An Empirical Analysis of the Impact of Risk Management Maturity on Robustness in the Upstream and Downstream Supply Chains

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This research explores the relationships among dimensions of supply chain risk management maturity (SCRMM) and supply chain (SC) robustness in upstream and downstream organizations. The dimensions of SCRMM include risk management orientation (RMO), improvement of risk management processes (IMP), internal risk management processes (IRM), external risk management processes (ERM) and risk mitigation (MIT). A structural equation model is tested based on the participation of over 100 managers spanning multiple industry sectors, while upstream and downstream organizations are analyzed to determine whether the model relationships differ by SC position. The results indicate that the SCRMM framework positively influences robustness in both research groups. In upstream organizations, the relationship between RMO and both IRM and ERM is fully mediated by IMP, while in downstream firms the link between RMO and ERM is only partially mediated. The findings suggest that companies can benefit from a continuous improvement culture regardless of their SC position.

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I. INTRODUCTION

Modern supply chains have become more complex involving multiple suppliers, manufacturers, and distributors. This trend toward complexity increases exposure to various risks, such as geopolitical uncertainties, natural disasters, and economic fluctuations (Glushkova, Lomakina and Sakulyeva, 2019; Mwangola and Bridges, 2018). Different solutions exist, including the development of a culture of continuous improvement (CI), and the establishment of a systematic approach to risk that ensures risks are identified, considered, and controlled to prevent or mitigate the undesired effects of risk events.

In this challenging environment, effective supply chain risk management (SCRM) helps ensure operational continuity. Specifically, SCRM involves developing

strategies and contingency plans to mitigate the impact of disruptions and enable quick recovery to ensure continued operations. Companies that proactively manage these risks stand to gain a competitive advantage and be better positioned to respond to disruptions through supply chain (SC) resilience (Akın Ateş, Suurmond, Luzzini and Krause, 2022).

In the post-pandemic period, SCRM has become an even higher priority for SC managers (Shafiq and Johnson, 2020). Managers must proactively identify, assess, and manage potential risks to ensure SC stability, reliability, and resilience. This involves managing a combination of risk assessment, scenario planning, diversification of suppliers, robust communication strategies, and the implementation of contingency plans. Even still, SCs are vulnerable to a wide range of disruptions, including supplier bankruptcies, natural disasters, geopolitical conflicts, labor strikes, and disease outbreaks. These disruptions can lead to production stoppages, shortages, and increased costs (D'Amato and Papadimitriou, 2013; Regattieri, Bartolini, Cima, Fanti and Lauritano, 2018). Further, SC disruptions can negatively impact the firm's standing in the marketplace, result in financial losses, and affect overall firm performance (Abeysekara, Wang and Kuruppuarachchi, 2019; Akın Ateş, Suurmond, Luzzini and Krause, 2022; Sun and Varshney, 2023).

The academic literature on SCRM continues to evolve and adapt to the changing business landscape. In this respect, the number of SCRM papers published in top supply chain management (SCM) journals has increased by almost 80% (Swanson, Goel, Francisco and Stock, 2018). Specifically, the SCRM literature has expanded to address various aspects of risk identification, assessment, mitigation strategies, and their impacts on SC performance (Ho, Zheng, Yildiz and Talluri, 2015; Pournader, Kach and Talluri, 2020). Resilience and robustness are prominent concepts in SCRM. Scholars have investigated how SCs can be designed to bounce back quickly from disruptions and adapt to changing conditions (Alvarenga, de Oliveira and de Oliveira, 2023; El Baz and Ruel, 2021). These studies explore building redundancy into processes, creating organizational agility, and enhancing flexibility in the SC.

The current study extends prior research by exploring the relationships among different dimensions of supply chain risk management maturity (SCRMM) and SC robustness (ROB). Unique to our study, we take SC position into consideration by viewing and delineating these relationships in the context of both upstream and downstream SC organizations. To this end, we propose and test a set of hypotheses using a structural equation model based on the participation of over 100 SC managers representing multiple industry sectors. In the model, SCRMM is characterized by factors of risk management orientation (RMO), improvement of risk management processes (IMP), internal risk management processes (IRM), external risk management processes (ERM) and SC risk mitigation (MIT). The findings indicate that the model constructs help predict robustness (ROB) throughout the SC, suggesting that companies can benefit from a culture of CI regardless of their position in the SC.

The contributions of this research are two-fold. First, the empirical findings of this study provide a firm-level framework to guide managerial decision-making in SCRM and enhance understanding of how firms address the complex challenges inherent in risk management. This is especially valuable for businesses navigating the increasingly complex and uncertain global SC environment. By gaining a better understanding of how firms view risk management, the findings equip managers with insights to improve decision-making, build resilience across the SC, and proactively manage risks and other disruptions.

This contribution also holds direct implications for improving organizational performance and sustainability.

Second, the SCRMM measurement scale of Dellana, Rowe, and Liao (2022) is applied in the context of robustness as a performance outcome thereby extending the applicability of this tool. As a result, our study provides support for an instrument that allows scholars and practitioners to assess an organization's SCRM and connect it to specific performance outcomes. Together, the contributions of our study address gaps in both the academic literature and practical understanding of SCRM.

In the following sections we provide a review of the literature and put forth our hypotheses, describe our methodology, analysis and results, and discuss implications for theory and practice. The paper concludes with an analysis of the limitations of the study and identifies areas for future research.

II. THEORETICAL BACKGROUND AND REVIEW OF THE LITERATURE

This study explores the relationships between SCRM constructs and SC robustness. The SCRM constructs studied in this research derive principally from the work of Dellana, Rowe and Liao (2022). The researchers developed a scale for measuring risk management maturity of the firm in the SC. Five distinct scale constructs were found in that study (referred to as dimensions or sub-dimensions), which included SC Risk Management Orientation, SC Risk Collaboration, SC Risk Mitigation, Improvement of Risk Management Processes, and Organization Internal Risk Management. While the researchers proposed a scale for assessing the risk management maturity of the firm within the SC, they did not model the relationships of the dimensions involved and their relationship to a SC's ability to manage risks that could lead to disruptions. This research adds to the literature by addressing this gap.

In the current study, Robustness was chosen as the construct for assessing the ability of firms to manage SC disruptions. The Robustness construct in this research was adapted from work by Brandon-Jones, Squire, Autry and Petersen (2014). Resilience is another measure of SC response to disruptions. Brandon-Jones, Squire, Autry and Petersen (2014) defined resilience as "the ability of a system to return to its original state, within an acceptable period of time, after being disturbed." Thus, resilience tends to assess the decline in regular operations from a disruption and how quickly the SC recovers. Robustness has been defined in the literature as, "the ability of the supply chain to maintain its function despite internal or external disruptions" (Brandon-Jones, Squire, Autry and Petersen, 2014). Thus, robustness tends to measure how well the SC manages disruption and continues to operate with minimal impact to regular operations. The Robustness construct was considered a more suitable measure because the maturity scale statements consider the efforts already in place to minimize the effects of a SC disruption.

The expected relationships among the risk management constructs and with the Robustness construct are explored in this literature review. Further, it is expected that how these relationships are characterized may vary by specific factors, such as industry (e.g., service versus manufacturing), relative firm sizes, and the stages or positions in the SC (e.g., upstream versus downstream). In this respect, organizations are strongly influenced by different internal and external factors that create complex challenges for managers and influence an organization's strategic approach (Hofer, 1975; Zeithaml, Varadarajan and Zeithaml, 1988). This is consistent with the concept of contingency theory, which forms the basis for

the conceptual model and hypotheses developed in this research.

2.1. Contingency Theory

Contingency theory suggests the effectiveness of organizational strategy is contingent upon the specific conditions faced by the organization (Tachizawa and Wong, 2014). In a SC context, contingency theory emphasizes the need for organizations to adapt strategies and practices to fit the unique characteristics of the SC environment (Tachizawa and Wong, 2014). According to contingency theory, strategies that enhance SC resilience and robustness may vary depending on the specific context in which the SC operates. For example, Brandon-Jones, Squire, Autry and Petersen (2014) propose a contingent resource-based view of SC resilience and robustness, which suggests that the resources and capabilities needed to enhance resilience, or robustness may differ based on the environmental conditions faced by the SC.

Contingency theory has also been applied to the study of SCRM. Risk management involves identifying, assessing, and mitigating risks that may impact the performance and continuity of the SC (Talluri, Kull, Yildiz and Yoon, 2013). According to contingency theory, the choice of risk mitigation strategies should be contingent upon the specific context and the types of risks faced by the SC. For example, Talluri, Kull, Yildiz and Yoon (2013) established that strategies focusing on flexibility, rather than redundancy, are more efficient in mitigating SC risks.

SC scholars have used contingency theory to examine other aspects of SCM that highlight the importance of considering specific challenges faced by managers when making strategic decisions and implementing practices. Contingency theory provides a valuable framework for understanding and managing a SC in diverse and dynamic environments. Organizations that recognize the contingent nature of SCM can better adapt strategies and practices to fit the specific challenges managers face, leading to a more robust SC and improved performance. With this context, we next examine the influence of SC position on risk management attitudes and practices.

2.2. Supply Chain Position and Supply Chain Risk Management

In this research, the position of the firm in the SC is considered as a key aspect of determining relationships among risk management constructs. This expectation is due, in part, to prior research relating to measures of maturity and performance by SC position or industry as a surrogate measure for position.

In a study of 565 firms in the United States, Dellana and Kros (2014) found that SC quality practice and maturity varied by SC position. They noted that there was a substantial overlap between industry and position in the SC. They considered four positions, from upstream to downstream, as materials manufacturing, products manufacturing, distribution, and retail/services. They reported that quality maturity tended to drop moving downstream in the SC. Earlier studies report similar findings (Choi and Rungtusanatham, 1999; Rahman, 2006). Quality maturity has been associated with SCRMM in prior studies (Florio, 2017), so there is an overlap of the two concepts.

The literature also reports on studies that find differences in manufacturing-oriented firms versus service-oriented firms on a variety of measures. This may also be considered a rough representation of SC position since manufacturing activities are typically classified as upstream in the SC and service-oriented firms tend to use the products from manufacturing-oriented firms, often placing them more so downstream in the SC. Even pure

services use manufactured goods to some extent in fulfilling customer needs. In a study by Bouranta and Psomas (2017), service and manufacturing firms were found to differ on their competitive priorities. Manufacturing firms ranked cost ahead of customer focus, while service firms reported the opposite. In a study of various types of SC risks, Truong and Hara (2018) compared manufacturing- and service-oriented firms. They reported differences in performance between manufacturing- and service-oriented firms regarding various risks. They found that service-oriented firms were not impacted as negatively by risk events as manufacturing-oriented firms.

The findings of these studies support the idea that a firm's position in the SC may impact on the construct relationships that characterize risk management maturity and resulting robustness. This is consistent with contingency theory, which would suggest that differences in SC position might motivate different attitudes and approaches to SC risks.

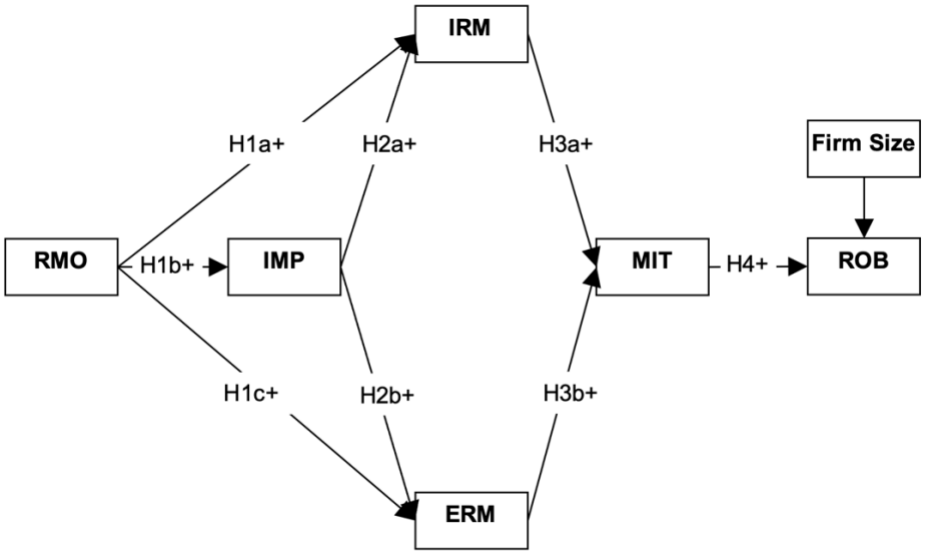
III. DEVELOPMENT OF THE MODEL AND RELATED HYPOTHESES

Based on the preceding literature review and theoretical background, a model of the variables involved may be developed along with related research hypotheses. These hypotheses are discussed and developed in the next three subsections. Figure 1 displays the proposed theoretical model for this research. The model suggests that an orientation toward risk management (RMO) in the SC precedes the improvement of risk management processes (IMP). Further, efforts to effectively improve risk management processes foster SC integration and improved internal risk management (IRM) performance. In the proposed model, the development of internal and external risk management (ERM) processes precedes effective mitigation of risk (MIT) events, while improved mitigation efforts are expected to have a positive effect on overall SC robustness (ROB). Finally, the size of the organizations (measured in terms of number of employees) is included in the model as a control variable. The resulting research hypotheses are presented and theoretically supported in the following section.

3.1. Orientation, Improvement and Risk Management Integration

Regarding SCRM in general, prior research has shown that developing RMO differentiates firm effectiveness in dealing with risk events. It is the first step in developing a culture of risk management and necessarily precedes all other actions, such as IMP, IRM and ERM actions in the SC, and MIT. For example, Chowdhury and Quaddus (2016) report that orientation to risk management is a precondition to risk mitigation and includes the need for top management support in the risk orientation of the firm. Further, Bendul and Skorna (2016) found that risk orientation was related to risk prevention. Specifically, a higher level of risk orientation primed employees to take preventive measures to manage or avoid risk, such as working with suppliers and customers to monitor for risk events.

FIGURE 1. PROPOSED MODEL



It should be noted that risk management integration can take two forms. In the scale development work by Dellana, Rowe and Liao (2022) they report that integration occurs both within the organization (IRM) and across the SC (ERM). Both ERM and IRM were treated as separate and distinct dimensions in their research. ERM reflects coordination and collaboration among SC partners, whereas IRM reflects the risk management strategies, tools, and integration within the organization. Mishra, Sharma, Kumar and Dubey (2016) propose that firms with an established risk management orientation lean toward building strong connections with SC partners in risk mitigation efforts. This is also supported by other researchers in the field (e.g., Fan, Li, Sun and Cheng, 2017; Huo, Han and Prajogo, 2016). SCRM is an ongoing process involving continuous monitoring of changes in risk factors and external conditions, reviewing risk management strategies, and adjusting priorities, assessment, and key actions in response to existing and potential risk events. This process of CI (continuous improvement) relies on translating individual insights into knowledge that can be transferred and shared throughout the organization. From an information processing perspective, Yang, Xie, Yu and Liu (2021) conceptualize RMO as an informal and organic risk control mechanism for information processing capacity. It is critical that firms integrate and synthesize a variety of information to better inform the improvement of SCRM practices. In addition, according to Bode, Wagner, Petersen and Ellram (2011), risk management orientation fosters a motivation to continuously pursue better solutions to disruptions.

In line with the constructs in our model, contingency theory emphasizes that organizations must develop internal capabilities, like RMO and IRM, to respond effectively to environmental uncertainties. RMO creates the foundation for these capabilities by embedding risk awareness within the organization's culture and fostering the adoption of tools and strategies for internal risk management. A strong RMO enhances the organization's ability to synthesize risk-related information, allowing firms to align internal processes, mitigate vulnerabilities, and improve resilience (Yang, Xie, Yu and Liu, 2021). Likewise, a well-integrated IRM approach is critical for addressing risks efficiently and effectively, particularly in complex SC

environments. Therefore, we hypothesize the following:

H1a. RMO directly and positively contributes to IRM efforts in upstream/ downstream SC organizations.

Contingency theory also suggests that organizations can achieve superior performance when their processes are designed to meet environmental uncertainties. RMO facilitates this by promoting a CI mindset within risk management practices. As highlighted by Bode, Wagner, Petersen and Ellram (2011), RMO involves an ongoing commitment to identifying and implementing better solutions to disruptions, enabling firms to adapt their risk management strategies as conditions change. By driving process improvements (IMP), firms can enhance their ability to mitigate risks, ensuring that their risk management practices are responsive and effective. Therefore, we hypothesize the following:

H1b. RMO directly and positively contributes to IMP efforts in upstream/ downstream SC organizations.

Contingency theory further highlights the need for inter-organizational alignment to better manage external uncertainties. RMO plays an important role in enabling collaboration and coordination across SC partners. By creating a shared risk orientation among upstream and downstream stakeholders, RMO strengthens ERM efforts (Mishra, Sharma, Kumar and Dubey, 2016; Huo, Han, and Prajogo, 2016). Firms with a strong RMO are better equipped to develop strong partnerships and integrate SCRM practices, both of which are essential for identifying and mitigating risks across the SC. This external alignment with SC partners enhances the firm's ability to manage disruptions and reinforces the need for collaborative risk management strategies. Therefore, we hypothesize the following:

H1c. RMO directly and positively contributes to ERM efforts in upstream/ downstream SC organizations.

CI systems enhance a firm's SC integration, performance, and risk management effectiveness. For example, Florio (2017) reported that maturity of a firm's quality management system relates positively to its risk management maturity. Chiarini (2017) found that organizations certified to the ISO 9001:2015 quality standard improved SCRM effectiveness. In a recent study by Dellana, Kros, Falasca and Rowe (2019) the authors found that firms certified to ISO 9001:2015 achieved enhanced SC integration and performance compared to non-certified firms. This is not altogether surprising since the implementation of a CI system, such as total quality management or ISO 9001:2015, requires top management commitment, customer focus, and effective supplier relationship management (Terziovski and Hermel, 2011; Vouzas and Psychogios, 2007). Liu and Wei (2022) provide empirical evidence that strong SC RMO drives a proactive search for information, which aids learning from SC disruptions. This results in improved IRM practices as well as improved ERM on SC issues.

According to contingency theory, organizations facing dynamic environments must adopt flexible processes to manage internal risks effectively. CI systems strengthen a firm's ability to standardize, refine, and improve processes, which directly contributes to the maturity of their risk management approach. For example, firms with mature quality management systems (e.g., ISO 9001:2015 certifications) exhibit higher risk management maturity by embedding systematic approaches for continuous monitoring and improvement. From this perspective, IMP encourages an organizational culture of adaptability, enabling firms to align their IRM practices with changing operational requirements. Liu and Wei (2022) further support this by demonstrating that proactive information gathering and learning from SC disruptions—key principles of CI—enhance internal integration and improve IRM practices.

In line with contingency theory, firms implementing IMP are better positioned to handle internal uncertainties, thereby enhancing their IRM efforts. Therefore, we hypothesize the following:

H2a. IMP efforts directly and positively contribute to IRM efforts in upstream/ downstream SC organizations.

Contingency theory highlights the critical role of external alignment needed to manage environmental uncertainties. As CI systems emphasize top management commitment, customer focus, and supplier relationship management (Terziovski and Hermel, 2011; Vouzas and Psychogios, 2007), they inherently promote collaboration across the SC. Dellana, Kros, Falasca and Rowe (2019) provide evidence that ISO 9001:2015-certified firms achieve enhanced SC integration and performance due to these characteristics. By improving risk management processes (IMP), firms develop structured approaches to sharing information and coordinating activities with upstream and downstream partners. This aligns with the findings of Liu and Wei (2022), who demonstrate that proactive sharing of information enhances ERM efforts. Further, firms that consistently improve risk management processes are better equipped to integrate with SC partners, enabling more effective responses to disruptions. Therefore, we hypothesize the following:

H2b. IMP efforts directly and positively contribute to ERM efforts in upstream/ downstream SC organizations.

3.2. Risk Management Integration and Risk Mitigation

From a contingency theory perspective, effective risk mitigation requires tailored strategies based on a firm's internal capabilities and its ability to coordinate risk management activities with external partners. IRM focuses on integrating risk management processes and resources within the organization, enabling it to anticipate and address risks proactively. For example, developing flexible processes and conducting crisis planning exercises are contingency-based adaptations that improve a firm's ability to respond to disruptions (Birkie, Trucco, and Fernandez Campos, 2017). ERM, on the other hand, extends risk management integration across the SC by enabling collaboration with upstream suppliers and downstream customers. This external alignment enhances SC visibility, which is critical for detecting, interpreting, and responding to risks in real-time (Yang, Xie, Yu, and Liu, 2021). Enhanced collaboration with SC partners allows firms to leverage resources and capabilities, ensuring timely responses to disruptions.

Risk mitigation activities and approaches are well-documented in the literature. For example, the ISO 31000 Standard (International Organization for Standardization, 2018) section on risk management is a source for mitigation concepts. Bendul and Skorna (2016) studied activities related to risk mitigation. The activities involve predicting risk events, monitoring for potential risks, and developing risk mitigation plans should a risk event occur. They report that the development of a risk management planning system is key to minimizing the negative effects of a risk event. Risk planning can range from conducting regular crisis planning exercises to developing more flexible processes internally and across the SC (Birkie, Trucco and Fernandez Campos, 2017; Chowdhury and Quaddus, 2016).

The literature supports the idea that enhanced IRM and ERM leads to more effective risk MIT. Zhao, Huo, Sun and Zhao (2013) found that enhanced SC integration impacts positively on schedule attainment, competitive performance, and customer satisfaction. Further, SC risk decreases as SC integration increases. Links with SC partners promote insights into the capabilities and processes of suppliers (Liu and Wei, 2022). SC visibility, driven by external collaboration, fosters the collection of timely and accurate information

for scanning, detecting, and interpreting SC risks (Yang, Xie, Yu and Liu, 2021). Furthermore, IRM and ERM efforts are vital for aligning and reconfiguring internal and external resources, processes, and structure (Azadegan, Mellat Parast, Lucianetti, Nishant and Blackhurst, 2020; Liu and Wei, 2022). As a result, SC risk MIT performance capabilities are improved.

Prior discussion shows a relationship between SC industry and SC position (i.e., upstream versus downstream). Zelbst, Green, Sower and Reyes (2009) found that the relationship of SCRM integration with risk mitigation may differ by industry or sector (e.g., manufacturing versus service). Martínez-Sánchez, Vela-Jiménez, Pérez-Pérez and de-Luis-Carnicer (2008) demonstrated different effects of collaboration in service versus manufacturing organizations. Therefore, it may be expected that the relationship of IRM and ERM with risk MIT may differ by whether an organization is positioned upstream versus downstream in the SC. Contingency theory provides a clear framework for understanding why IRM and ERM efforts contribute positively to MIT effectiveness in SCs. Specifically, by aligning internal and external risk management practices with specific SC contingencies, firms can better mitigate risks, adapt to environmental uncertainties, and achieve improved performance. The potential variation in effectiveness based on SC position further emphasizes the importance of tailoring risk management strategies to fit the unique context of the organization. Therefore, we hypothesize the following:

H3a. IRM efforts directly and positively contribute to MIT efforts in upstream/ downstream SC organizations.

H3b. ERM efforts directly and positively contribute to MIT efforts in upstream/downstream SC organizations.

3.3. Risk Mitigation and Robustness

The literature on risk management in the SC demonstrates that enhanced risk MIT strategies that leverage relational competencies among SC members contribute positively to resilience, robustness, and agility in the face of SC disruption (Wieland and Wallenburg, 2013). Brandon-Jones, Squire, Autry and Petersen (2014) studied how SC connectivity and information sharing relate to SC visibility and, in turn, to performance (i.e., robustness and resilience). SC visibility (i.e., risk mitigation capability) is considered by the researchers to be key to reducing SC risk. They report, based on empirical evidence, that SC visibility is an important antecedent of both SC robustness and resilience. Therefore, it would be expected that an enhanced ability of the SC to mitigate risks will result in a more robust system, which should impact positively on overall SC performance.

Through the lens of contingency theory, MIT efforts represent tailored strategies that enable firms to address environmental uncertainties across the SC. These strategies, like information sharing and collaboration, enhance SC robustness by reducing vulnerabilities and improving resilience and performance. From a contingency perspective, SC managers will seek to reduce the possibility of a risk event occurring, transfer the risk to a third party, or reduce the likelihood and severity of the risk by developing mitigation strategies (Jüttner, Peck and Christopher, 2003). In this way, a contingency approach helps organizations minimize the effect of SC disruptions. In turn, successful efforts at SC risk MIT are expected to enhance SC ROB. Therefore, we hypothesize the following:

H4. MIT efforts directly and positively contribute to ROB in upstream/downstream SC organizations.

3.4. Organization Size

In many studies involving organizational performance, the size of the

organization has been shown to differentially influence the performance outcome (Zawawi, Wahab, Al Mamun, Ahmad and Fazal, 2017). Organizations are typically classified as small, medium, and large as a function of either the workforce size or financial measures, such as annual revenue or profitability. In the literature, smaller organizations have tended to find it more challenging to mitigate SC disruptions than larger organizations (Kumar, 2011; Skipper, Hanna and Gibson, 2010). Further, the type of industry can also play a role in firm performance as a function of organization size. For example, Fernández, Iglesias-Antelo, López-López, Rodríguez-Rey and Fernandez-Jardon (2019) found a difference based on firm effects (i.e., attributes of the organization) versus industry effects (e.g., service versus manufacturing). They report that firm effects were more prevalent in firm performance for small and large firms, while industry effects were more prevalent for medium-size firms. Consequently, organization size is included as a variable of interest in the current study.

IV. METHODOLOGY

4.1. Survey Development

To test the proposed model, an online survey was developed and delivered via Qualtrics. The target population consisted of mid-to-high level SC managers in different industry sectors.

As previously explained, the measures for RMO, IMP, IRM, ERM and MIT were adapted from the scale developed in the previous empirical study conducted by Dellana, Rowe and Liao (2022). On the other hand, the survey items for ROB were adapted from earlier empirical work by Brandon-Jones, Squire, Autry and Petersen (2014).

The orientation (RMO) items are intended to assess the opinions of managers regarding the culture of SC risk management in the organization. They reflect the shared values, beliefs, attitudes, and related behaviors within the organization. Top management must necessarily be supportive of this culture. This emerges from the belief that customers will be more satisfied if the organization is not compromised by disruptions, which can lead to competitive advantage. Further, a culture of risk management is characterized by a focus on and prioritizing of managing SC risks. A process improvement philosophy is fundamental to achieving process excellence, which includes the risk management process. The improvement (IMP) items reflect that philosophy. A mature and systematic risk management process that engages the firm's employees and SC partners should be the goal. As part of this effort, employees of the firm as well as those of SC partners should be trained in how to improve the risk management system. In the items related to internal risk management (IRM), the internal operations of the firm are considered part of but distinct from the risk efforts related to SC partners. Risk management efforts internal to the firm should be consistent with efforts focused outward. This reflects the quality management concept of internal customers. Employees are trained in risk management, and risk information is shared across the organization. Further, the integration of the risk management process is a focus for improvement leading to a high level of performance to minimize the impact of disruptions on the firm. The items related to external risk management (ERM) by way of collaboration incorporate both suppliers and customers. Communication as well as sharing risk-related information and costs are important aspects of effective SC collaboration. This extends to the engagement of partners in risk planning and reviewing the effectiveness of the risk management process. Risk mitigation (MIT) can take many forms based on the type of risk. The survey items generally cover planning for risk events by way of various approaches and analysis. Additionally, the effectiveness of the mitigation

process when a risk event occurs is also considered.

The robustness (ROB) construct items are intended to assess the degree to which the organization would be impacted by a SC disruption. Robustness suggests an organization can absorb disruptions. Thus, a robust organization should not have a substantial degradation of actions involved in meeting its obligations. These include the continuance of operations, fulfillment of customer demand, minimization of deviation from performance targets, and maintenance of all the various required functions. These statements are intended to gage the robustness construct from various perspectives.

The different items utilized a seven-point Likert scale where: 1 = 'Strongly Disagree', 4 = 'Neutral', and 7 = 'Strongly Agree'. The different survey items are presented in Table 1.

TABLE 1. SCALE ITEMS

Risk management orientation (RMO)
Please indicate the degree to which you agree or disagree with the following statements. (1 = 'Strongly Disagree' to 7 = 'Strongly Agree') RMO1. Our top management emphasizes the importance of managing risks in our supply chain. RMO2. In our organization we believe our customers are better served when we proactively manage supply chain risks. RMO3. In our organization we believe that managing risks in the supply chain makes us more competitive. RMO4. Managing risks in the supply chain is a top priority in our organization.
Internal risk management processes (IRM)
Please indicate the degree to which you agree or disagree with the following statements. (1 = 'Strongly Disagree' to 7 = 'Strongly Agree') IRM1. We routinely share risk-specific information across departments within our organization. IRM2. We make sure all employees in our organization have a good understanding of our internal risk management process. IRM3. Our organization exhibits a high degree of internal integration for risk management. IRM4. Our organization has a mature internal risk management process that ensures our internal operations are not easily disrupted.
External risk management processes (ERM)
Please indicate the degree to which you agree or disagree with the following statements. (1 = 'Strongly Disagree' to 7 = 'Strongly Agree') ERM1. We encourage our suppliers to use a structured risk management process (e.g., ISO 31000). ERM2. We typically involve our immediate supply chain partners in our risk planning and review process. ERM3. We typically share risk data with our supply chain partners.

ERM4. We typically share costs of risk impacts with our supply chain partners.
Improvement of risk management processes (IMP)
Please indicate the degree to which you agree or disagree with the following statements. (1 = 'Strongly Disagree' to 7 = 'Strongly Agree') IMP1. Our organization regularly provides risk management training to our employees. IMP2. Our organization regularly involves supply chain partners in risk management process improvement training. IMP3. Our organization involves supply chain partners in the improvement of the risk management process. IMP4. After a risk event occurs, our organization always employs a systematic review to improve our risk management process.
Supply chain risk mitigation (MIT)
Please indicate the degree to which you agree or disagree with the following statements. (1 = 'Strongly Disagree' to 7 = 'Strongly Agree') MIT1. We typically rank potential risks based on quantitative analysis. MIT2. We usually consider the difficulty of risk detection when planning for potential risks. MIT3. We often simulate risk events to assess our ability to respond effectively. MIT4. When a risk event occurs, we usually have a well-defined contingency plan available to reduce the impact of the event.
Supply chain robustness (ROB)
Please indicate the degree to which you agree or disagree with the following statements. (1 = 'Strongly Disagree' to 7 = 'Strongly Agree') ROB1. In the event of an unexpected disruption within our supply chain, operations would be able to continue. ROB2. In the event of an unexpected disruption within our supply chain, we would be able to meet customer demand. ROB3. In the event of an unexpected disruption within our supply chain, performance would not deviate significantly from targets. ROB4. In the event of an unexpected disruption within our supply chain, the supply chain would still be able to carry out its regular functions.

4.2. Data Collection

The survey was sent through Qualtrics to 4,698 contacts in the USA. The names and contact information of SC managers across many industries in the USA were obtained from a USA-based digital marketing services company.

A total of 154 usable responses were obtained, (representing a response rate of 3.4%), while 117 respondents identified their companies as either upstream or downstream SC organizations. Multiple factors likely account for the relatively low response rate. First, participation in the research study was voluntary. Second, a speed check and an attention check truncated survey completion for invalid responses. Also, only one distribution channel was used (social media and professional networks were not utilized). Finally, the research study targeted front-line, middle-level, and top-level SC managers, who often have very demanding schedules. Survey demographics are presented in Table 2.

TABLE 2. SURVEY DEMOGRAPHICS

Respondent Current Position	No.
Top level supply chain managers	26
Mid-level supply chain managers	44
Front-line supply chain managers	34
Non-manager professionals	13
Total	117
Organization Size	**No.**
100 employees or less	30
More than 100 to 1,000 employees	38
More than 1,000 to 10,000 employees	26
More than 10,000 employees	23
Total	117
Industry	**No.**
Downstream Supply Chain:	
Healthcare Services	25
Logistics/Transportation/Distribution/Warehousing	22
Retail Trade	10
Wholesale Trade	16
Subtotal	73
Upstream Supply Chain:	
Chemicals/Plastics Manufacturing	4
Components Manufacturing (Electrical/Electronic, Industrial)	8
Final Assembler (Aerospace Products, Automotive Products, Electronic Products, Equipment/Machinery, Medical Products)	12
Food/Beverage/Tobacco Products	9
Pharmaceutical Products	7
Software Development	4
Subtotal	44

Respondents included top-, mid-, and entry-level SC professionals. More specifically, mid-level managers made up the majority (40%) of the study participants, top-level SC managers made up 20% of the respondents, while entry-level managers represented 30% of the participants. 10% of the participants were non-manager professionals (buyers, planners, analysts, etc.).

The number of employees was used to characterize the size of the organizations. Small and medium businesses (SMBs) (i.e., organizations with 100 employees or less) represented 26% of the participants, small and medium enterprises (SMEs) (i.e., organizations that had between 100 and 1,000 employees) accounted for 32%, while large enterprises (i.e., organizations with more than 1,000 employees) represented 42% of the sample (49 out of 117).

Several different categories were employed to identify the respondents' business sectors. Table 2 presents a detailed breakdown

of the survey participants by sector. In this respect, 38% of the responses came from upstream SC firms, while the remaining 62% came from downstream SC firms. Scale item descriptive statistics for both the upstream and the downstream groups are presented in Table 3.

TABLE 3. SCALE ITEMS DESCRIPTIVE STATISTICS

	Upstream (n = 44)		Downstream (n = 73)	
Item	*Mean*	*Std. Dev.*	*Mean*	*Std. Dev.*
RMO1	5.932	1.232	5.767	1.176
RMO2	6.250	1.090	6.205	1.059
RMO3	5.932	1.355	6.000	1.216
RMO4	5.250	1.597	5.247	1.560
IRM1	5.227	1.663	5.301	1.411
IRM2	4.977	1.777	5.082	1.450
IRM3	4.818	1.709	4.808	1.644
IRM4	5.591	1.337	5.274	1.387
IMP1	4.295	1.659	4.384	1.795
IMP2	4.091	1.607	4.096	1.753
IMP3	4.318	1.549	4.301	1.685
IMP4	4.818	1.527	5.027	1.630
ERM1	4.727	1.572	4.466	1.622
ERM2	5.023	1.422	4.658	1.581
ERM3	4.886	1.434	4.507	1.509
ERM4	4.545	1.499	4.452	1.517
MIT1	4.750	1.448	4.452	1.562
MIT2	4.886	1.570	4.712	1.592
MIT3	4.159	1.731	4.068	1.801
MIT4	4.886	1.584	4.726	1.616
ROB1	5.386	1.071	5.822	0.881
ROB2	5.273	1.008	5.356	1.186
ROB3	4.614	1.385	4.986	1.438
ROB4	4.795	1.289	5.329	1.206

4.3. Non-Response Bias

Early versus late respondents were compared to evaluate non-response bias (Armstrong and Overton, 1977). The first and last quartiles of survey responses were tested for differences in construct means. The results indicated that there were no significant differences between the mean construct responses obtained from the first and last quartiles across all six research constructs (all the resulting p-values were larger than 0.05). The test results therefore suggested that non-response bias was not a threat to the integrity of the survey data.

4.4. Common Method Bias (CMB)

Harman's single factor test was used to assess the potential for common method bias (CMB) (Harman, 1976; Podsakoff, MacKenzie, Lee and Podsakoff, 2003). A factor analysis was performed using all survey items included in the study to determine if most of the variance in the model was accounted for by one general factor. Since the percentage of variance explained by a single factor was less than 50 percent (the percentage of variance extracted by a single factor was equal to 45.6%), CMB was not deemed an issue.

4.5. Measurement Model

The assessment of the measurement model included an analysis of the individual indicators' reliability, the research constructs' internal consistency, as well as the constructs' convergent and discriminant validity.

As previously explained, two research groups (upstream and downstream SC organizations) were identified and analyzed to determine whether the relationships among the constructs differ by position in the SC. However, performing group comparisons can lead to misleading conclusions unless the invariance of the study measures is established (Hair, Sarstedt, Ringle and Gudergan, 2018). Measurement invariance is therefore a significant issue when performing multigroup analyses.

In this study, the invariance of the study measures was established using the Measurement Invariance of Composite Models (MICOM) procedure (Henseler, Ringle and Sarstedt, 2016). This three-step procedure allows analyzing measurement invariance before undertaking multigroup comparisons.

In the first step, configural invariance was automatically established by running the same model set-up with the same settings for both groups. In step two, permutation-based confidence intervals were generated to determine if any of the composites had a correlation between the two groups that was significantly lower than one. Since this was not the case, compositional invariance was established, confirming the different composites did not differ significantly across both groups. Finally, in the third step, permutation-based confidence intervals were developed for all the composites' means and variances to determine whether the mean and variance of each composite differed significantly across the two groups. The findings indicated that the means and variances did not differ significantly across groups. As a result, full measurement invariance was established, supporting both multigroup analysis and pooled data analysis.

4.6. Item Reliability, Construct Reliability and Convergent Validity

Outer loadings were examined to evaluate the reliability of the survey items. In this respect, the outer loadings of the different individual indicators were significant at the 0.001 level. Furthermore, all survey items had loadings above the suggested cutoff of 0.70 (Hair, Hult, Ringle and Sarstedt, 2017). Overall, the results indicate an acceptable reliability level for the different indicators.

The internal consistency of the research constructs was evaluated next using Cronbach's α, reliability coefficient ρ_A (Dijkstra and Henseler, 2015) as well as Composite Reliability estimates. As shown in Table 4, all values were above the 0.70 cut-off recommended by Hair, Hult, Ringle and Sarstedt (2017), suggesting an adequate level of internal consistency across the six constructs included in the study.

Finally, Average Variance Extracted (AVE) estimates were used to assess convergent validity. The AVE values show that all six constructs explain more than half of the variance of their indicators, indicating acceptable convergent validity levels across all six constructs.

TABLE 4. CONSTRUCT RELIABILITY AND CONVERGENT VALIDITY

Construct	Cronbach's α	ρ_A	Composite Reliability (CR)	Average Variance Extracted (AVE)
RMO	0.902	0.938	0.931	0.770
IRM	0.891	0.904	0.925	0.756
IMP	0.906	0.908	0.935	0.782
ERM	0.888	0.894	0.923	0.750
MIT	0.889	0.897	0.923	0.751
ROB	0.901	0.917	0.930	0.770

4.7. Discriminant Validity

Next, the constructs' discriminant validity was assessed. The Fornell-Larcker criterion was used to determine whether the constructs met the conditions for discriminant validity (Fornell and Larcker, 1981). As displayed in Table 5, the square roots of the AVEs for each of the six constructs were higher than the correlations of the constructs with the remaining latent variables included in the proposed model. The results of this portion of the analysis suggest that all six constructs included in the study represent unique concepts.

TABLE 5. FORNELL-LARCKER CRITERION

Construct	RMO	IRM	IMP	ERM	MIT	ROB
RMO	*0.878*					
IRM	0.535	*0.870*				
IMP	0.562	0.817	*0.884*			
ERM	0.565	0.720	0.725	*0.866*		
MIT	0.542	0.812	0.831	0.702	*0.866*	
ROB	0.401	0.482	0.455	0.388	0.446	*0.877*

Note: Square root of the AVE on diagonals in italics.

4.8. Collinearity

The measurement model was also assessed for potential collinearity issues by examining Variance Inflation Factor (VIF) values. All the estimated outer VIF values were smaller than five, while the different inner VIF values were smaller than three. Since all the VIF values were below the maximum threshold of five recommended by Hair, Hult, Ringle and Sarstedt (2017), collinearity was not deemed an issue.

V. RESULTS

5.1. Hypotheses Testing

The research hypotheses were tested next. The proposed structural equation model was assessed using SmartPLS, a popular PLS-SEM software package (Ringle, Wende and Becker, 2015). Regarding the relatively small size of the samples used in our study, Beuckelaer and Wagner (2012) had originally

established that small sample research in the field of SCM is fairly common. Past research has shown that PLS-SEM performs well with small sample sizes (Esposito Vinzi, Trinchera and Amato, 2010; Hwang, Malhotra, Kim, Tomiuk and Hong, 2010). Based on the criteria established by Hair, Hult, Ringle and Sarstedt (2017), our study meets the minimum PLS-SEM sample size recommendations.

The two subsamples (the sample of 44 upstream SC firms and the sample of 73 downstream SC firms) were used to test the hypotheses and determine whether the relationships among the constructs differ by position in the SC. A bootstrap resampling method (5,000 resamples) was used to estimate the level of significance of the standardized path coefficients. The results are presented in Table 6.

TABLE 6. SUMMARY OF HYPOTHESES TESTING

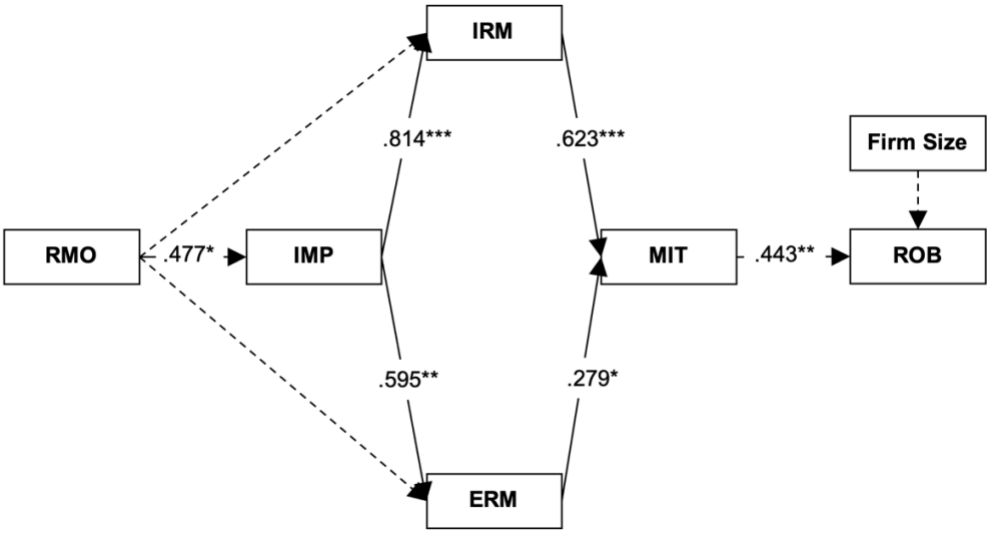
	Upstream			Downstream		
Path	*St. Weight*	*p*	*Conclusion*	*St. Weight*	*p*	*Conclusion*
H1a: RMO → IRM	0.038	0.804	Not Supported	0.151	0.186	Not Supported
H1b: RMO → IMP	0.477	0.011	Supported	0.703	<0.001	Supported
H1c: RMO → ERM	0.218	0.224	Not Supported	0.284	0.029	Supported
H2a: IMP → IRM	0.814	<0.001	Supported	0.735	<0.001	Supported
H2b: IMP → ERM	0.595	0.001	Supported	0.553	<0.001	Supported
H3a: IRM → MIT	0.623	<0.001	Supported	0.653	<0.001	Supported
H3b: ERM → MIT	0.279	0.038	Supported	0.276	0.005	Supported
H4: MIT → ROB	0.443	0.001	Supported	0.502	<0.001	Supported

In the case of upstream SC organizations, RMO was found to have a significant direct positive effect on IMP. The findings therefore provide support for H1b at the 0.05 level of significance. On the other hand, RMO was found to have an insignificant direct positive effect on both IRM and ERM. Thus, H1a and H1c are not supported for the upstream SC sample. IMP was found to have a statistically significant positive effect on both IRM and ERM. The findings thus provide support for H2a and H2b at the 0.001 level of significance in upstream SC firms.

With respect to MIT, both IRM and ERM were found to have a significant positive effect in upstream SC firms. H3a and is therefore supported at the 0.001 level of significance, while H3b is supported at the 0.05 level of significance. Finally, MIT was found to have a statistically significant positive effect on ROB (providing support for H4 at the 0.001 level), while the control variable organization size was not found to be significant at the 0.05 level in the case of upstream SC firms. The model findings for the upstream SC sample are summarized in Figure 2 below.

In the downstream SC sample, RMO was found to have an insignificant direct positive effect on IRM. H1a is therefore not supported. On the other hand, RMO was found to have a significant direct positive effect on both IMP and ERM. The findings thus provide support for H1b at the 0.001 significance level, while H1c is supported at the 0.05 level of significance. IMP was found to have a significant direct positive effect on both IRM and ERM in downstream SC firms. The findings therefore provide support for H2a and H2b at the 0.001 level of significance.

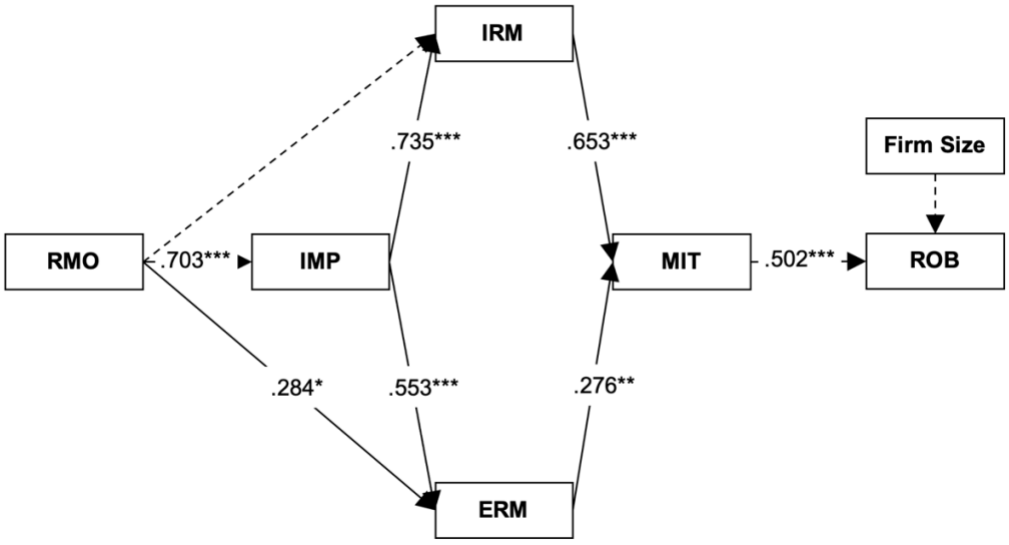
FIGURE 2. UPSTREAM SC RESULTS



Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Similarly, IRM and ERM were found to have a significant direct positive effect on MIT in the downstream SC group. Thus, H3a is supported for the downstream SC group at the 0.001 significance level, while H3b is supported at the 0.01 level of significance. Finally, MIT was found to have a significant positive effect on ROB in downstream SC firms (providing support for H4 at the 0.001 level), while the control variable firm size was not significant at the 0.05 level. Figure 3 summarizes the model findings for the downstream SC sample.

FIGURE 3. DOWNSTREAM SC RESULTS



Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.2. Mediation Analyses

Based on the results obtained from the two groups, the mediating role of IMP in the links between RMO and both IRM and ERM was examined in more detail. The results of the mediation analyses are summarized in Table 7.

TABLE 7. SUMMARY OF MEDIATION ANALYSIS

Effect	Upstream				Downstream			
	Direct	*Indirect*	*Total*	*Conclusion*	*Direct*	*Indirect*	*Total*	*Conclusion*
RMO → IRM	0.038	0.388**	0.426*	Full Mediation	0.151	0.516***	0.667***	Full Mediation
RMO → ERM	0.218	0.283**	0.501**	Full Mediation	0.284*	0.389***	0.672***	Partial Mediation

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

In upstream SC firms, the findings indicate that IMP fully mediates the link between RMO and both IRM and ERM. Statistically significant indirect effects coupled with insignificant direct effects suggest that efforts to effectively improve risk management processes help explain a considerable portion of the effect of RMO on both internal and external risk management processes and, ultimately, on SC robustness. Overall, the empirical results corroborate the crucial role of CI of risk management processes in upstream SC organizations.

In the case of downstream SC organizations, the results presented in Table 7 indicate that IMP fully mediates the link between RMO and IRM. On the other hand, the significant direct effect of RMO on ERM indicates that CI of risk management processes only partially explains the impact of an orientation towards risk management on external risk management processes in downstream SC firms.

VI. DISCUSSION

The purpose of this research was to explore the relationships among different dimensions of supply chain risk management maturity (SCRMM) and SC robustness (ROB) in both upstream and downstream SC firms. To accomplish the research objective, a structural equation model was proposed and tested.

The results indicate that the SCRMM framework positively influences ROB. Also, for both upstream and downstream organizations, a higher level of risk management orientation (RMO) is associated with greater improvement of risk management processes (IMP). In addition, IMP contributes positively to both internal risk management (IRM) and external risk management (ERM) processes in upstream and downstream SC firms. The relationship between risk management orientation and both IRM and ERM processes is fully mediated by IMP in upstream SC organizations. In the case of downstream firms, the relationship between RMO and IRM is fully mediated by IMP, while the relationship between RMO and ERM is only partially mediated. In both research groups, IRM and ERM processes have a significant direct positive effect on SC risk mitigation efforts and, ultimately, on SC robustness.

Overall, the study results indicate that the model constructs help predict robustness throughout the SC. Therefore, SC managers can feel confident that the framework and dimensions of SCRMM contribute to SC robustness and can enhance SC robustness by implementing a systematic approach to risk

management. The empirical findings also demonstrate that both upstream and downstream organizations can leverage risk management process improvement efforts that ultimately have a positive impact on SC robustness, suggesting that companies can benefit from a culture of CI, regardless of their position in the SC.

6.1. Implications for Theory and Practice

The first contribution of this study to the SC risk management literature is characterizing the role of IMP in SC risk management. IMP processes involve activities of continuous learning, training, and systematic review of risk management through collaboration with SC partners and the development of a strong governance mechanism. Risk management is not a one-time activity, but a continuous process that requires constant monitoring, evaluation, and improvement. The mediation effect of IMP on the relationship between RMO and both IRM and ERM found in this study reveal the value of continuous process improvement in SC risk management. An IMP system is important to knowledge creation through critical internal analysis and experience and knowledge transfer through leveraging knowledge across SC boundaries. IMP should be a cross-functional effort with participants representing every node of a value chain, ranging from line managers to suppliers.

Second, from a theory perspective, the SCRMM scale of Dellana, Rowe and Liao (2022) shows a positive relationship with the measure of SC robustness, which appears to support the value of this scale. Also, given the differences observed in the mediation analysis, the relationship of SC position or industry type on SCRMM supports the applicability of contingency theory to SCRMM and its associated practices. This finding also supports prior research that found differences in quality maturity and SC risk maturity by SC position or industry (Dellana and Kros, 2014; Florio, 2017). Particularly, we demonstrate a unique perspective on SC risk management processes and robustness regarding the firm's position upstream or downstream in the SC. IMP represents a catalyst between a firm's RMO and both IRM and ERM. Specifically, the improvement of risk management processes aligns with the dynamic capability perspective, which posits that risk management constitutes a dynamic capability (Nair, Rustambekov, McShane, and Fainshmidt, 2014; Nel, 2024). Firms must continuously adapt and enhance their processes to effectively manage risks, both internally and in collaboration with SC partners. Implementation of CI can create an awareness of innovation, learning and knowledge sharing, which in turn enables an enduring effort in process optimization and external collaboration, and risk management process evolution over time to meet new challenges (Kwak, Seo and Mason, 2018; Eichholz, Hoffmann and Schwering, 2024). The improvement of risk management processes plays a pivotal role in translating risk management culture into actionable strategies by fostering a proactive and systematic approach throughout the SC.

Although the culture of CI helps explain the model relationships in both the upstream SC and the downstream SC, the mediating effect of CI in the risk management process differs subtly. Firms in the upstream SC, primarily manufacturing and sourcing-focused, are functional and mechanistic, characterized by relatively stable and structured processes. The study findings suggest upstream SC managers may benefit more from an IMP system primarily because these processes are easier to implement and manage with greater consistency and predictability in both internal and external risk management processes. While the proposed framework offers significant potential for enhancing SC robustness, its successful implementation is not without challenges. For upstream members of the SC, it starts with the orientation of the firm towards SC risk management. This may require strengthening a

culture of risk management for firms that are weak in this domain. This is no small task as it will require the development of shared values, attitudes, and behaviors within the firm and its SC partners to facilitate collaborative management and prioritization of SC risks. Add to this the culture of CI and this creates a further challenge for firms that do not currently embrace this type of culture or lack maturity in its implementation. A mature culture of CI requires a corporate philosophy with related language and tools, both quantitative and qualitative, that can take years to implement let alone reach a high level of maturity. Clearly, managers in firms that are weak in these cultural domains will benefit from outside training and possibly expert consulting support. Employees will also benefit from training in risk management and tools such as lean-six sigma.

For the downstream SC members, the challenges just discussed will likely be even greater regarding adoption or strengthening of the prerequisite cultures of risk management and CI. This is partly because the firms further downstream in the SC tend to become more service focused as they get closer to the end consumer. This adds further complexity. For downstream SC members that feed their distributors, wholesalers, and retailers, other major challenges associated with the complexity relate to customer expectations for faster delivery times and flexible order fulfillment options (Truong and Hara, 2018). Dealing with these challenges will require a strong internal risk management process that more consistently identifies those risks and designs appropriate controls (Duhamel, Carbone and Moatti, 2016). Because firms positioned in the downstream SC have become more closely tied to customer dependencies and unpredictable customer behaviors, they experience more volatility of the market and risks from poor forecasting. The full mediation effect suggests that beyond RMO, IMP should attract the attention of downstream firms seeking to optimize their internal risk management process. However, the partial mediation effect of IMP on the relationship between RMO and ERM highlights the importance of a dual approach to address external collaboration effectively. Firms should focus on implementing systems for CI while simultaneously strengthening their risk management orientation.

We encourage managers to evaluate and improve their organizations using a risk management maturity scale such as that of Dellana, Liao, and Rowe (2022). In that study, the relative SCRMM performance was analyzed using cluster analysis, resulting in three organizational groupings characterized as top performers, middle performers, and low performers. The groups were studied by the SCRMM dimensions of SC Risk Management Orientation, Organization Internal Risk Management, Improvement of Risk Management Processes (IMP in the current study), SC Risk Management Collaboration (ERM in the current study), and SC Risk Mitigation. The relative ranking of the dimensions was consistent for Orientation, Internal, and Mitigation, with Orientation toward risk clearly at the top. However, the relationships switched for Improvement and Collaboration. Firms with high SCRMM placed greater emphasis on Improvement (i.e., IMP) than on Collaboration (i.e., ERM). A recent study of SCRMM by Guerra, de Souza, Pires, and de Sa (2024) involved interviews with six aerospace companies. Their approach involved analyzing eight dimensions, including but not limited to: leadership, process formalization, emphasis, and involvement of SC members. Improvement of RM processes (IMP) was not directly addressed in the study. Results from the study found that leadership, formalization, and emphasis, which relate to Orientation in the current study, scored near the top. Involvement, which relates to ERM, scored near the bottom. While it is not possible to draw direct comparisons between the two studies, their results appear to be consistent. Orientation

toward risk is vital to developing SCRMM. IMP is more important than ERM in firms that achieve high SCRMM. Further, a culture of SC risk management (i.e., risk management orientation) is associated with improved firm performance (Akbar and Isfianadewi, 2023; Bahrami and Shokouyar, 2022). These empirical observations should inform and help guide managers in their efforts to improve and mature their risk management systems, which can enhance their competitive advantage.

It was anticipated that firm size might also play a role given the prior research on firm size and performance (Zawawi, Wahab, Al Mamun, Ahmad and Fazal, 2017). However, this variable did not emerge as a differentiator. It should be noted that only 30 out of the 117 firms studied were classified as small (100 or fewer employees) compared to 49 firms classified as large (more than 1000 employees). It is possible that the relatively greater number of larger firms unduly influenced the outcome. Although no significant effects of size were found, the study findings suggest that even smaller SC organizations, who often have greater resource constraints than larger SC firms, can benefit from a culture of risk management CI.

Empirical studies regarding the effect of risk management maturity on SC robustness are rather limited. This is one of the first studies to characterize the benefits of using mature structured approaches for risk management in both upstream and downstream SC organizations. Overall, the empirical results advance knowledge of how firms address the challenging issue of risk management in the SC, while offering a firm-level SC risk management framework for managerial decision-making.

VII. RESEARCH LIMITATIONS AND FUTURE RESEARCH OPPORTUNITIES

The first limitation in this research is related to the issue that all the survey participants were from the United States. Regional/national cultural influence, regulatory uncertainty, and economic environment variability can lead to different perceptions on SCRMM and execution of a risk management system. Some risk management maturity practices may not easily translate to other geographical contexts. For example, a culture emphasizing innovation and technology adoption may drive different risk management practices compared to regions with slower technology integration or differing values regarding innovation (Chowdhury, Rodriguez-Espindola, Dey and Budhwar, 2023). This issue limits the generalizability of the study findings to different countries or regions. Therefore, empirical research on how the different dimensions of SCRMM might affect SC robustness in upstream and downstream SC organizations should be expanded to additional countries and/or geographic regions. Although the sample size was adequate, including a larger number of respondents in future studies could enhance the robustness of the findings as well as enable a more detailed analysis of SCRMM by business sector (e.g., healthcare services).

An additional limitation is related to the fact that a dynamic process was assessed at a single point in time. In this sense, a longitudinal study would allow researchers to analyze additional issues such as the impact of the different dimensions of SCRMM on SC robustness over time. Regarding the scale items used in the study, the items represented managerial perceptions of SCRMM and SC robustness. While items representing subjective perceptions have been shown to satisfy the requirements of reliability and validity in construct measurement (Ketokivi and Schroeder, 2004), the use of actual SC performance metrics related to the constructs in our study would be desirable.

One final limitation that should be discussed is the relatively low response rate. Even though the study results suggested that non-response bias did not compromise the integrity of the survey data, the low response

rate may limit the applicability of the study findings to the broader population. To address this limitation, future SCRMM research should consider enhancing the distribution of the survey instrument by distributing the survey through more than one channel (e.g., email, social media, and professional networks). Despite these limitations, the findings presented in this study add to the increasingly important topic of SCRM.

REFERENCES

Abeysekara, N., Wang, H., & Kuruppuarachchi, D. (2019). Effect of Supply-Chain Resilience on Firm Performance and Competitive Advantage: A Study of the Sri Lankan Apparel Industry. *Business Process Management Journal*, 25(7), 1673-1695.

Akbar, H. M. & Isfianadewi, D. (2023). The role of supply chain resilience to relationships supply chain risk management culture and firm performance during disruption. *Research in Business & Social Science*, 12(2), 643-652.

Akın Ateş, M., Suurmond, R., Luzzini, D. & Krause, D. (2022). Order from Chaos: A Meta-Analysis of Supply Chain Complexity and Firm Performance. *Journal of Supply Chain Management*, 58(1), 3-30.

Alvarenga, M. Z., de Oliveira, M. P. V., & de Oliveira, T. A. G. F. (2023). The Impact of Using Digital Technologies on Supply Chain Resilience and Robustness: The Role of Memory under the Covid-19 Outbreak. *Supply Chain Management: An International Journal*, 28(5), 825-842.

Armstrong, J. S. & Overton, T. S. (1977). Estimating Nonresponse Bias in Mail Surveys. *Journal of Marketing Research*, 14(3), 396-402.

Azadegan, A., Mellat Parast, M., Lucianetti, L., Nishant, R., & Blackhurst, J. (2020). Supply Chain Disruptions and Business Continuity: An Empirical Assessment. *Decision Sciences*, 51(1), 38-73.

Bahrami, M. & Shokouhyar, S. (2022). The role of big data analytics capabilities in bolstering supply chain resilience and firm performance: a dynamic capability view. *Information Technology & People*, 35(5), 1621-1651.

Bendul, J. C. & Skorna, A. C. (2016). Exploring Impact Factors of Shippers' Risk Prevention Activities: A European Survey in Transportation. *Transportation Research Part E: Logistics and Transportation Review*, 90(June), 206-223.

Beuckelaer, A. D. & Wagner, S. M. (2012). Small Sample Surveys: Increasing Rigor in Supply Chain Management Research. *International Journal of Physical Distribution & Logistics Management*, 42(7), 615-639.

Birkie, S. E., Trucco, P., & Fernandez Campos, P. (2017). Effectiveness of Resilience Capabilities in Mitigating Disruptions: Leveraging on Supply Chain Structural Complexity. *Supply Chain Management: An International Journal*, 22(6), 506-521.

Bode, C., Wagner, S. M., Petersen, K. J., & Ellram, L. M. (2011). Understanding Responses to Supply Chain Disruptions: Insights from Information Processing and Resource Dependence Perspectives. *Academy of Management Journal*, 54(4), 833-856.

Bouranta, N. & Psomas, E. (2017). A Comparative Analysis of Competitive Priorities and Business Performance between Manufacturing and Service

Firms. *International Journal of Productivity and Performance Management*, 66(7), 914-931.

Brandon-Jones, E., Squire, B., Autry, C. W., & Petersen, K. J. (2014). A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness. *Journal of Supply Chain Management*, 50(3), 55-73.

Chiarini, A. (2017). Risk-Based Thinking According to Iso 9001: 2015 Standard and the Risk Sources European Manufacturing Smes Intend to Manage. *The TQM Journal*, 29(2), 310-323.

Choi, T. Y. & Rungtusanatham, M. (1999). Comparison of Quality Management Practices: Across the Supply Chain and Industries. *Journal of Supply Chain Management*, 35(4), 20-27.

Chowdhury, M. M. H. & Quaddus, M. (2016). Supply Chain Readiness, Response and Recovery for Resilience. *Supply Chain Management: An International Journal*, 21(6), 709-731.

Chowdhury, S., Rodriguez-Espindola, O., Dey, P., & Budhwar, P. (2023). Blockchain technology adoption for managing risks in operations and supply chain management: evidence from the UK. *Annals of Operations Research*, 327, 539-574.

D'Amato, I. & Papadimitriou, T. (2013). Legitimate vs Illegitimate: The Luxury Supply Chain and Its Doppelganger. *International Journal of Retail & Distribution Management*, 41(11/12), 986-1007.

Dellana, S., Kros, J. F., Falasca, M., & Rowe, W. J. (2019). Risk Management Integration and Supply Chain Performance in Iso 9001-Certified and Non-Certified Firms. *International Journal of Productivity and Performance Management*, 69(6), 1205-1225.

Dellana, S., Rowe, W. J., & Liao, Y. (2022). A Scale for Measuring Organizational Risk Management Maturity in the Supply Chain. *Benchmarking: An International Journal*, 29(3), 905-930.

Dellana, S. A. & Kros, J. F. (2014). An Exploration of Quality Management Practices, Perceptions and Program Maturity in the Supply Chain. *International Journal of Operations & Production Management*, 34(6), 786-806.

Dijkstra, T. K. & Henseler, J. (2015). Consistent Partial Least Squares Path Modeling. *MIS Quarterly*, 39(2), 297-316.

Duhamel, F., Carbone, V., & Moatti, V. (2016). The Impact of Internal and External Collaboration on the Performance of Supply Chain Risk Management. *International Journal of Logistics Systems and Management*, 23(4), 534-557.

Eichholz, J., Hoffmann, N., & Schwering, A. (2024). The Role of Risk Management Orientation and the Planning Function of Budgeting in Enhancing Organizational Resilience and its Effect on Competitive Advantages During Times of Crises. *Journal of Management Control*, 35, 17-58.

El Baz, J. & Ruel, S. (2021). Can Supply Chain Risk Management Practices Mitigate the Disruption Impacts on Supply Chains' Resilience and Robustness? Evidence from an Empirical Survey in a Covid-19 Outbreak Era. *International Journal of Production Economics*, 233, 107972.

Esposito Vinzi, V., Trinchera, L., & Amato, S. (2010). PLS Path Modeling: From Foundations to Recent Developments and Open Issues for Model Assessment and Improvement. In Esposito Vinzi, V., Chin, W., Henseler, J., & Wang, H. (eds.), *Handbook of Partial Least*

*Square*s (pp. 47-82). Berlin, Heidelberg, Germany: Springer.

Fan, H., Li, G., Sun, H., & Cheng, T. C. E. (2017). An Information Processing Perspective on Supply Chain Risk Management: Antecedents, Mechanism, and Consequences. *International Journal of Production Economics*, 185(March), 63-75.

Fernández, E., Iglesias-Antelo, S., López-López, V., Rodríguez-Rey, M., & Fernandez-Jardon, C. M. (2019). Firm and Industry Effects on Small, Medium-Sized and Large Firms' Performance. *BRQ Business Research Quarterly*, 22(1), 25-35.

Florio, T. (2017). Exploring the Relationship of Supply Chain Risk Management to Quality Management. In Kounis, L. D. (ed.), *Quality Control and Assurance - an Ancient Greek Term Re-Mastered* (pp. 135-154). Rijeka, Croatia: InTech.

Fornell, C. & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, 18(1), 39-50.

Glushkova, S., Lomakina, O., & Sakulyeva, T. (2019). The Economy of Developing Countries in the Context of Globalization: Global Supply Chain Management. *International Journal of Supply Chain Management*, 8(1), 876-884.

Guerra, J. H. L., de Souza, F. B., Pires, S. R. I., & de Sa, A. L. B. (2024). A maturity model for supply chain risk management. *Supply Chain Management: An International Journal*, 29(1), 114-136.

Hair, J. F., Hult, G. T. M., Ringle, C., & Sarstedt, M. (2017). *A Primer on Partial Least Squares Structural Equation Modeling (Pls-Sem)* (2nd ed.). Los Angeles, CA: SAGE Publications.

Hair, J. F., Sarstedt, M., Ringle, C. M., & Gudergan, S. P. (2018). *Advanced Issues in Partial Least Squares Structural Equation Modeling.* Thousand Oaks, CA: SAGE Publications.

Harman, H. H. (1976). *Modern Factor Analysis* (3rd ed.). Chicago, IL: University of Chicago Press.

Henseler, J., Ringle, C. M., & Sarstedt, M. (2016). Testing Measurement Invariance of Composites Using Partial Least Squares. *International Marketing Review*, 33(3), 405-431.

Ho, W., Zheng, T., Yildiz, H., & Talluri, S. (2015). Supply Chain Risk Management: A Literature Review. *International Journal of Production Research*, 53(16), 5031-5069.

Hofer, C. W. (1975). Toward a Contingency Theory of Business Strategy. *Academy of Management Journal*, 18(4), 784-810.

Huo, B., Han, Z., & Prajogo, D. (2016). Antecedents and Consequences of Supply Chain Information Integration: A Resource-Based View. *Supply Chain Management: An International Journal*, 21(6), 661-677.

Hwang, H., Malhotra, N. K., Kim, Y., Tomiuk, M. A., & Hong, S. (2010). A Comparative Study on Parameter Recovery of Three Approaches to Structural Equation Modeling. *Journal of Marketing Research*, 47(4), 699-712.

International Organization for Standardization (2018). *Iso 31000:2018 Risk Management – Guidelines*. Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:31000:ed-2:v1:en:ed%E2%80%901:v1

Jüttner, U., Peck, H., & Christopher, M. (2003). Supply Chain Risk Management: Outlining an Agenda for Future Research. *International Journal*

of Logistics: Research and Applications, 6(4), 197-210.

Ketokivi, M. A. & Schroeder, R.G. (2004). Perceptual Measures of Performance: Fact or Fiction? *Journal of Operations Management*, 22(3), 247-264.

Kumar, S. (2011). Managing Risks in a Relief Supply Chain in the Wake of an Adverse Event. *OR Insight*, 24(2), 131-157.

Kwak, D. W., Seo, Y. J., & Mason, R. (2018). Investigating the Relationship Between Supply Chain Innovation, Risk Management Capabilities and Competitive Advantage in Global Supply Chains. *International Journal of Operations and Production Management*, 38(1), 2-21.

Liu, H. & Wei, S. (2022). Leveraging Supply Chain Disruption Orientation for Resilience: The Roles of Supply Chain Risk Management Practices and Analytics Capability. *International Journal of Physical Distribution & Logistics Management*, 52(9/10), 771-790.

Martínez-Sánchez, A., Vela-Jiménez, M. J., Pérez-Pérez, M., & de-Luis-Carnicer, P. (2008). Workplace Flexibility and Innovation: The Moderator Effect of Inter-Organizational Cooperation. *Personnel Review*, 37(6), 647-665.

Mishra, D., Sharma, R., Kumar, S., & Dubey, R. (2016). Bridging and Buffering: Strategies for Mitigating Supply Risk and Improving Supply Chain Performance. *International Journal of Production Economics*, 180, 183-197.

Mwangola, W. & Bridges, T. (2018). Conceptualizing Supply Disruption Management: Organizational and Inter-Organizational Influences. *Journal of Supply Chain and Operations Management*, 16(2), 198-218.

Nair, A., Rustambekov, E., McShane, M., & Fainschmidt, S. (2014). Enterprise Risk Management as a Dynamic Capability: A Test of its Effectiveness During a Crisis. *Managerial and Decision Economics*, 35, 555-566.

Nel, J. D. (2024). The Role of Supply Chain Risk Mitigation Strategies to Managemen Supply Cahin Disruptions. *Journal of Transport and Supply Chain Management*, 18, a1035.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies. *Journal of Applied Psychology*, 88(5), 879-903.

Pournader, M., Kach, A., & Talluri, S. (2020). A Review of the Existing and Emerging Topics in the Supply Chain Risk Management Literature. *Decision Sciences*, 51(4), 867-919.

Rahman, S. U. (2006). Quality Management in Logistics: An Examination of Industry Practices. *Supply Chain Management: An International Journal*, 11(3), 233-240.

Regattieri, A., Bartolini, A., Cima, M., Fanti, M. G., & Lauritano, D. (2018). An Innovative Procedure for Introducing the Lean Concept into the Internal Drug Supply Chain of a Hospital. *The TQM Journal*, 30(6), 717-731.

Ringle, C. M., Wende, S., & Becker, J.-M. (2015). *Smartpls 3*. Boenningstedt, Germany: SmartPLS GmbH.

Shafiq, A. & Johnson, P. F. (2020). Managing Supply Risks for Low-Cost Country Sourcing: The Mediating Role of Purchasing Teams and Implications for Firm Performance. *Journal of Supply Chain and Operations Management*, 18(2), 274-296.

Skipper, J. B., Hanna, J. B., & Gibson, B. J. (2010). Alabama Power Response to Katrina: Managing a Severe Service Supply Chain Disruption. *Journal of*

the International Academy for Case Studies, 16(1), 21-31.

Sun, Y. & Varshney, S. (2023). An Optimization Approach to Time-Segmented Regression with Application on Capturing the Impact of Supply Chain Disruption on Financial Markets. *Journal of Supply Chain and Operations Management*, 21(1), 24-27.

Swanson, D., Goel, L., Francisco, K., & Stock, J. (2018). An Analysis of Supply Chain Management Research by Topic. *Supply Chain Management: An International Journal*, 12(3), 100-116.

Tachizawa, M. E. & Wong, C. Y. (2014). Towards a Theory of Multi-Tier Sustainable Supply Chains: A Systematic Literature Review. *Supply Chain Management: An International Journal*, 19(5/6), 643-663.

Talluri, S. S., Kull, T. J., Yildiz, H., & Yoon, J. (2013). Assessing the Efficiency of Risk Mitigation Strategies in Supply Chains. *Journal of Business Logistics*, 34(4), 253-269.

Terziovski, M. & Hermel, P. (2011). The Role of Quality Management Practice in the Performance of Integrated Supply Chains: A Multiple Cross-Case Analysis. *Quality Management Journal*, 18(2), 10-25.

Truong, H. Q. & Hara, Y. Supply Chain Risk Management: Manufacturing- and Service-Oriented Firms. *Journal of Manufacturing Technology Management*, 29(2), 2018, 218-239.

Vouzas, F. & Psychogios, A. (2007). Assessing Managers' Awareness of TQM. *The TQM Magazine*, 19(1), 62-75.

Wieland, A. & Wallenburg, C. M. (2013). The Influence of Relational Competencies on Supply Chain Resilience: A Relational View. *International Journal of Physical Distribution & Logistics Management*, 43(4), 300-320.

Yang, J., Xie, H., Yu, G., & Liu, M. (2021). Antecedents and Consequences of Supply Chain Risk Management Capabilities: An Investigation in the Post-Coronavirus Crisis. *International Journal of Production Research*, 59(5), 1573-1585.

Zawawi, N. F. B. M., Wahab, S. A., Al Mamun, A., Ahmad, G. B., & Fazal, S. A. (2017). Logistics Capability, Information Technology, and Innovation Capability of Logistics Service Providers: Empirical Evidence from East Coast Malaysia. *International Review of Management and Marketing*, 7(1), 326-336.

Zeithaml, V. A., Varadarajan, P. R., & Zeithaml, C. P. (1988). The Contingency Approach: Its Foundations and Relevance to Theory Building and Research in Marketing. *European Journal of Marketing*, 22(7), 37-64.

Zelbst, P. J., Green, K. W., Sower, V. E., & Reyes, P. (2009). Impact of Supply Chain Linkages on Supply Chain Performance. *Industrial Management & Data Systems*, 109(5), 665-682.

Zhao, L., Huo, B., Sun, L., & Zhao, X. (2013). The Impact of Supply Chain Risk on Supply Chain Integration and Company Performance: A Global Investigation. *Supply Chain Management: An International Journal*, 18(2), 115-131.