equipment	26	Between 1000 and 5000	12
28	Machinery and equipment not elsewhere classified	26	Between 5001 and 10000	5
29	Motor vehicles, trailers and semi-trailers	16	10001 and above	2
30	Other transport equipment	9		
	Total	121	Total	121

3.2 *Measures*

The items corresponding to various constructs and the measurement models used in this study are provided in Table 2. In the current study, risk assessment is measured using three different constructs: (i) supplier failure, (ii) operational failure and (iii) shipment failure. While items under each of these constructs were borrowed from previous research (e.g. Ellis, Henry, and Shockley, 2010), due to the formative nature of the items and the constructs, risk assessment is modeled as a second-order formative construct. As noted earlier, risk has been traditionally measured as a product of the impact of a risk event and the probability occurrence of such an event (Manuj and Mentzer 2008; Vilko and Hallikas 2012). The shortcoming of such a construct is that a high intensity and low probability event is equated with a low intensity and high probability event (Yates and Stone 1992; Ellis, Henry, and Shockley 2010). A formative construct is capable of better explaining the variance in supply chain risk mitigation due to change in the risk assessment in such conditions.

To indicate the effort put in for various risk mitigation strategies, the respondents were asked to answer questions on four different action programs viz. preventing operations risks, detecting operations risks, responding to operations risks and recovering from operations risks. They were asked to indicate the effort put in the last 3 years into implementing, and the current level of implementation of these action programs on a 5-point Likert scale, where 1 indicates no implementation

Table 2. Items and constructs.

Constructs and items	Measurement model
Supply Chain complexity (SCC) (1-Not at all, 5- To a great extent)	First-order reflective
1. Your demand fluctuates drastically from week to week.	
2. Your total manufacturing volume fluctuates drastically from week to week.	
3. The mix of products you produce changes considerably from week to week.	
4. Your supply requirements (volume and mix) vary drastically from week to week.	
5. Your products are characterised by a lot of technical modifications.	
6. Your suppliers frequently need to carry out modifications to the parts/components they deliver to your plant.	
Preventive Risk Mitigation Efforts (PRM) (1- None, 5- High)	First-order formative
1. Preventing operations risks (e.g. select a more reliable supplier, use clear safety procedures, preventive maintenance)	
2. Detecting operations risks (e.g. internal or supplier monitoring, inspection, tracking)	
Reactive Risk Mitigation Efforts (RRM) (1- None, 5-High)	First-order formative
1. Responding to operations risks (e.g. backup suppliers, extra capacity, alternative transportation modes)	
2. Recovering from operations risks (e.g. task forces, contingency plans, clear responsibility)	
Risk Assessment (Impact and Probability) (1- Low, 5-High)	Second-order formative
Inbound Risk (IR)	First-order formative
1. A key supplier fails to supply affecting your operations	
Process Risk (PR)	First-order formative
1. Your manufacturing operations are interrupted affecting your shipments	
Shipment Risk (SR)	First-order formative
1. Your shipment operations are interrupted affecting your deliveries	
Sustainability Efforts (1-None, 5-High)	Second-order formative
Environmental Sustainability Efforts (ESE)	First-order formative
1. Environmental certifications (e.g. EMAS or ISO 14001)	
2. Energy and water consumption reduction programs	
3. Pollution emission reduction and waste recycling programs	
Social Sustainability Efforts (SSE)	First-order formative
1. Social certifications (e.g. SA8000 or OHSAS 18000)	
2. Formal occupational health and safety management system	
3. Work/life balance policies	
Supplier Sustainability Development (SSD)	First-order formative
1. Suppliers' sustainability performance assessment through formal evaluation, monitoring and auditing using established guidelines and procedures	
2. Training/education in sustainability issues for suppliers' personnel	
3. Joint efforts with suppliers to improve their sustainability performance	
Actual Supply Chain Risk (ASCR)	First-order formative
1. Number of days of lost production last year due to supply failures or operations disruption	
2. Percentage of customer deliveries affected by operational failures	

and 5 indicates high level of implementation. While previous studies (e.g. Speier et al., 2011) used these items to measure the risk mitigation strategies at generic level, we wanted to separate these action programs into two different categories: (i) preventive risk mitigation and (ii) reactive risk management, based on the description of the items and existing literature .

Sustainability efforts by the firm are measured in terms of (i) environmental sustainability efforts, (ii) social sustainability efforts within their firms and (iii) efforts in making their suppliers sustainable. The items for these constructs have been adapted from existing literature (Krause, Scannell, and Calantone 2000; Longo, Mura, and Bonoli 2005; Weinhofer and Busch 2012). Actual supply chain risk of the firm is measured in terms of (i) number of days of lost production due to supply

Table 3. Assessment of formative indicators.

Formative constructs	Formative indicators	Mean	SD	VIF	Outer weights	Outer loadings
IR	IR1	3.185	1.195	3.28	1.105	0.986***
	IR2	3.542	1.187	3.79	−0.199	0.454
PR	PR1	2.985	1.160	4.97	1.165*	0.959***
	PR2	3.5	1.282	3.51	−0.351	0.335
SR	SR1	2.985	1.160	3.58	0.976	0.999***
	SR2	3.457	1.175	5.27	0.035	0.683**
SSE	SSSE1	3.8	1.199	1.83	−0.116	0.166
	SSE2	3.942	0.849	1.60	1.149**	0.928***
	SSE3	4.014	0.770	1.87	−0.398	0.119
ESE	ESE1	4	1.063	2.25	0.120	0.679*
	ESE2	3.971	0.884	1.75	0.189	0.681**
	ESE3	4.085	0.880	1.99	0.805	0.979***
SSD	SSD1	4.071	0.786	1.46	−0.090	0.369
	SSD2	3.842	0.862	2.09	0.164	0.706**
	SSD3	4	0.780	2.21	0.926*	0.990***
PRM	PRM1	4.114	0.733	1.76	−0.118	0.443
	PRM2	4.185	0.839	2.40	1.057	0.995**
PRM	RRM1	4.271	0.657	1.67	1.074***	0.821***
	RRM2	4.014	0.908	1.90	−0.625	−0.188
ASCR	ASCR1	7.200	7.166	1.58	1.023*	0.999***
	ASCR2	3.378	3.715	1.62	−0.047	0.477

Significance at level - *** - 1%; ** - 5% ; * - 10%.

and operational disruptions and (ii) number of customer deliveries affected by operational failures. Between these two items, they measure the actual supply chain risk experienced by the firm in terms of supply (inbound) risk, process (operational) risk and shipment (delivery) risk. Size of the firm and supply chain complexity were used as control variables to make the results more generalizable. The items for supply chain complexity were adapted from Lee (2002), and constitute degree of fluctuations in demand, volume and product mix of production and technical specifications.

3.3 *Reliability and validity*

In this subsection, we discuss the necessary reliability and validity tests carried out on the data used in this study. As we use three different data-sets corresponding to Indian manufacturing firms, Chinese manufacturing firms and firms from OECD countries, reliability and validity tests were conducted separately for each of the three data- sets. As an illustration, we discuss in detail the various tests conducted on the Indian data. The conceptual model shown in Figure 1 was tested using the Partial Least Squares Structural Equation Modeling[5] (PLS-SEM) with the help of the application, *SmartPLS version 2.0 M3* (Ringle, Wende, and Will 2005). The PLS-SEM approach was chosen over the covariance-based (CB-SEM) approach because it is most suitable for small sample sizes and can handle formative and reflective indicators (Hair et al. 2013):

Multicollinearity is one of the major issues in formative measurement models as it can distort the results of the model. To assess the level of collinearity, VIF values for various indicators are calculated. The VIF values are provided in Table 3. As seen in the table, the VIF values are all well within permissible limit. To assess the significance of the indicators used in the measurement model, bootstrapping was used. The outer weights and the outer loadings of the indicators along with the significance values are provided in Table 3.

For the control variable supply chain complexity, we use reflective measurement model. The composite reliability and Cronbach's alpha values are provided in Table 4. Composite reliability values of 0.6 to 0.7 are acceptable for exploratory research and the composite reliability value for the reflectively measured construct; supply chain complexity was found to be 0.914. The indicator reliability is reflected by the higher outer loadings of the indicators of a reflectively measured construct. As seen in Table 5, all indicators have highly significant outer loadings. Also, as shown in Table 5, the AVE value for the reflectively measured construct is 0.646 (which is greater than 0.5), thus establishing convergent validity. Fornell–Larcker criterion suggests that the square root of each construct's AVE has to be greater than the correlation of that construct with any other construct (Fornell and Larcker 1981). While, discriminant validity is not applicable to formative measurement models, the latent variable correlations along with the square-root of AVE values (along the diagonal) are provided in Table 5.

Table 4. Assessment of reflective measurement models.

Reflective constructs	Reflective indicators	Mean	SD	Outer loadings
	SCC1	2.485	1.073	0.891***
	SCC2	2.542	1.125	0.925***
Supply Chain Complexity (SCC)	SCC3	2.442	1.281	0.800***
($\alpha = 0.895$, *CR =0.914* , *AVE =0.646*)	SCC4	2.685	1.136	0.861***
	SCC5	3.142	1.039	0.590***
	SCC6	2.871	1.089	0.700***

Table 5. Discriminant validity using Fornell-Larcker criterion.

	SCC	ASCR	ESE	PRM	PR	RRM	SR	Size	SSE	SSD	IR
SCC	0.646										
ASCR	0.348	#									
ESE	0.179	−0.144	#								
PRM	0.294	0.045	0.289	#							
PR	0.319	0.165	−0.053	0.329	#						
RRM	−0.005	0.108	0.11	0.028	−0.302	#					
SR	0.339	0.154	0.045	0.179	0.714	−0.282	#				
Size	−0.132	−0.126	−0.036	−0.075	0.034	−0.176	0.129	$			
SSE	−0.201	−0.351	0.352	0.032	−0.260	0.166	−0.238	0.110	#		
SSD	0.252	−0.081	0.358	0.287	−0.153	0.024	−0.047	0.106	0.258	#	
IR	0.309	0.247	0.045	0.190	0.720	−0.249	0.690	0.028	−0.251	−0.099	#

- Formative construct; $ - Single item construct.

3.4 *Structural model validation*

We discuss the main results using the data from the Indian manufacturing firms and compare and contrast these results with those of Chinese and OECD countries. The conceptual model in Figure 1 was tested using PLS-SEM with the help of SmartPLS 2.0 application (Ringle, Wende, and Will 2005). As we had higher order constructs in our study, we tested our model using a two-stage model as prescribed by Hair et al. (2013). In the first stage, latent variable scores were collected, and these values were used to find the relationships between the constructs in the second stage. As the number of missing values exceeded 5 percent, we used a case-wise deletion method. As a result of this, our Indian sample size reduced to 70 from 121. Similar process was followed for other regions and as a result, our final sample size from China was 74 and from OECD countries it was 445. To test the impact of the moderating variables in explaining the total variance in the dependent variable (actual supply chain risk), f^2 value was calculated. $R^2_{included}(= 0.369)$ was calculated with the interaction terms in the structural model, and $R^2_{excluded}(= 0.234)$ was calculated without the interaction terms. The f^2 effect size value of 0.213 was obtained for Indian data. An f^2 value above 0.15 represents a medium effect (Cohen 1988), and hence we conclude that the interaction effect between sustainability efforts and the two risk mitigation strategies has a significant role in explaining the variance in the dependent variable (Actual supply chain risk). The f^2 values for Chinese data and OECD, countries data were found to be 0.0803 and 0.0130, respectively, indicating a weak contribution of interaction terms. The results corresponding to the hypothesised structural model for Indian data are shown in Figure 2.

4. Results and discussion

As may be noted from Table 6, we find support for Hypothesis H1a (standardised β values of 0.330, 0.532 and 0.253 for India, China and OECD respectively), which posits that there is a positive correlation between risk assessment and preventive risk mitigation efforts, in all the geographical regions. We find support for Hypothesis H1b, which conjectures a positive correlation between risk assessment and reactive risk mitigation efforts, but only in the case of OECD countries (standardised β value of 0.244) and not in case of China and India. Our results seem to suggest that, while firms in OECD countries are investing in both types of risk mitigation efforts whenever their assessment of supply chain risk is high, Indian and Chinese firms are shying away from investments into reactive risk mitigation activities.

Table 6. Summary of results for various geographical regions.

Hypothesis	India	China	OECD
H1a: Risk assessment →PRM	Yes, significant ($\beta = 0.330$*)	Yes, significant ($\beta = 0.532$***)	Yes, significant ($\beta = 0.253$***)
H1b: Risk assessment → RRM	No, significant ($\beta = -0.303$**)	Not significant($\beta = 0.061$)	Yes, significant ($\beta = 0.244$***)
H2a: PRM → ASCR	Not significant ($\beta = 0.008$)	Not, significant ($\beta = 0.076$)	Yes, significant ($\beta = -0.208$**)
H2b: RRM →ASCR	Not significant ($\beta = 0.122$)	Not significant($\beta = 0.037$)	Not significant ($\beta = 0.082$)
H3a: Sustainability Efforts→ ASCR	Yes, significant ($\beta = -0.421$***)	Yes, significant($\beta = -0.446$***)	Yes, significant ($\beta = -0.099$*)
H3b: Sustainability Efforts*PRM →ASCR	Not significant ($\beta = 0.062$)	Not significant($\beta = 0.128$)	Not significant ($\beta = 0.069$)
H3c: Sustainability Efforts*RRM →ASCR	Yes, significant ($\beta = -0.399$***)	Not significant($\beta = -0.252$)	Not significant ($\beta = -0.068$)
Sample sizes	N = 70	N = 74	N = 426
R^2	36.9%	30.3%	7.2%

PRM - Preventive Risk Mitigation; RRM - Reactive Risk Mitigation; ASCR - Actual Supply Chain Risk.
Significance at level - *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

Hypotheses H2a and H2b conjecture the impact of preventive and reactive risk mitigation strategies, respectively on actual supply chain risk. We find support for Hypothesis H2a (standardised β value of -0.208), again in case of OECD countries only. We also did not find support for H2b, which hypothesises the relationship between reactive risk mitigation efforts and actual supply chain risk, in any geographical region.

We find strong support for H3a (standardised β values of -0.421, -0.446 and -0.099 for India, China and OECD, respectively) in all the regions, supporting our claim that sustainability efforts can reduce the overall supply chain risk experienced by the firm.[6] Hypotheses H3b and H3c conjecture the impact of the interaction between the risk mitigation efforts (preventive and reactive respectively) and sustainability efforts on actual supply chain risk. As one may note from Table 6, we did not find support for H3b in any of the geographical regions, which suggests that the interaction between preventive risk mitigation efforts and sustainability efforts is not very effective in reducing actual supply chain risk. Even though we did not find support for H3c also in China and in OECD countries, we do find support for this hypothesis with the Indian data (standardised β value of -0.399). In case of India, the sustainability efforts of firms seem to complement their reactive risk mitigation efforts and hence are instrumental in reducing the overall supply chain risk. As sustainability efforts tend to reduce the probability of occurrence of risk event, whereas reactive risk mitigation efforts reduce the impact of a risk event, their combination (to reduce both the probability and the impact) seemed to be more effective in reducing the actual risk experienced by firms. Among the control variables, supply chain complexity has a positive effect on actual supply chain risk in all geographical regions as supported by previous research (e.g. Speier et al., 2011). However, the effect of size was not significant in case of India or China but had a negative effect on overall risk experienced by firms in OECD countries, indicating that bigger firms experience lower levels of supply chain risk. This can be attributed to better preparedness, as bigger firms tend to have relatively more resources than smaller firms.

5. Discussion, conclusion and future research

Every year Gartner announces Top 25 supply chains in the world based on various supply chain practice parameters. Apple Inc. and Unilever are among a few firms which have been consistently topping the charts in this list.[7] However, despite their supply chain best practices, these firms have been exposed to disruptions due to environmental and social risks. Apple Inc., for example, had to face a lot of embarrassment over the issues of riots and suicides in iPhone factories in Foxconn, China. In India, Unilever is under scrutiny due to their toxic mercury releases into human settlements.[8] These are but a few examples of the serious disruptions to business continuity of these firms due to lack of appropriate sustainability initiatives, despite maintaining the best supply chains in the world. Our objective in the current study therefore was to examine the impact of sustainability practices in reducing supply chain risk. Despite some conceptual work and case studies, there was no empirical work that systematically examined this relationship in the academic literature. To the best of our knowledge, this is among the first studies to examine this novel relationship between a firm's sustainability efforts and its supply chain risk empirically,

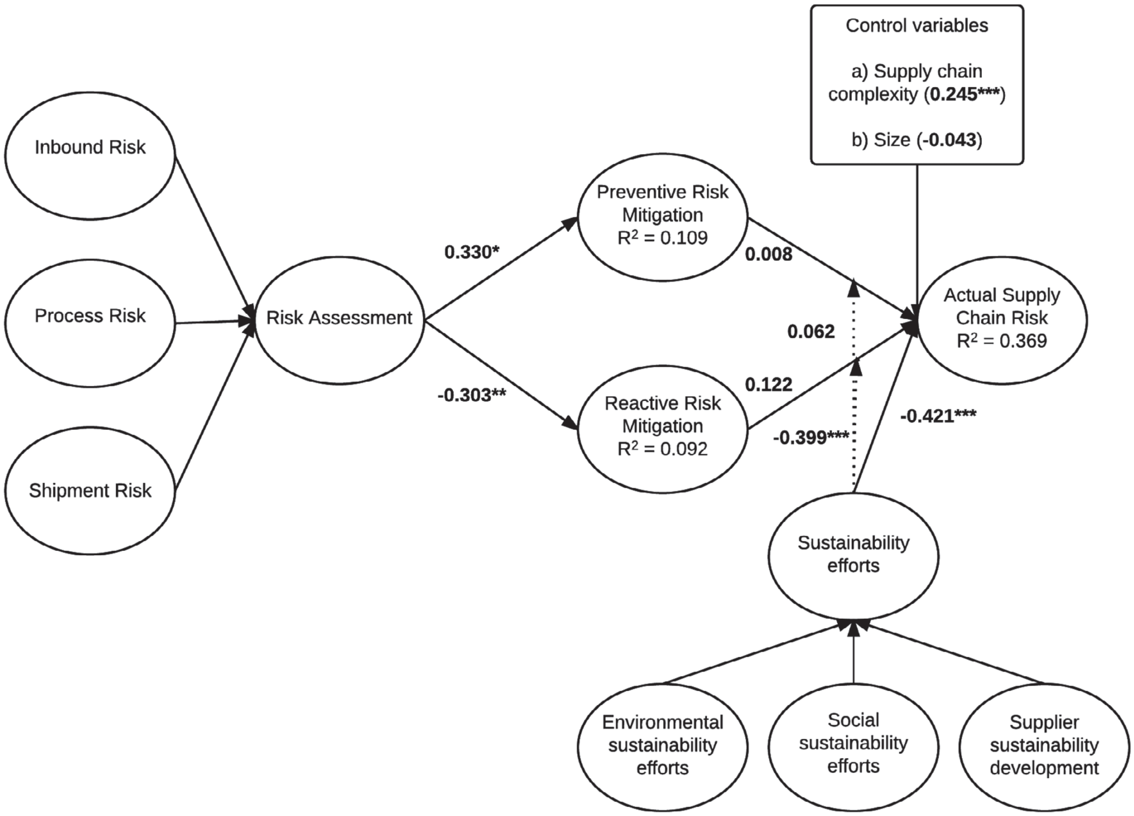

Figure 2. Results of structural model - India. Significance at level - *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

using primary data across different geographical regions. Below, we discuss the managerial implications of our study results and provide cues for future research.

5.1 *Managerial and research implications*

A survey by Economist (2009) indicated that about 35 percent of respondents believe there is lack of understanding of supply chain risk at the board level. Also, about half the respondents felt their company underestimates the potential impact of supply chain risk and lacks expertise in dealing with it. Even though many academic researchers have proposed a variety of risk mitigation strategies, data from industry reports seem to indicate a gap in the understanding of various risks and implementation of risk management strategies in practice. A study by Deloitte (2013) in fact reported that, only half of the surveyed executives believe risk management strategies to be effective. According to a recent Accenture report, very few firms that implemented risk management strategies have seen over 100 percent positive returns on their investments in supply chain risk management. These reports indicate that a fresh outlook on supply chain risk management is necessary in order to increase the effectiveness of the strategies being implemented.

Previous research on risk management (Thun, Drüke, and Hoenig 2011; Kern et al. 2012) has conceptually established that higher risk mitigation efforts lead to lower levels of supply chain risk and consequently to better supply chain performance. However, our findings indicate that the effectiveness of specific risk mitigation strategies depends on country-specific factors. We find that the reactive risk mitigation efforts do not have any significant impact on the actual supply chain risk irrespective of where the firm is located, whereas preventive risk mitigation efforts are effective only in the developed nations (OECD countries). Our qualitative analysis points towards less mature supply chain capabilities of emerging market firms as the reason. A recent Gartner report[9] findings indicate that maturity of supply chains in emerging markets such as India and China is very low. Another report also indicates that BRIC countries (Brazil, Russia, India and China) suffer from low levels of maturity in infrastructure, manufacturing, supply chain skill availability, distribution and technology adoption (Accenture 2013). Supply chain maturity therefore is an important aspect of risk mitigation that not only supply chain managers, but also academic researchers need to focus on. Also note that, while there seem to be no immediate returns from preventive risk mitigation efforts for firms in emerging markets, it is likely that they provide benefits in the longer term. A longitudinal study of firms investing in preventive risk mitigation efforts is therefore needed to better understand the long-term impact of preventive risk mitigation strategies.

Second and more importantly, we provide evidence that sustainability efforts play a significant role in reducing supply chain risk. In addition, our results show that firms which invest in sustainability efforts along with reactive risk mitigation efforts reduce their supply chain risk further. Through this empirical research, we establish that sustainability efforts, which until now were perceived to provide benefits such as stakeholder approval, increased operational efficiency and larger market share, also provide other *expected unexpected side benefits* such as supply chain risk reduction.

The other interesting result from our study was the effectiveness of reactive risk mitigation efforts in the presence of sustainability efforts. While reactive risk mitigation efforts were not found to be effective on their own, their interaction with sustainability efforts seem to reduce the actual supply chain risk experienced by firms. As the sustainability efforts reduce the probability of occurrence of a risk event, and reactive risk mitigation efforts tend to reduce the impact of supply chain risk, together they seem to be more effective in reducing supply chain risk. Another reason why we were not able to see significant impact of reactive risk mitigation efforts on supply chain risk could be that they are not effective when implemented in isolation. An example of Cisco maintaining backup suppliers with constant monitoring that we discussed earlier led us to explore if reactive risk mitigation efforts are effective in the presence of preventive risk mitigation efforts. We built a second model (without sustainability efforts or its interaction terms with other risk mitigation efforts) and tested the impact of the interaction between preventive efforts and reactive efforts on actual supply chain risk. We found that the interaction term did have a significant impact on (standardised β value of -0.221) reducing the actual supply chain risk, supporting the above conjecture.

From a policy perspective, the results suggest the need for lawmakers to emphasize on sustainability efforts by firms thus improving the efficiency and economic performance of firms. Non-governmental organisations such as Greenpeace and Global Reporting Initiative and industry groups such as Auto Component Manufacturing Association (ACMA) and Electronic Industries Association of India (ELCINA) should support such investments. The impact of country-level regulations in driving supply chain risk down is another interesting avenue for researchers to work on.

From an industry standpoint, this study provides managerial implications in two main areas. First, supply chain risk managers need to assess risks meticulously and invest in focused risk mitigation strategies, since current efforts seem to have no significant impact on reducing risk. As exemplified by our results, firms need to also focus on aligning their goals with the triple bottom line performance to reduce the actual supply chain risk. Firms should actively engage in undertaking environmental and social sustainability certifications such as EMAS, ISO 14001, SA 8000 and OSHAS 18000. and also educate their supply chain partners to adopt them.

5.2 *Conclusion*

As firms endeavor to reduce supply chain risk by employing various risk mitigation strategies, it becomes important for researchers to re-examine the choice of strategies and their implementation in the context of a specific business setting. In this paper, we proposed a conceptual model to investigate the relationship between supply chain risk assessment, risk mitigation efforts and sustainability efforts of a firm using supply chain risk management and strategic management theories such as Resource-Based View. Our research model found strong validation from the data, providing support for our claim about the relationship between sustainability and supply chain risk. Our results in various geographical regions also provide a nuanced view of the choice of risk mitigation efforts that firms should choose to implement. We hope that this study stimulates further research on our understanding of the ways in which firms can mitigate various types of supply chain risk through implementation of appropriate risk mitigation strategies.

The sample used for this study represents a sizeable number of manufacturing firms in respective geographical regions and hence gives us some confidence in generalising the results to firms in other industries. Even though careful attention was paid to test the rigor of the measurement and structural models, we acknowledge some limitations. The firms included in our sample, as a part of IMSS VI, belong to industrial categories with ISIC code 25 to 30 and hence our results can be applied fully only to these industries. Future research can look at the differences in the impact of risk mitigation strategies within the sub-segments of each of these industries as well as try to include other industry segments to generalize the results. Impact of sustainability initiatives in other industries such as food supply chains and healthcare supply chains may be particularly useful. The data collected for this study is cross-sectional in nature. However, risk mitigation efforts and sustainability efforts take time to build and the amount of investment is dependent on many other variables such as financial performance and regulations. Therefore, a longitudinal study may be able to uncover causal relationships between efforts and capabilities, and their impact on supply chain performance better (in our case, supply chain risk).

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Notes

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5. We had also tested an alternative model using Covariance Structural Equation Modeling for robustness. However, the resulting fit statistics from the reflective measurement model and structural model did not indicate a good model fit.
6. We have also examined the relationship between sustainability efforts and supply chain risk across different supply chains. For this, we divided the data into different subgroups based on ISIC Code, Size and Age of the firm. While the results were not found to be significant for some subgroups (due to the low sample size in each subgroup), we consistently found a negative relationship between sustainability efforts and supply chain risk. This further strengthens our conjecture that sustainability efforts do result in reduced supply chain risk for the firm.
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