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Managing country disruption risks and improving operational performance: risk management along integrated supply chains

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Abstract

Increasingly complex supply chains and heightened disruption risks are bringing risk management to the forefront of managerial and research efforts. We examine how country disruption risks are related to the adoption of combined risk management and external supply chain integration practices, and how these combinations in turn are related to operational performance. We frame our propositions using information processing theory and complementarity theory. We combine primary data from the 6th International Manufacturing Strategy Survey on 21 countries, and secondary data on country level disruption risks to study these links. Our results indicate that companies in riskier countries, characterized by high operational contingencies risk, natural hazard and terrorism and political instability, use combined arcs of external supply chain integration and risk management practices. Such a combined approach is also related to higher operational performance. The findings suggest to managers that companies adopting risk management practices in combination with external integration achieve best operational results. We extend the *arcs of integration* concept to include also risk management practices thus showing that holistic risk management approaches along supply chains are positively related to operational performance. The combination of primary and secondary data, as well as the focus on exogenous risks distinguishes our approach from previous, mostly conceptual, studies on risks.

Keywords: Supply Chain Risk Management, External Integration, Disruption Risk, Secondary data

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1. Introduction

With the implementation of lean manufacturing, increased outsourcing, shorter product life-cycles and time-based competition, supply chains are more fragile to disruption risks, such as operational contingencies, market and technology changes, natural hazard, terrorism and political instability (Zsidisin *et al*., 2005; Trkman & McCormack, 2009; Tang & Musa, 2011) and these are also becoming costlier (Bhattacharyya *et al*., 2010) and affecting operational performance (Blome & Schoenherr, 2011). Unfortunately, more and more unexpected events affect not only single companies, but their whole supply chain, often at global scale. Well known examples range from the fire at a Philips plant in New Mexico in 2000 that disrupted the supply chains of both Nokia and Ericsson (Chopra & Tang, 2004), to the earthquake, tsunami and nuclear disaster that affected Japan in 2011 with consequences on supply chains at global level (Park *et al*., 2013). As a result, risk management along supply chains has become a key industry concern (Blome & Schoenherr, 2011; Khan & Burnes, 2007).

The main challenge of environments characterized by high disruption risks is related to the impossibility for the firms to plan and operate deterministically, due to lack of information and its reliability (Bode *et al*., 2011). Information-related problems have been extensively investigated through the information processing theory and two main strategies have been proposed to deal with these issues (Galbraith, 1973): i) reducing the needs to processing information through slack resources and ii) increasing the information processing capability through investing in information sharing. In traditional competitive environments, firms adopted risk management practices aiming to reduce information needs: Possible sources of risk were identified and faced with buffering strategies. These buffers typically included inventories, excess capacity cushions, and multiple and back-up suppliers (Newman *et al*., 1993). In today's dynamic and complex competitive environments, an alternative approach suggested to face disruption risks is to increase the firm's information processing capability through increased control over operational activities, also outside the firm boundaries

(Jüttner *et al.*, 2003; Kleindorefer & Saad, 2005). This external integration typically refers to supply chain integration (SCI) practices including coordination and collaboration practices with suppliers and customers (Frohlich & Westbrook, 2001; Schoenherr & Swink, 2012).

In line with complementarity theory (Milgrom & Roberts, 1995), these two sets of practices are not mutually exclusive and can be complementary (Bode *et al*., 2011), contributing to operational performance. For example, a firm may detect risks and increase internal buffers to face them while increasing supplier integration and through it collect information about the external environment. Complementarity theory argues that activities or groups of them are complements if increasing one activity increases the benefits of doing more of the other activity (Milgrom & Roberts, 1995), i.e. an activity provides greater returns in the presence of another activity (Zhu, 2004).

We believe that it is important for managers to understand the options they have for managing risk. It is also important to understand the impact which these options have, implemented in isolation or combined, on the operational performance of the firm. In the past, most research has examined each of these options independently (Zsidisin, 2003; Flynn *et al*., 2010). We feel that there is both a practical and theoretical need to address the combination of these options to understand the formulation of an effective risk management strategy. Specifically, our research aim is to investigate *whether the combined use of risk management and integration practices is associated with greater levels of country disruption risks in the focal company environment, and whether such combined approaches lead to higher performance*. As supply chain managers strive for chains with both efficiency and competitiveness as well as responsiveness (Nooraie & Parast, 2016), we assume that according to the level of risks that firms are facing, they may identify the best integration approach fitting to their environment and risk management practices.

To achieve our goal, we combine primary firm level survey data and secondary country level risk indexes. This combination of two types of data is an important contribution. There are increasingly calls to use more secondary data in supply chain research (Rabinovich & Cheon, 2011) yet few examples of secondary data analysis, or of its combination with primary data exist (e.g., Vachon & Mao, 2008; Wiengarten *et al*., 2014 & in press).

Through our aims, this study contributes to both risk management and SCI literatures. Most previous literature on risks is conceptual or descriptive (e.g., Zsidisin, 2003; Christopher *et al*., 2011) and the literature on risk management has in many cases disregarded an important division of risks based on their origin: from within a chain (endogenouos risks) or from the outside environment (exogenous risks) (Trkman & McCormack, 2009). Despite limited research focused on the role of exogenous disruption risks to which a firm is exposed, they may be critical (Kleindorfer & Van Wassenhove, 2004), and shape the intensity of risk management efforts along the supply chain a firm adopts. Therefore we focus on these risks and investigate them in relation to the adoption of risk management practices (i.e. detection, prevention and mitigation and integration), along the supply chain.

The paper is structured as follows. First, we present a literature review on risk management, external SCI and disruption risks and performance. We present propositions on the relationships between these concepts. Secondly, our methods and data are described. Third, results of statistical analyses are presented. Discussion and conclusions summarize the study.

2. Literature review

Below, we will discuss the literature on risk management and external SCI practices and their relation with country disruption risks and operational performance.

2.1 Risk management and external SCI

Supply chain risk management is defined as *''the identification and management of risks for the supply chain, through a co-ordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole''* (Jüttner *et al*. 2003; 201). This approach is developed through the adoption of different risk management practices, which entail four basic facets: (1) assessment of risk sources, (2) identifying risks through definition of consequences, (3) tracking of these risks in the chain and (4) mitigation (Jüttner *et al*. 2003).

The main issue related to risk management is the unpredictability of the environment and the lack of reliable information to plan and operate deterministically (Bode *et al*., 2011). In line with the information processing theory (Galbraith, 1973), the approaches developed by companies to manage such an issue range from the most reactive ones – aiming to reduce the needs to process information, to the most proactive ones – aiming to increase the capability of the organization to process information. According to a path analysis study by Colicchia & Strozzi (2012), early stages of risk management research took a reactive approach to supply chain risks. Often, firms have used buffering mechanisms to handle the uncertainty of complex environments. These buffers typically include inventories, quoted lead times, excess capacity cushions and back-up suppliers (Newman *et al.*, 1993). These buffering strategies reduce the information processing needs related to a specific relationship through redundant and slack resources (Bode *et al*., 2011). More recently, Kleindorfer & Saad (2005) mark a turn towards a more proactive, mitigative approach that extends throughout the whole chain (Colicchia & Strozzi, 2012). This new stream of research emphasizes the role of external SCI in risk mitigation (e.g. Zsidisin & Smith, 2005; Tachizawa & Gimenez, 2010). Among them, Tang (2006) suggests that coordinated/collaborative mechanisms along the supply chain - supply, demand, product and information management – are a powerful risk mitigation approach. External SCI allows increasing information processing capabilities to cope with risks. It is an effort to manage resource dependencies and enlarge a firm's influence over supply chain partners, accessing reliable and timely information about disruptions and their consequences (Bode *et al*., 2011).

Flynn *et al.* (2010; 59) define SCI "*as the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organization processes".* SCI can be categorized into multiple dimensions considering the width of the integration, most prevalently into internal, customer and supplier integration, the latter two together forming the concept of external SCI (Schoenherr & Swink, 2012; Wiengarten *et al.*, 2014). Specifically, external SCI can be defined as "*the degree to which a manufacturer partners with its external partners to structure inter-organizational strategies, practices and processes into collaborative, synchronized processes*" (Flynn *et al.*, 2010, p. 59). Supplier and customer integration respectively involve core competencies related to coordination and collaboration with critical suppliers or customers (Flynn *et al*., 2010). The extent to which firms invest in supplier and customer integration has been operationalized in the concept of *arcs of integration* by Frohlich & Westbrook (2001) who found 5 types of arcs depending on the width of integration done by the focal firm (i.e., inward-facing, periphery-facing, customer-facing, supplier-facing and outward-facing). These were later re-validated by Schoenherr & Swink (2012).

Here we attempt to expand the concept of *arcs of integration* by Frohlich & Westbrook (2001) to examining how risk management can be developed along supply chains as the combined adoption of traditional risk management practices and arcs of external SCI practices. Specifically, we investigate whether different combined risk management and integration practices are adopted in relation to different levels of firm disruption risks at the country level, and how these different risk management approaches along the supply chain impact operational performance. In the following, propositions are presented regarding both.

2.2 Country level disruption risks and risk management along supply chains

In general, risk is defined in terms of likelihood of occurrence and impact (Colicchia & Strozzi, 2012). A firm's or supply chain's vulnerability to risks and disruptions is highest when both the likelihood and the impact of disruptions are high and vulnerability maps can be used to direct management attention (Sheffi & Rice, 2005). Disruptions are unplanned and unanticipated events that break the normal flow of goods and materials within a chain and expose it to operational and financial risks (Craighead *et al*., 2007). There are many drivers for disruptions, such as natural disasters, labor disputes, war and terrorism (Chopra & Sodhi, 2004). According to Kleindorfer & Saad (2005), disruption risks include:

- Operational Contingencies: equipment malfunctions and failures (e.g., in relation to the logistic infrastructure) or abrupt discontinuity of supply;
- Natural Hazards: earthquakes, hurricanes, and storms;
- Terrorism and Political Instability: sabotage, destructive competitive acts, political instability.

While many risks are supply chain specific, stemming from e.g. choice of supplier, inventory decisions and dependency of the supplier (Thun & Hoenig, 2011), macroeconomic and wider environmental risks stemming from e.g. political, economic, social, regulatory and natural environment impact all firms (Peck, 2005). Blackhurst *et al.* (2005) assume organizations as open systems impacted by their external environment such as disruptions as well as active in determining their fate relative to these disruptions.

In this study, we focus on risks related to the external environment and their sources at the country level, thus the three types of risk identified by Kleindorfer & Saad (2005) are analysed considering the country macroeconomic environment and natural and terroristic risks. The disruption risks considered often have severe impacts in terms of magnitude in the area of their occurrence and are fairly unpredictable (Martha & Subbakrishna, 2002; Kleindorfer & Saad, 2005). For this reason, we consider that these three types of risk can be classified as disruption risks and, thus, an organization, perceiving them, may adopt a specific set of practices determined by the information processing needs related to high magnitude and low predictability.

Risk perceptions influence business strategy as well as purchasing decision-making (Ellis *et al.*, 2010). While detailed vulnerability assessment regarding one's supply chain can be difficult and time-consuming, several third party indices provide information on country risks to managers; firms can be assumed to be aware of the disruption risks prevalent in their environment. This is evidenced also by the increasing number of industry reports, practitioner conferences and consultancy documents focused on the topics (Nooraie & Parast, 2015); there is heightened management awareness of external risks (Sting & Huchzermeier, 2014). Peck (2005) also argues that susceptibility to such macroeconomic risks can be assessed for risk management purposes. A recent study suggests that boards of directors, CEOs and CFOs identified mainly macroeconomic risks as their top five risk concerns (Protiviti, 2014). It could thus be expected that firms operating under high country disruption risks - of which they are assumed to be broadly aware - would adopt combined risk management approaches along supply chains characterized by *greater arcs of external SCI combined with risk management practices* to cope with these risks than those operating in more stable environments. Firms operating under high country disruption risks will face higher needs to process information that, according to the information processing theory, need different approaches (Gailbraith, 1973; Bode *et al*., 2011): From one side, to reduce these information needs; and from the other side, to increase the information processing capability of the company. Accordingly, we expect these companies to complementary adopt risk management practices, to reduce information processing needs, and supply chain integration to increase information processing. Accordingly, risks extend beyond internal risks and transmit among supply chains and networks, therefore effective information processing and reactive actions requires relevant inter-firm collaboration practices (Li *et al*., 2015; Kamalahmadi & Parast, 2016). Therefore we formulate our first proposition:

P1: A greater arc of external SCI combined with risk management practices is associated with greater levels of country (a) operational contingency risks, (b) natural hazard, and (c) terrorism and political instability.

2.3 Risk management and external SCI practices in relation to operational performance

The ultimate goal of effective risk management is to create robust and resilient supply chains (Colicchia & Strozzi, 2012) potentially impacting operational performance (Narasimhan & Talluri, 2009). As mentioned previously, risk management may be deployed though different types of practices (i.e., traditional risk management practices and integration practices). The economic theory of complementarities suggests that resource combinations have superadditive value (Mishra & Shah, 2009). Activities are complementary when increased use of any increases the returns of using others (Milgrom & Roberts, 1995), i.e. an activity is of more value in the presence of other activities (Mishra & Shah, 2009). Complementarity does not only occur between a pair of activities but can also occur among groups of activities (Milgrom & Roberts, 1990), which is what we assume here as we study external integration compassing customer and supplier facing activities together with risk management practices. Complementary relationships between organizational factors can have significant performance improving effects (Ennen & Richter, 2009), and in the following we discuss this issue specific to the activities relevant to our study to develop our proposition.

We suggest that traditional risk management practices and external SCI are complementary and have a superadditive impact on operational performance. Three main reasons may explain their complementarity, meaning that the presence of a practice may increase the benefits of the other (Milgrom & Roberts, 1995). Firstly, traditional risk management practices allow reacting to the external environments improving operational performance (e.g., Zsidisin, 2003). However numerous studies have stated that nowadays firms need to implement external SCI to meet the new challenges of the global competitive environment and competing alone may not be sufficient (Frohlich & Westbrook, 2001; Zhao *et al.*, 2013). The majority of the related empirical research has shown that SCI leads to increased operational performance (Van der Vaart & van Donk, 2008), especially if it includes both supplier and customer integration. Specifically, Frohlich & Westbrook (2001) and then Schoenherr & Swink (2012) argue that a greater arc of external SCI as opposed to a narrow approach leads to greater operational performance improvements. Therefore, external SCI practices complement traditional risk management practices to increase operational performance, building operational capabilities among supply chain partners. Thus, risk management practices are more effective thanks to the application of its impacts on the supply chain through supply chain integration.

Second, supplier and customer integration are important in achieving effective supply chain risk management (Li *et al.*, 2015) through increased information sharing. External SCI allow collecting timely and reliable information (Swink *et al.*, 2007; Schoenherr & Swink, 2012), thus feeding with such information traditional risk management practices related to risk detection, prevention, reaction and mitigation. Some recent studies are indeed considering the benefits of SCI to firms facing supply chain risks (Zhao *et al.*, 2013, Wiengarten *et al*., in press), as integration among supply chain partners improves visibility and the speed of response (Wieland & Wallenburg, 2013). This is especially true when integration covers both inbound and outbound activities. Already earlier it has been suggested that with risks becoming predominant, firms are likely to engage in more information sharing, alignment of objectives and programming of supplier activities (Zsidisin & Ellram, 2003). Among the ten principles of risk management that Kleindorfer & Saad (2005; 56) define, the seventh suggests that cooperation, coordination, and collaboration must exist across supply chains; anything else would be overly costly and expose weak links. Visibility has been stressed as key to risk and disruption management (Nooraie & Parast, 2015), and supply chain integration allows information sharing, responsiveness and thus reducing vulnerability (Chopra & Sodhi 2004; Giunipero & Eltantawy, 2004; Hallikas *et al*., 2004). Thus, we suggest a super-additive effects on operational performance when both sets of practices are adopted reinforcing information processing.

Third, despite the several benefits of integrated supply chains, they bring with them also the risk that disruptions can be propagated and amplified along the supply chain if not properly managed (Świerczek, 2014). Supply chain risks impact not only the single firm, but all the integrated chain (Li *et al.*, 2015) and various external sources of risks can hinder the achievement of the benefits from integrated supply chains (Wiengarten *et al*., in press). Adopting traditional risk management practices combined with external SCI may then help to prevent, mitigate and cope with potential disruption risks avoiding possible negative effects and further increasing SCI operational benefits. Thus, supply chain integration impacts are higher in the presence of risk management practices.

These arguments about risk management practices and external SCI support their combined impact on operational performance and are rooted in complementarity theory (Milgrom & Roberts, 1995). We focus here on five key performance dimensions outlined in many previous studies on manufacturing (e.g. Frochlich & Dixon, 2001; Rho *et al*. 2001): *quality, delivery, flexibility, cost* and *customer service* performance.

Focusing on *quality* performance, risk management practices together with supplier integration help identify and moderate failure risks (Giunipero & Eltantawy, 2004). Specifically, risk management practices allow identifying possible failures and external SCI practices allow providing the capabilities to react quickly to failures, jointly improving quality and having a super-additive effects. External SCI creates a knowledge base and joint capabilities that lead to higher quality products to cope with quality failure risks (Wieland & Wallenburg, 2012). Additionally, external SCI increases trust and cooperation with suppliers increasing the potential for investments in fixed assets and R&D activities to improve product and process quality (Zhao *et al*., 2013).

Furthermore, both risk management and external SCI practices have been linked to greater *delivery* performance and complement each other making them more effective. As Zsidisin (2003) indicates, risk may result in the inability of firms to meet their customers' requirements. Delays in materials from suppliers could paralyze production, which in turn prolongs manufacturers' lead-times and delivery times. Also in this case, traditional risk management practices allow detecting potential risks (Wieland & Wallenburg, 2012). External SCI practices offer the capability to cope with such risks: the exchange of information with supply chain partners which in turn may result in increased forecasting and delivery accuracy and reduced lead times (Lee *et al*., 1997; Handfield, 1993; Frohlich, 2002), complements traditional risk management practices. The mutual exchange of information enables manufacturing companies to develop and update their production plans thus increasing their delivery performance (Flynn *et al.,* 2010).

Similarly, the combination of risk management and external SCI practices has links to *flexibility* performance and if jointly adopted may have super-additive effects. According to Sheffi & Rice (2005), resilience, i.e. ability to bounce back from a disruption, can be accomplished through redundancy or increased flexibility, the latter of which can increase day-to-day operational competitiveness as well. Redundancy is related to traditional risk management practices such as inventories or back-up suppliers. Increased flexibility can be deployed also through external SCI. Different than vertical integration it allows a decrease in fixed costs and thus increased flexibility. Further, external SCI is a way to share information and jointly develop product and process improvements enabling increased product and volume flexibility (Handfield, 1993; Frohlich, 2002).

Risk management and external SCI practices are related also to *cost* reduction and can impact more effectively if jointly adopted. Risk management practices aim to avoid supply failures with potentially significant cost impacts (Craighead *et al*., 2007). This is usually done using back-up and buffering strategies that may also increase administrative costs. To counter balance this possible negative effect, adopting external SCI, firms reduce overall transaction and production costs (Das *et al*., 2006). Further, higher level of supplier integration is usually related to fewer suppliers, which can lead to economies of scale and reduce material and product costs. Wieland & Wallenburg (2013) argue that integration could also improve risk preparedness by reducing risk-prevention costs, suggesting that the combined approaches of integration and risk management practices would have cost reducing effects.

Finally, a combination of risk management and external SCI practices may positively impact *customer service*. Frohlich & Westbrook (2001) and Vickery *et al*. (2003) find that firms with higher levels of external SCI achieve better customer service. Research has shown a link between supplier integration and manufacturer's customer service as well as customer integration and customer satisfaction (Flynn *et al*., 2010). Supplier and customer integration helps manufacturers enhance the understanding of customer preferences (Swink *et al*., 2007) and enables manufacturers to meet customers' requirements effectively and efficiently (Stank *et al*., 2001; Koufteros *et al*., 2005). Risk management practices support the efficiency and effectiveness of external SCI preventing possible material or product delivery failures (Zsidisin, 2003) which could lead to service failures and customer dissatisfaction if allowed to materialize.

Based on the above mentioned discussions on the complementarities of external SCI and risk management practices in impacting operational performance, we propose:

P2: A greater arc of external SCI combined with risk management practices is associated with greater levels of (a) quality, (b) delivery, (c) flexibility, (d) cost and (e) customer service performance improvement.

3. Methodology

We use a combination of primary and secondary data in analyzing the propositions. Data collected in the 6th edition of the International Manufacturing Strategy Survey (IMSS 2013) constitute the primary data source. IMSS is a long-lasting research project, initiated in 1992 by the London Business School and Chalmers University of Technology, which periodically surveys manufacturing and supply chain strategies, practices and performance around the world (www.manufacturingstrategy.net). The authors are active members of the network and have collaborated to all phases of the project, from the design to data collection. Secondary data are collected from several publicly available data sources. Recently, Wiengarten *et al.* (in press) have used a similar approach in combining data from the 5th IMSS survey with country level secondary data on the rule of law in a country, and linking this to the effectiveness of SCI practices. Our approach is more extensive, as we use a combination of secondary measures to capture the environmental risk, and we also study the combined adoption and effects of external SCI and risk management through the arcs of integration approach. Using secondary data provides several advantages (Calantone & Vickery, 2010): it is publicly available enabling replication and validation and can be more objective as it is not influenced by respondent perceptions and memories. Using secondary data mitigates the chances of biases from both source and researcher but secondary data do not often completely capture the constructs of interest; therefore a combination of primary and secondary data provides the benefits of both approaches (Calantone & Vickery, 2010; Boyer *et al.*, 2012).

3.1 Secondary data

We use secondary data from the World Economic Forum (WEF) report on Global Competitiveness 2013-2014, the UN World Risk Report 2012 and the WEF report on Global risks 2013. Specifically, these three reports provide country-specific indicators regarding disruption risks, i.e. operational contingencies risks (logistics infrastructure and supplier availability), natural hazards and terrorism and political instability. In a recent study, Bhattacharyya *et al.* (2010) found that no single third-party risk index can serve as an indicator of a country's internal environment but that they should be used in combination instead. The Global Competitiveness Report is an annual publication of WEF which provides the most up-to-date data source for several countries on their comparative strengths and weaknesses (Vachon & Mao, 2008). Different competitiveness pillars are measured on a 7-point Likert scale (1=minimum value, 7=maximum value). In our study, the Global Competitiveness Report provides the information to measure disruption risks in terms of operational contingencies. Specifically, we measure the *operational contingencies risks* in relation to the supply in terms of local supplier quantity and quality (Vachon & Mao, 2008); and in terms of quality of the infrastructure (overall infrastructure, roads, railways and ports). Moreover, the Global Competitiveness Report allows measuring the *terrorism and political instability risks* in terms of business cost of terrorism, business cost of crime and violence and ethical behavior of firms.

The UN World Risk Report 2012[1] is commissioned to the Alliance Development Works by the United Nations University Institute for Environment and Human Security. The natural hazard risk of the country is evaluated considering five aspects:

- Exposure to natural disasters (e.g., earthquake, hurricanes): the annual average number of individuals who are potentially exposed to hazard events.
- Susceptibility: the likelihood of harm, loss and disruption in an extreme event triggered by a natural hazard.
- Vulnerability: the probability to undergo extreme damages due to extreme natural risks.
- Coping capabilities: the capability of the society to react and minimize the impact of natural disasters. It encompasses measures and abilities that are immediately available to reduce harm and damages in the occurrence of an event. To calculate the index, the opposite value, i.e. the lack of coping capacities, has been used, which results from the value 1 minus the coping capacities.
- Adaptive capabilities: the capability of the society to adapt to natural disasters implementing structural changes. It encompasses measures and strategies dealing with and attempting to address the negative impacts of natural hazards and climate change in the future. The lack of adaptive capacities is calculated in analogy to the coping capacities.

These data are combined into the World Risk Index (WRI), which measures the overall risk exposure of a country as a percentage value. In our sample, the country with the highest risk exposure is Japan (13.53%), followed by the Netherlands (8.49%) and India (7,28%). The countries with the lowest exposure are Sweden (2.15%), Finland (2.24%) and Norway (2.31%). Finally, we considered the Risk Management Score (RMS) provided by the WEF on the basis of the Executive Opinion Survey. The RMS represents the effectiveness of the risk management process of a country. It is measured on a 7

[1] The UN World Risk Report data is not available for one of our survey countries, Taiwan.

points Likert scale (1=not effective; 7=effective). The whole set of secondary data is reported in Appendix 1.

3.2 Survey data

The 6th edition of the IMSS involved 22 countries worldwide. The survey targets manufacturing units within the assembly industry (ISIC 25-30). The respondent is the operations or supply chain manager, who provides information about the strategy, practice and performance of the plant. In this paper we used the questions regarding the adoption of risk management practices (Speier *et al.,* 2011), external SCI and operational performance. All countries collecting data for the survey adhere to a strict protocol to ensure consistency in methods and that the data can be pooled. A minimum of 20% response rate must be achieved, and respondents are contacted by phone prior to the survey being sent to ensure commitment. Non-response and late-response bias checks have been conducted on the data using a joint protocol that each country had to follow. The common method bias was tested with Harman single factor test. Less than 50% of the common variance were explained by one single factor which indicates that problematic common method variance does not exist (Podsakoff et al., 2003). Discriminant validity was tested by comparing the average variance extracted estimates for each factor with the squared interfactor correlations associated with these factors. (Hair et al., 2006, p. 808). With multi-country data, measurement equivalence is to be considered. Calibration equivalence was ensured in survey design through the use of standardized Likert scales items in all countries (Wiengarten *et al.,* in press). Translation equivalence was ensured through the careful translation guidelines followed in all countries. We assessed metric equivalence post-survey by calculating individual Cronbach's alphas for each country for all the four item constructs and all provide results above threshold values individually. This was not done for the two-item performance constructs as the limited number of items compared with limited number of responses per country would not provide reliable results (Eisinga *et al.*, 2013). Tables 1a and 1b provide the descriptive statistics of the IMSS data used in the paper (we excluded Taiwan given the unavailability of secondary data).

Table 1a – Descriptive statistics in terms of (a) country, (b) size

Country	N	%	Country	N	%	Size*	N	%
Belgium	27	3.2	Malaysia	12	1.4	Small	397	47.6
Brazil	30	3.6	Netherlands	48	5.8	Medium	142	17.0
Canada	25	3,0	Norway	25	3.0	Large	293	35.1
China	113	13.5	Portugal	31	3.7	missing	2	0.2
Denmark	35	4.2	Romania	39	4,7	**Total**	**834**	**100.0**
Finland	31	3.7	Slovenia	17	2.0			
Germany	12	1.4	Spain	27	3.2			
Hungary	53	6.4	Sweden	31	3.7			
India	90	10.8	Switzerland	23	2.8			
Italy	47	5.6	USA	37	4.4			
Japan	81	9.7	**Total**	**834**	**100**			

*Size: Small: <= 250 employees. Medium: 251-500 employees. Large: > 500 employees

Table 1b – Descriptive statistics in terms of industrial sector (ISIC codes[2])

ISIC Code	N	%	ISIC Code	N	%
25	260	31.2	28	208	24.9
26	104	12.5	29	86	10.3
27	135	16.2	30	41	4.9
			Total	**834**	**100**

Since IMSS data refer to single plants within a country, we associated to each plant the corresponding country values obtained from secondary sources (as explained above).

3.3 Constructs measures

Risk management was measured in terms of efforts spent in the last three years to detect, predict, avoid or reduce the effects of disruptions and defaults along the supply chain through buffering strategies (e.g. backup suppliers, extra capacity, alternative transportation modes) and contingency plans (Helferich & Cook, 2003). External SCI was measured by *supplier and customer integration*. According to previous studies (e.g., Wiengarten *et al.*, 2014), customer and supplier integration were

[2] ISIC Code (Rev. 4): 25 Manufacture of fabricated metal products, except machinery and equipment; 26 Manufacture of computer, electronic and optical products; 27 Manufacture of electrical equipment; 28 Manufacture of machinery and equipment not elsewhere classified; 29 Manufacture of motor vehicles, trailers and semi-trailers; 30 Manufacture of other transport equipment

each measured considering the efforts in the last three years in the adoption of coordination and collaboration practices. The scale measuring all practices ranged from 1 (no effort) to 5 (high effort). Operational performance was measured on dimensions of cost, quality, flexibility, delivery, and customer service (Shin *et al*., 2000; Rosenzweig & Roth, 2004). Respondents were asked to address multiple items for each dimension indicating their performance improvement in the last 3 years on a 5-point Likert-scale where 1 =decrease, 3 =slight increase, and 5 =strong increase. All items are listed in Table 2.

3.4 Data analysis

To study our propositions based on the literature review, we conducted multiple steps. We conducted confirmatory factor analysis (CFA) to validate our measures and confirm our proposed factor structure. Then to investigate the combined risk management and integration practices and differences in terms of country risks and performance, we followed a stepwise staggered method most typical in systems approach studies of complementarity theory (Ennen & Richter, 2009), i.e. we first clustered our practice variables to identify configurations of activities and then examined their relationship to both the external environmental variables and the performance variables. First, we ran cluster and ANOVA similarly as previous studies investigating SCI strategies (e.g., Frohlich & Westbrook, 2001; Schoenherr, & Swink, 2012) and extending their research including risk management practices. The cluster analysis was performed on risk management, supplier and customer integration practices to identify configurations of combined risk management and integration practices adopted by the firms. Due to the large number of firms analyzed and the instability of hierarchical clustering algorithms, a two-step clustering procedure was used (Ketchen & Shook, 1996). We tested the discriminant validity of the cluster analysis by mean of ANOVA and Post Hoc Scheffè Test to identify the significant differences among clusters. In addition, we performed Canonical Discriminant Analysis to test the predicted cluster membership: 96.3% of cases were correctly classified. Several ANOVA analyses were conducted to test for differences in disruption risks and operational performance among clusters.

MANOVA was used to check for the impact of control variables, namely industry (ISIC code) and size class (small, medium and large).

4. Results

Results of the measurement model testing (CFA) are presented in Table 2. We analyzed construct validity in terms of content validity, convergent validity, and reliability (Anderson & Gerbing, 1988). Firstly, we believe that content validity is addressed through the several development and design stages of the IMSS that include key contributions from managers and academics. The IMSS is now in its sixth iterative stage. It has been improved and further developed based on the qualitative assessment of the respondents and researchers and also based on the quantitative statistical results over the years. Furthermore, through the CFA we tested for convergent validity (O'Leary-Kelly & Vokurka, 1998). Our proposed structure of the items measuring risk management, customer integration, supplier integration and five dimensions of operational performance (cost, quality, delivery, flexibility, and customer service) resulted in reasonably well fitting models indicating convergent validity (Bollen, 1989). Additionally, all factor loadings exceeded the value of .50 (see Table 2) (Vickery *et al*., 2003), the standardized factor loadings all exceeded twice the value of their associated standard error, and the Average Variance Extracted (AVE) exceeded 0.5, which also indicates for the existence of convergent validity (Flynn *et al.,* 2010). Finally, Cronbach's alpha (α) and Composite Reliability (CR) have been used to test for reliability, and the values in Table 2 are all above the commonly accepted level of .70, indicating reliability is reasonable. Based on the above analyses, the validity and reliability of our scales were established. Subsequently, we continue with our analysis by computing the standardized factor scores.

Table 2 Survey items and confirmatory factor analysis results

Constructs/Variables	Mean	S.D.	Std. Loading
Risk Management α = .859 AVE = .621 CR = .867			
Preventing operations risks (e.g. select a more reliable supplier, use clear safety procedures, preventive maintenance)	3.391	0.9838	.733
Detecting operations risks (e.g. internal or supplier monitoring, inspection,	3.241	0.9934	.829

tracking)			
Responding to operations risks (e.g. backup suppliers, extra capacity, alternative transportation modes)	3.210	0.9850	.808
Recovering from operations risks (e.g. task forces, contingency plans, clear responsibility)	3.100	1.0693	.778
Customer Integration α = .823 AVE = .620 CR = .867			
Sharing information with key customers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	3.018	1.0956	.838
System coupling with key customers	2.927	1.1365	.747
Developing collaborative approaches with key customers	2.720	1.2168	.846
Joint decision making with key customers	3.015	1.0980	.710
Supplier Integration α = .848 AVE = .600 CR = .857			
Sharing information with key suppliers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	3.163	1.0106	.779
System coupling with key suppliers	3.126	1.0394	.837
Developing collaborative approaches with key suppliers	2.976	1.0294	.785
Joint decision making with key suppliers	2.770	1.1419	.691
Quality performance α = .838 AVE = .726 CR = .841			
Conformance quality	3.137	0.9381	.834
Product quality and reliability	3.282	0.967	.870
Flexibility performance α = .744 AVE = .592 CR = .743			
Volume flexibility	3.249	1.0011	.790
Mix flexibility	3.159	0.9723	.748
Customer service α = .809 AVE = .675 CR = .806			
Product assistance/support	2.924	0.9297	.857
Customer service quality (e.g. training, information, help-desk)	2.917	0.9451	.785
Delivery performance α = .838 AVE = .725 CR = .841			
Delivery speed	3.204	0.9766	.827
Delivery reliability	3.239	0.9944	.876
Cost performance α = .750 AVE = .606 CR = .754			
Unit manufacturing cost	2.498	0.9736	.797
Ordering costs	2.408	0.8868	.759
Fit statistics: χ^2**=432.567, d.f.=181, Prob >** χ^2 **= 0.0000; RMSEA 0.043; CFI 0.970; TLI 0.961**			

Table 3 presents the results of the cluster analysis based on risk management, customer and supplier integration adoption. Results show that the sample is grouped into four clusters. Given our aim to explore the nature of risk management strategies along supply chain as a combination of arcs of SCI practices and risk management practices, we did not impose the number of clusters expected but we identified the best number of clusters based on the hierarchical cluster analysis and then used it to perform the k-means cluster analysis generating our results. The four clusters show a different combination of risk management and SCI practices (based on Scheffé post-hoc test with significance < 0.05). For this reason we named the different approaches defining them as different Supply Chain Risk Management (SCRM) strategies: outward-facing SCRM, supplier-facing SCRM, customer-facing SCRM and peripheral SCRM strategy. These names reflect the current clusters' extension of the arcs of integration by Frohlich & Westbrook (2001); and Schoenherr & Swink (2012). The outward-facing SCRM strategy combines extensive adoption of risk management together with customer and supplier integration. The supplier-facing SCRM strategy combines an average level of adoption of risk management together with supplier integration. The customer-facing SCRM strategy combines an average level of adoption of risk management together with customer integration. The peripheral SCRM strategy is characterized by low levels of risk management, supplier and customer integration practices.

Table 3: Clusters average values and ANOVA[3]

	N	Risk Management	Customer integration	Supplier integration
Outward-facing SCRM (1)	228	**0.89**	**0.79**	**0.77**
		2, 3,4	2, 3,4	3,4
Supplier-facing SCRM (2)	207	-0.21	*-0.98*	0.60
		1, 4	1, 3	3,4
Customer-facing SCRM (3)	279	-0.05	0.38	-0.66
		1, 4	1,2, 4	1,2, 4
Peripheral SCRM (4)	90	*-1.55*	-0.87	*-1.31*
		1,2,3	1,3	1, 2, 3

Note*:* The bold and italic values in the first rows represent highest and lowest score, respectively, for each variable. ***Cluster differences*** have been assessed by means of a Scheffé post-hoc test with significance < 0.05 and indicated in the second row

Tables 4, 5 and 6 present the ANOVA analysis on the different disruption risks. Results in Table 4 show that the outward-facing SCRM group is characterized by lower quality of the overall infrastructure, quality of roads and local supplier quality than the other three groups and by lower

[3] In all ANOVA tables, the first rows represent the average nominal value of the construct in each cluster. Cluster significant differences have been assessed by means of a Scheffé post-hoc test with significance < 0.05 and indicated in the second row (Group 1: Outward-facing SCRM, Group 2: Peripheral SCRM, Group 3: Supplier-facing SCRM).

quality of ports compared to the customer-facing and supplier-facing SCRM. Moreover results in Table 5 show that the outward-facing SCRM group is also operating in an environment characterized by higher levels of terrorism and political instability risks compared to the other three groups. Considering natural hazard (Table 6), the outward-facing SCRM group is facing more vulnerability and susceptibility to natural hazards, and lack of coping and adaptive capabilities compared to the average operating environments of the other three SCRM strategies. These results support *Propositions 1a-c*, i.e. companies in countries with a high disruption risk are more likely to use a combination of greater arcs of SCI and risk management practices.

Table 4: ANOVA on operational contingencies risks[3]

	Quality of the overall Infrastructure	Quality of Roads	Quality of Railroads	Quality of Ports	Local supplier quantity	Local supplier quality
Outward-facing SCRM (1)	***4.760***	*4.344*	4.468	*4.649*	**5.257**	*4.938*
	2,3,4	***2,3,4***	-	***2,3***	-	***2,3,4***
Supplier-facing SCRM (2)	**5.195**	4.899	4.738	4.992	5.231	**5.212**
	1	***1***	-	***1***	-	***1***
Customer-facing SCRM (3)	5.184	*4.889*	**4.763**	**4.993**	5.213	5.180
	1	***1***	-	***1***	-	***1***
Peripheral SCRM (4)	5.126	**4.796**	*4.563*	4.929	*5.194*	5.206
	1	***1***	-	-	-	***1***

Note: For all risk indicators in table 4, the lower the number, the poorer the environment regarding that indicator
The bold and italic values in the first rows represent highest and lowest score, respectively, for each variable.
Cluster differences by Scheffé post-hoc test with significance < 0.05 in the second row

Table 5: ANOVA on Terrorism and political instability risks[3]

	Business cost of terrorism	Business cost of crime and violence	Ethical behavior of firms
Outward-facing SCRM (1)	***5.432***	**4.997**	***4.463***
	-	-	***2,3,4***
Supplier-facing SCRM (2)	**5.568**	5.035	4.870
	-	-	***1***
Customer-facing SCRM (3)	5.515	**5.081**	4.830
	-	-	***1***
Peripheral SCRM (4)	5.518	*4.962*	**4.941**

	-	-	***1***

Note: For all risk indicators in table 5, the lower the number, the poorer the environment regarding that indicator
The bold and italic values in the first rows represent highest and lowest score, respectively, for each variable.
Cluster differences by Scheffé post-hoc test with significance < 0.05 in the second row

Table 6: ANOVA on natural hazard risks[3]

	RM score	Exposure	Vulnerability	Susceptibility	Lacking of coping capabilities	Lacking of adaptive capabilities
Outward-facing SCRM (1)	*4.102*	16.00	**42.00**	**24.00**	**17.15**	**11.39**
	2	-	***2,3,4***	***2,3,4***	***2,3,4***	***2,3,4***
Supplier-facing SCRM (2)	**4.394**	*15.84*	36.52	19.42	14.70	8.166
	1	-	***1***	***1***	***1***	***1***
Customer-facing SCRM (3)	4.247	***17.34***	36.60	19.55	14.53	8.031
	-	-	***1***	***1***	***1***	***1***
Peripheral SCRM (4)	4.262	16.54	*35.91*	*19.10*	*14.21*	*6.877*
	-	-	***1***	***1***	***1***	***1***

Note: For RM score, the lower the number the lower effectiveness of the risk management process of a country. For other indicators in table 6, the higher the number, the poorer the environment regarding that indicator
The bold and italic values in the first rows represent highest and lowest score, respectively, for each variable.
Cluster differences by Scheffé post-hoc test with significance < 0.05 in the second row

Table 7 presents the ANOVA analysis on firm operational performance. Results show that the outward-facing SCRM group achieves significantly higher levels of performance improvements compared to the Peripheral SCRM strategy firms, except for delivery. In terms of customer service, the outward-facing SCRM group performs better also than Supplier-facing firms. These results provide partial support for *Propositions 2a, c, d and e,* but not for *P2b*.

Table 7: ANOVA on operational performance[1]

	Quality	Delivery	Flexibility	Cost	Customer service
Outward-facing SCRM (1)	**0.144**	**0.076**	**0.171**	**0.181**	**0.230**
	4	-	***4***	***4***	***2,4***
Supplier-facing SCRM (2)	0.023	*-0.071*	-0.045	-0.063	-0.121
	-	-	-	-	***1***
Customer-facing SCRM (3)	-0.044	0.039	-0.007	-0.024	0.015
	-	-	-	-	-
Peripheral SCRM (4)	*-0.324*	-0.067	*-0.253*	*-0.207*	*-0.315*
	1	-	***1***	***1***	***1***

Note*:* The bold and italic values in the first rows represent highest and lowest score, respectively, for each variable.
Cluster differences by Scheffé post-hoc test with significance < 0.05 in the second row

Finally, the MANOVA analysis showed that industry and size, combined with the cluster membership, do not have significant relationships with either country risk or operational performance.

5. Discussion

As research surrounding risk management and external SCI in combination is underdeveloped, we deemed it crucial to combine these two aspects by revisiting Frohlich & Westbrook's (2001) and Schoenherr & Swink's (2012) conceptualizations of *arcs of integration* to include risk management. We also related these to firm disruption risks at the country level as well as to operational performance achievement.

We frame this paper in the information processing theory and the complementarity theory suggesting that potentially neither external SCI practices nor traditional risk management practices alone can suffice in facing risky environments and improving operational performance. Risk management practices to be deployed need information that can rest within different nodes along the supply chain (Sheffi & Rice, 2005). External SCI may be a way to mitigate risk through increased visibility and information along the supply chain and, in case of disruptions occurring, also help to jointly deploy processes to face them (e.g., Zsidisin & Smith, 2005; Tachizawa & Gimenez, 2010). Risk management practices of assessment, monitoring and detection may identify potential supply chain risks in advance determining whether SCI can be employed as risk mitigation strategy or not, or to prevent possible risks in integrated supply chains.

Contributing to previous research investigating the role of risk management practices and external SCI independently, our results show that these two sets of practices are adopted in relation to disruption risks and are also combined in different ways, into different SCRM strategies of arcs of SCI combined with risk management practices. High adoption of risk management practices is associated with high supplier and customer integration, revising the traditional outward-facing SCI paradigm (Schoenherr & Swink, 2012). Instead when only supplier integration or customer integration prevails, risk management practices are adopted to an average extent constituting the supplier-facing and customer-facing SCRM strategies. Finally when customer and supplier integration are adopted to a low extent, also risk management practices are adopted to a low extent constituting the peripheral SCRM strategy. However this last SCRM paradigm is adopted with a lower frequency compared to the other strategies, showing that firms appear to understand the benefits of SCI and risk management adoption as suggested previously (e.g., Vereecke & Muylle, 2006; Wiengarten *et al*., 2014). These findings extend the concept of the *arcs of integration* linking them to SCRM.

We also show that the four combined SCRM strategies identified are found in environments characterized by different levels of disruption risks and are related to different level of operational performance achievement. Specifically, the greater the level of country disruption risks, the higher is the adoption of the outward-facing SCRM strategy and, in relation to this strategy the higher is the level of operational performance achievement. The findings related to our two propositions are discussed in more detail below.

5.1 Combined SCRM strategies and country disruption risks

Concerning our first proposition relating combined SCRM strategies to country disruption risks, our results show that to face higher levels of operational risks, natural hazard and terrorism and political instability, firms are much more likely to adopt the outward-facing SCRM strategy. This would suggest that firms do use approaches such as vulnerability mapping (Chopra & Sodhi, 2004) and act accordingly i.e. firms with higher vulnerability adopt more strategies for coping than those in more stable environments. Managers appear to be aware of at least the macroeconomic and infrastructural risk environment and preparing for them, even if detailed risk maps on the endogenous risks stemming from within the chain itself may be difficult to execute (Harland *et al.*, 2003). Thus, in accordance to Tachizawa & Gimenez (2010) who argued that supply flexibility strategies, such as

SCI, are driven by certain environmental risk factors, we find that the presence of exogenous risk factors is related to the adoption of greater arcs of external SCI combined with risk management practices.

As suggested by the information processing theory, firms may use two approaches to face risks and uncertainty: reducing information needs and increasing the capacity to process information. We show that these two approaches are enacted in supply chain management through the combined adoption of traditional risk management practices and external SCI. We propose that these two sets of practices are not mutually exclusive and they are combined in riskier environments to get benefits from both approaches.

Our study complements a recent study by Zhao *et al*. (2013) who investigated the relationship between supply risks and integration with a global dataset from the High Performance Manufacturing study. Their research suggests that risks stemming from the chain itself hinder integration efforts of the focal firm. We have, however, shown that country disruption risks (to which all parties in the chain are exposed to) are linked to the use of external SCI practices and do not hinder it. Potentially the managers are also aware of their extensive integration exposing them more to these high risks in their environment (Świerczek, 2014), and thus we see high levels of SCI combined with high levels of risk management. We also complement Zhao *et al*.'s view by demonstrating how external SCI practices are used in combination with risk management practices to reinforce their positive effects. This is also shown in a recent study by Wiengarten *et al*. (in press) who show that combining supplier integration with risk management increases the performance efforts of the former, when done in an environment characterized by low rule of law. Therefore, based on Zhao *et al.* (2013), Wiengarten *et al.* (in press) and our findings, we show that for firms in environments characterized by high country disruption risks, it is fundamental to identify the right supplier and customer to invest in integration practices and combine SCI practices with risk management.

5.2 Combined arcs of risk management and SCI & operational performance

Concerning our second proposition relating the combination of arcs of external SCI with traditional risk management practices to operational performance, it is partially supported. We can conclude that risk management and external SCI practices are complementarities as described in complementarity theory (Milgrom & Roberts, 1995). Our systems approach of a complementarity theory has demonstrated the performance effects of configurations of practices, and given that we used continuous, not categorical variables as most other complementarity theory studies with a similar approach, our results provide more detailed information of the complementarity effects (Ennen & Richter, 2009), i.e. the performance effects of various combination levels of the practices studied.

Our results show that the outward-facing SCRM strategy combining greater arcs of external SCI and risk management is positively related to operational performance compared to the peripheral SCRM strategy. In particular, a significant effect is found for quality, flexibility, cost and customer service, but not for delivery. In terms of customer service performance, this is also the case compared to the supply-facing SCRM strategy. Integration with customers and suppliers is suggested to improve information flow, coordination and collaboration between partners along the chain to improve operational performance (Frohlich & Westbrook, 2001; Schoenherr & Swink, 2012). However risk management practices coupled with integration with suppliers or customers only (supplier-facing SCRM or customer-facing SCRM) do not provide more benefits than simply not investing in risk management and external SCI at all (peripheral SCRM). It would appear that focusing on only one side of the chain is not enough to make full use of risk management and external SCI potential.

Moreover these combined arcs of SCRM are a way to overcome possible negative impacts of risks associated with higher SCI and customer and supplier dependency (Zhao *et al*., 2013). The combined adoption of these practices might explain why these firms perform better, shedding some light on the contradictory results of the impacts of SCI on operational performance shown in previous studies (e.g., Flynn *et al*., 2010; Zhao *et al*., 2011). In complementarity theory, best practices are viewed with suspicion, as it is assumed that the performance impacts of activities and resources are contingent on the combinations within which they are applied (Ennen & Richter, 2009). We can demonstrate that external SCI has complementarities at least with risk management practices, and in line with Li *et al.* (2015) thus advocate a supply chain management perspective to managing risks.

6. Conclusions

This study contributes to SCRM and SCI literatures by empirically investigating the relationships among risk management practices, external SCI practices, exogenous disruption risks and operational performance. Specifically, doing so we contribute to the information processing theory showing that supply chain integration and risk management practices can be complementary practices related to the information needs characterizing disruption risks. Disruption risks have been suggested to be related to information needs and reactive approaches but they do not have been often analyzed in the light of the information processing theory. We believe that considering such theory in relation to disruption risks allows to make a contribution in the supply chain management literature, identifying how companies may deal with such risks, and also to contribute to the information processing theory, identifying a new set of practices related to supply chain and risks, operationalizing the concepts of information need reduction and information sharing increase and extending this theory to the risk management research stream.

Disruption risks and risk management and supply chain practices are studied using primary data from a global database (IMSS) covering more than twenty countries, combined with secondary data measuring country disruption risks. Secondary data usage has so far been rather overlooked in supply chain research (Rabinovich & Cheon, 2011) even though e.g. third-party indices can aid supply chain-related decision-making (Bhattacharyya *et al.*, 2010). Therefore we contribute to SCRM and SCI research by combining primary firm-level data, referring to specific manufacturing units, with country-level data, referring to exogenous country risks.

Risks in the supply chain context are receiving growing attention in SCM research (e.g., Peck, 2005; Ellis *et al.,* 2010; Zhao *et al*., 2013) and according to Blackhurst *et al.* (2005), disruption risks are rising to the forefront of supply-chain issues. Firms need to manage risks and their supply chains to improve agility and resilience in today's highly turbulent and uncertain global environments (Braunscheidel & Suresh, 2009). Our study responds to calls for more research on risk management, specifically disruptions, in relation to SCI by Zhao *et al.* (2013), as well as to their call on considering country effects in relation to risks and SCI. We show that SCI is seen as beneficial by firms facing exogenous disruption risks.

Previous studies have investigated different sets of practices (i.e., traditional risk management practices and integration practices) to face disruption risks independently. Instead, based on the information processing theory, we show that different sets of practices may be combined to face different needs (i.e., reducing information processing needs while increasing information processing capabilities). Accordingly, we show that risk management practices may enhance SCI benefits by reducing possible risks stemming from the dependency to suppliers and customers (Power, 2005) and SCI may increase the capability to collect timely and reliable information and the capability to cope and jointly react to risks (Bode *et al*., 2011). Specifically, this study reveals SCRM strategies as combinations of external SCI and risk management practices. Adoption of these combined practices is positively related to exogenous disruption risks.

The findings of this study also support extant SCI literature, i.e. that greater arcs of supplier and customer integration are positively related to operational performance (e.g. Frohlich, 2002; Swink *et al.*, 2007). However, our study highlights the importance of combining such practices with risk management practices, also potentially explaining contradictory effects shown in previous studies. The outward-facing SCRM strategy identified in this study, characterized by greater arcs of external SCI combined with risk management practices, is positively related to operational performance, especially compared to a peripheral SCRM strategy characterized by low external SCI and risk management practices adoption. These findings are in line with complementarity theory (Milgrom & Roberts, 1995), and we thus extend the use of this theory to SCM where its usage so far has been very limited (for few exceptions, see Mishra & Shah, 2009; Al Sheyadi, 2014) compared to its usage in management research overall (see Ennen & Richter, 2009 for an overview). Theoretically, we thus show that supply chain management practices can constitute *Edgeworth compliments* (Milgrom & Roberts, 1995) and should be considered as bundles of activities to achieve best outcomes. We have here specifically demonstrated the complementarity between risk management and external SCI, but we encourage the theory's wider application to other areas of SCM as well.

Finally, our results confirms previous studies suggesting that SCI involving only customers or only suppliers does not make full use of the potential offered in terms of information sharing and processing (Power, 2005). Instead integration with both customers and suppliers can remove the barriers between organizations. This leads to efficient linkages in a supply chain and strengthening operational performance, reducing information asymmetries and managing problems quicker (Frohlich & Westbrook, 2001).

6.1 Implications for practice

This study has some significant implications for managers. First, this study provides empirical evidence that both risk management and external SCI practices are adopted in contexts characterized by high exogenous disruption risks. Together they effectively integrate resources and capabilities of supply chain partners to manage exogenous risks and improve operational performance. This is particularly relevant in countries where the exposure and/or the vulnerability to natural risks is medium to high, such as Japan, The Netherlands, Italy, India, China, Hungary, Malaysia and Romania (considering only countries within our sample). It is worthwhile noticing that these countries are scattered in different continents and are characterized by very different economic and political situations, but they are all exposed to natural hazards.

Managers should be aware of the characteristics of the external environment where their operations (and in general their supply chains) are located and take decisions to prevent or mitigate exogenous risk through different risk management strategies along their supply chain. Indeed managers in riskier environments are adopting more combined risk management and integration practices and obtaining better performance. This should act as a signal and benchmark to firms residing or operating under these exogenous risks that to remain competitive, adoption of such strategies should be undertaken. While previous research has indicated that increasing supply chain resilience to risks has its own costs (Nooraie & Parast, 2016), we have demonstrated that combined approaches of risk management and external SCI improve cost performance. Therefore risk management approaches can be cost-efficient, when applied with correct complementary practices.

Finally, any government can and should of course develop infrastructures to protect their countries and establish regulations to guide behaviors of firms in their countries. Japan and The Netherlands are good examples of countries that, despite a high exposure to natural risks, have developed good risk management capabilities, resulting in relatively low vulnerability. If the country infrastructure is, however, limited in preventing potential exogenous risks, firms can adopt risk management practices of detecting, preventing and mitigating such risks to cope with disruption risks, avoiding production interruptions with consequent losses for other firms in the country. At the same time risk management strategies along integrated supply chains may improve firm operational performance. Regulations could encourage firms to adopt risk management practices and support collaboration and integration along supply chains.

6.2 Limitations

While this study contributes to both literature and practice, some limitations open up avenues for further research. First, risk is a multi-dimension concept, and we only investigated country exogenous disruption risks. There are many other forms of risks and future research should investigate the relationships between other dimensions of risk and combined SCRM strategies. Second, our research aimed to identify combined risk management and SCI practices in an exploratory way. Future research could extend the SCRM strategy concept here identified complementing it with other practices such as inventory management and demand management practices. Finally, as our study is not longitudinal, we are unable to explicitly test causality but draw on the literature and exploratory analysis to investigate the links between disruption risks, risk management and integration practices and operational performance. Future research could test our propositions using a longitudinal study.

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Appendix 1: Country risk data from secondary sources

Country	Risk Management Score	Business costs terrorism	Business costs crime violence	Ethical behavior firms	Quality overall infrastructure	Quality roads	Quality railroards	Quality ports	Local supplie quantity	Local supplier quality	WRI index	Exposure	Vulnerability	Susceptibility	Lack coping capabilities	Lack adaptive capabilities
Belgium	4.07	6.1	5.5	5.3	5.8	5.4	5	6.3	5.6	5.8	3.48	11.66	29.88	14.91	42.89	31.84
Brazil	4.16	6.3	3.4	3.7	3.4	2.8	1.8	2.7	5.3	4.8	4.3	9.53	45.18	25.31	68.39	41.83
Canada	5.41	5.2	5.3	5.7	5.8	5.6	5	5.5	5	5.5	3.18	10.25	31.04	14.29	45.06	33.77
China	4.51	5	4.8	4.2	4.3	4.5	4.7	4.5	5	4.5	7.05	14.43	48.83	28.58	71.53	46.39
Denmark	4.1	4.9	4.6	6.1	5.7	5.5	4.5	5.7	5.1	5.5	3.09	10.87	28.42	14.3	39.09	31.89
Finland	5.32	6.7	6.3	6.4	6.5	6.1	5.9	6.4	4.5	5.7	2.24	8.19	27.41	14.62	37.81	29.79
Germany	4.9	5.7	5.6	5.7	6.2	6	5.7	5.8	5.6	6	3.27	11.41	28.68	14.63	38.59	32.82
Hungary	3.03	6.4	4.9	3.7	4.9	4	3.6	3.9	4.4	4.5	5.87	15.61	37.61	16.18	55.28	41.38
India	4.31	4.7	4.7	3.7	3.9	3.6	4.8	4.2	5.7	4.4	7.28	11.94	60.95	40.88	81.78	60.18
Italy	4.24	5.7	4.5	3.6	4.8	4.4	4.2	4.3	5.4	5.1	4.82	13.85	34.78	16.05	54.84	33.44
Japan	3.67	5.2	5.2	5.8	6	6	6.7	5.2	6.2	6.1	13.53	45.91	29.46	16.52	36.31	35.56
Malaysia	4.97	5.3	4.6	5	5.5	5.4	4.8	5.4	5.3	5	6.53	14.6	44.74	20.87	70.3	43.04
Netherlands	5.06	6.1	5.5	6	6.2	6	5.5	6.8	5.4	5.8	8.49	30.57	27.76	13.89	39.14	30.26
Norway	5.15	5.7	5.7	6.2	5.3	3.7	3.6	5.5	4.8	5.5	2.31	8.58	26.87	13.75	37.98	28.87
Portugal	3.87	6.2	5.4	4.1	4	3	2.6	3.7	5	4.8	3.53	9.79	36.05	17.23	55.45	35.48
Romania	2.53	5.6	5.1	3.1	3.4	2.1	2.3	3	4.4	4	6.78	15.77	42.99	22.06	63.95	42.95
Slovenia	2.84	6.7	5.8	4.1	5.2	5.1	3.2	5.1	4.7	5	3.81	11.59	32.86	14.23	51.36	33
Sweden	5.41	6.1	5.5	6.2	5.7	5.5	4.6	5.8	4.9	5.6	2.15	7.97	27.01	14.32	36.85	29.86
Spain	4.03	5.2	5.5	4.1	6	6	5.9	5.8	5.3	5.1	3.4	10.23	33.28	15.07	50.87	33.91
Switzerland	4.82	6	5.7	6.2	6.6	6.2	6.6	5	5.5	6.2	2.59	9.56	27.14	13.99	36.93	30.51
USA	4.53	4.2	4.3	4.9	5.7	5.7	4.9	5.7	5.5	5.5	3.99	12.25	32.57	16.67	48.48	32.55