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Research Article

Risk management, robustness and resilience: mechanisms for stabilizing and improving agility performance

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Abstract

Paper aims: This study aims to empirically explore the mechanisms by which supply chain capabilities dedicated to risk management, robustness, and resilience contribute to improved agility performance in times of disruptions from unavoidable risks.

Originality: This is the first empirical research examining the direct and indirect effects of supply chain capabilities related to risk management, robustness, and resilience on improving agility performance in times of disruptions.

Research method: The study considers supply chain risk management as a dynamic capability and supply chain robustness and resilience as operational capabilities that have a mediating role in improving the agility performance of partner firms. Data collected through a survey was used for structural equation modeling and other tests to explore the respective effects of these supply chain capabilities in an environment marked by unavoidable risks, vulnerabilities, and disruptions.

Main findings: The development of a supply chain risk management capability supported by the generation and/or reconfiguration of the operational capabilities inherent in supply chain robustness and supply chain resilience results in improved agility performance for global supply chain partner firms in times of disruptions.

Implications for theory and practice: The results contribute to the theoretical development of issues related to the mechanisms by which supply chain capabilities, particularly risk management, robustness, and resilience work together to improve agility performance and achieve competitive advantage in times of disruptions.

Keywords

Risks. Disruptions. Robustness. Resilience. Agility.

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1. Introduction

Today's business environment has become increasingly complex and uncertain for a number of reasons, particularly the uncertain business cycle, increasingly demanding customers, the trend toward globalization, improved logistics, shorter product life cycles, and rapid technology development. This environment justifies the increased reliance of firms, according to recent studies, on developing competitive strategies based on the development of capabilities pertaining to supply chain risk management (SCRM), supply chain robustness (SCRob), and supply chain resilience (SCR) (Singh & Singh, 2019; Ahmed et al., 2020; Singh & Hong, 2017; Huma et al., 2020). However, few firms simultaneously integrate these capabilities into their global supply chain (GSC) networks to gain competitive advantages over their rivals, especially during times of disruption caused by unavoidable risks (Ahmed et al., 2019; Altay et al., 2018).

These challenging environments force manufacturing companies to focus on their core business and outsource non-core activities (Zeng, 2003; Krause et al., 2007; Sillanpää, 2014). In effect, internal risks have been reduced, but external risks associated with GSC partners have increased. As a result, manufacturing firms find themselves vulnerable to risks related to man-made and especially natural disasters, which are often uncontrollable (Kurniawan et al., 2017). That said, disruptions can often occur with the onset of these uncontrollable events, requiring more vigilance on the part of manufacturing firms (Knemeyer et al., 2009).

GSC risks can be classified into operational risks and disruption risks (Fahimnia et al., 2018; Ivanov, 2018; Xu et al., 2020). Operational risks cause ordinary disruptions in supply chain operations, especially fluctuations in lead times and demand. However, disruption risks primarily refer to low frequency, high impact events (Hosseini et al., 2019; Kinra et al., 2020). Therefore, vulnerabilities and disruptions in GSCs are now recognized as unavoidable findings in today's turbulent global business environment (Um & Han, 2021). Therefore, disruptions to GSCs caused by uncontrollable risks can threaten their robustness and resilience capabilities and, ultimately, their agility performance (AP) (Kumar & Chandra, 2010; El Baz & Ruel, 2021).

Dynamic capability theory stipulates that firms must respond to unexpected events and disruptive risks by integrating, building, and reconfiguring internal and external capabilities to cope with rapidly changing environments (Teece et al., 1997). Indeed, SCRM as a dynamic capability changes the way these firms achieve survival (Helfat & Winter, 2011). However, the integration and/or reconfiguration of operational capabilities dedicated to managing disruptions induced by unavoidable risks, particularly robustness and resilience, allow GSCs and their partners to survive in times of disruption.

After a review of the literature on risk management, it appears that little research has explored the mechanisms by which supply chain capabilities, particularly SCRM, SCRob, and SCR interact and subsequently impact AP stabilization and improvement during periods of GSC disruptions (Ivanov & Dolgui, 2020).

In light of the above, the primary objective of this study is to identify supply chain capabilities dedicated to managing risks, vulnerabilities, and disruptions and to explore the mitigating mechanisms by which these capabilities maintain superior performance in times of disruptions. Using SCRM, as a dynamic capability, and SCRob and SCR, as operational capabilities, this research examines how these capabilities interact to maintain superior AP in times of disruptions? Thus, the key objectives of this research are to:

- Understand the existing relationships between SCRM capability and those dedicated to disruptions management in GSCs, including SCRob capability and SCR capability;
- Explore the direct and indirect effects of these supply chain capabilities on improving AP and, consequently, on achieving a sustainable competitive advantage in a disruption environment.

In exploring these objectives, this research makes several important contributions. First, it expands the research literature on the interaction between dynamic capability dedicated to risk and vulnerability management and operational capabilities specialized in mitigating disruptions induced by unavoidable risks. Second, this research uses the dynamic capabilities perspective as a theoretical basis for answering the question of how firms cope with changing environments by leveraging this set of capabilities dedicated to risks and disruptions management (Barreto, 2010). Third, there are few empirical studies of supply chain capabilities devoted to the simultaneous management of risks, vulnerabilities, and disruptions, so the research picture is incomplete and still lacks insights for practitioners (Jüttner, 2005; Scholten et al., 2014; Um & Han, 2021). Indeed, this research demonstrates clear mechanisms for mitigating risks, vulnerabilities, and disruptions arising from unavoidable events through these three supply chain capabilities. This being the case, this research has decision-making and managerial implications in terms of the appropriate choice of collective supply chain capabilities that deserve to be developed, generated, and reconfigured by managers of firms belonging to GSCs.

The rest of the paper will be organized as follows. In Section 1, a literature review will be presented on SCRM, SCRob and SCR capabilities. Also, the research model and hypotheses will be announced. In section 2, the methodology will be discussed particularly the sample, data collection and measurement model. In section 3, the data as well as the results of the structural equation modeling will be discussed (SEM). In section 4, the main results of the research, their theoretical and managerial implications will be debated and the paper will conclude by discussing the limitations of the present research and suggesting future research topics.

2. Theoretical background and hypotheses development

A GSC is a complex network of changes, whose partners must have the survival capabilities to respond to these changes (Choi et al., 2001). It was argued that due to the very nature of GSCs, the capabilities to mitigate risks, vulnerabilities, and disruptions must be developed, generated, or reconfigured by the partner firms.

Indeed, this research proposes a conceptual framework representing the mechanisms by which GSC capabilities related to risk management, robustness, and resilience interact to contribute, in times of disruptions, to the stabilization and improvement of partner firms' AP. First, the dynamic SCRM capability influences the operational capabilities of robustness and resilience. Second, these supply chain operational capabilities act as mediating variables between SCRM capability and partner firms' AP. Third, the relationships between the different supply chain capabilities and AP are discussed in more detail and represented in the research framework shown in Figure 1. Fourth, the hypotheses that arise from the different relationships between the constructs of the model are announced.

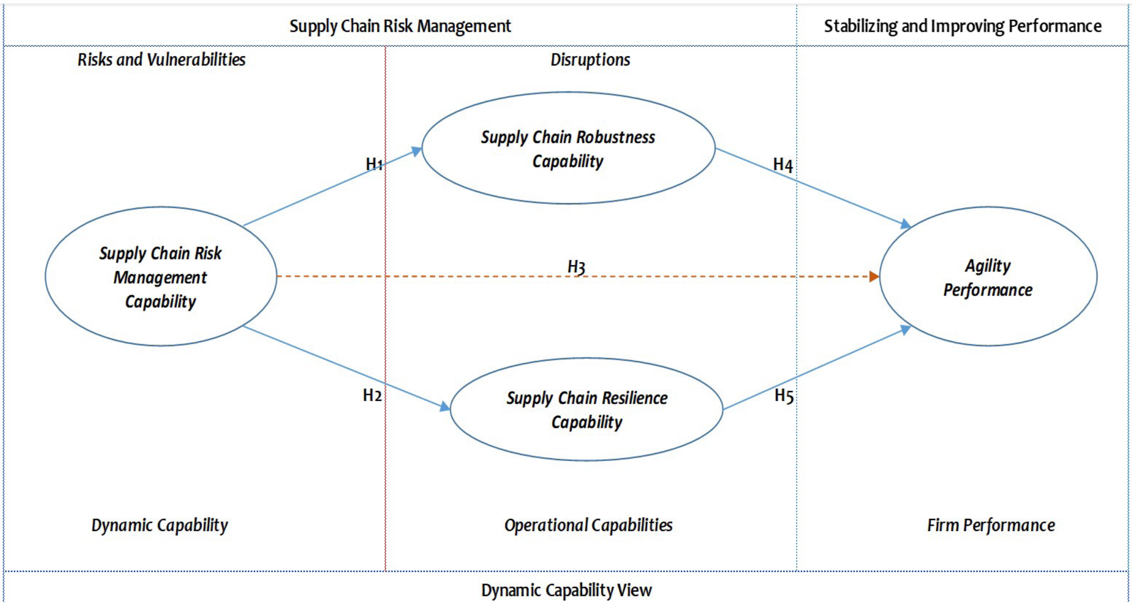


Figure 1. Research framework.

2.1. Dynamic capability view

According to this perspective, dynamic capabilities change the operational capabilities or the broader resource base of the firm and, as a result, cause a change in performance. Indeed, dynamic capabilities cannot explain performance, but rather changes in performance. Furthermore, several researchers have suggested that dynamic capabilities should be observed by the changes they cause in a firm's resource base or operational capabilities (Teece, 2014; Teece et al., 2016). Indeed, these changes do not necessarily lead to higher performance, especially since performance depends on both the quality of the operational capabilities generated or renewed (Zahra et al., 2006) and the scalability of dynamic capabilities (Helfat & Peteraf, 2009). Dynamic capabilities allow the firm to alter the resource base, change operational capabilities, and/or initiate change in the organization's external environment (Helfat & Winter, 2011; Barrales-Molina et al., 2014). Ordinary capabilities determine how a firm preserves its survival in the present, while dynamic capabilities enable the firm to change. Ordinary capabilities enable operational efficiency, while dynamic capabilities enable the firm to detect and seize new opportunities in the environment (Teece, 2014). However, an empirical distinction between ordinary capabilities that change and dynamic capabilities that provoke change is essential. Based on these arguments, SCRM was considered as a dynamic capability, while robustness and resilience are conceptualized as operational capabilities of GSCs.

2.2. Supply chain risk management capability

SCRM is the capability to manage day-to-day and exceptional risks throughout the supply chain, based on continuous risk assessment, with the goal of reducing vulnerabilities and ensuring continuity. Similarly, SCRM extends traditional risk management approaches through the integration of upstream and downstream risks of SCRM partners.

According to the theory of dynamic capabilities, firms that have been able to develop this dynamic capability in a substantial way can reduce the gap between the information required and that possessed and, consequently, the uncertainties arising from this informational gap. This is because these firms will be able to prevent, respond to, and return risks to the original or even improved state with higher performance (Scholten et al., 2014; Yang et al., 2021).

A high level of SCRM capability enables a focal firm to ensure continuity of operations, production, and delivery of quality products to its customers (Brusset & Teller, 2017). The development of this dynamic capability allows, also, companies to anticipate, respond to, and overcome uncontrollable supply chain risks through their prevention and detection before they lead to significant vulnerabilities and disruptions. However, once unavoidable risks generate supply chain disruptions, this dynamic capability dedicated to risk management generates and/or reconfigures operational robustness and resilience capabilities to absorb the negative effects of disruptions induced by unavoidable risks (Tang, 2006; Ali et al., 2017; Yang et al., 2021).

2.2.1. Relationship between SCRM and SCRob capabilities

According to the supply chain management (SCM) literature, robustness refers to the capability to withstand various shocks, human errors, and variability in the business environment (Wieland & Wallenburg, 2012). The operational capability of robustness plays an important role in mitigating uncontrollable risk-related disruptions upstream through SCRM capability (Kwak et al., 2018). This is because robust GSCs are able to withstand, cope with, and control disruptions by buying time to identify and implement the necessary coping mechanisms to mitigate the disruptions induced by unavoidable risks (Kwak et al., 2018; Shamout, 2019).

In light of the above, robustness is a capability of the supply chain to withstand changes without adapting its initial stable configuration. A robust supply chain remains effective for all plausible futures (Klibi et al., 2010) by maintaining the same situation before and after changes occur (Asbjørnslett, 2008). Indeed, the robust supply chain is insensitive to noise factors (Mo & Harrison, 2005). Therefore, a robust supply chain resists rather than responds to changes (Husdal, 2010). Therefore, it is hypothesized that:

H1. SCRM capability has a direct positive effect on SCRob capability.

2.2.2. Relationship between SCRM and SCR capabilities

Highly resilient GSCs have a priori an enhanced SCRM capability that generates or reconfigures operational resilience in response to disruptions induced by unavoidable risks. This SCR capability allows for continuity during severe disruptions caused by uncontrollable events, including Covid-19 and the Russian-Ukrainian war (Azadegan et al., 2020; Yang et al., 2021). Also, Jüttner & Maklan (2011) argued that there is an already recognized relationship between GSC resilience, vulnerabilities, and SCRM, while proposing that these three concepts are complementary for a well-designed supply chain. On the other hand, Heckmann et al. (2015) created a framework for SCRM where supply chain risks are considered by these authors as a concept in its primary state, while the resulting disruptions are considered as effects requiring, among other things, an SCR capability for their management. Resilience can be seen as an outcome of the SCRM concept (Pereira et al., 2014). Indeed, the generation or reconfiguration of the GSC resilience capability must build on the knowledge already created during the development of the SCRM capability (Ribeiro & Barbosa-Povoa, 2018). Therefore, it is hypothesized that:

H2. SCRM capability has a direct positive effect on SCR capability.

2.2.3. Relationship between SCRM capability and agility performance

The SCM literature has conceptualized agility at several levels ranging from a paradigm to a strategy to a capability (Narasimhan et al., 2006; Tallon & Pinsonneault, 2011; Sarkis et al., 2007; Yusuf et al., 2014; Sangari & Razmi, 2015). This research focuses on its level of performance, the results and measures of AP generally relate to improved product customization, reduced new product development and turnaround time, reduced system change time and cost, and efficient increase and decrease in operations (Sarkis et al., 2007; Narasimhan et al., 2006; Paulraj & Chen, 2007b; Jajja et al., 2018).

According to Yauch (2011), agility should be judged by performance measures. The focus on AP in this research finds legitimacy in the organizational need to perform on agility measures during turbulent times in the organization's internal and external business environment (Sharifi & Zhang, 2001; Sangari & Razmi, 2015; Gligor et al., 2016).

Previous studies have adopted various combinations of performance indicators to measure AP (Narasimhan et al., 2006). As such, Paulraj & Chen (2007b) used flexibility, time, delivery and responsiveness as four critical factors of AP. Other authors have associated cycle time, speed and reliability of delivery, customization, new product introduction, and flexibility (Narasimhan et al., 2006; Swafford et al., 2008). Supporting the previous literature, AP in this research refers to a combination of metrics measuring supply chain responsiveness to market needs in the areas of design, delivery, and flexibility (Sangari & Razmi, 2015; Yauch, 2011; Narayanan et al., 2015). These dimensions of performance play a critical role in assessing how partner firms in a GSC alter their operational states under uncertain and changing demands, and especially during periods of disruption (Narasimhan et al., 2006; Yauch, 2011).

Since the SCRM capability is viewed in this research as a dynamic capability embodying the mechanism for surviving disruptions in the GSC, it is expected to reduce the inherent risk vulnerabilities in a reactive and proactive manner. This capability is reactive in the sense that it monitors changes in the supply chain, customer needs, technology, partner strategies, and competitors and updates the risk assessment accordingly (Hallikas et al., 2004; Wieland & Wallenburg, 2012). In addition, the SCRM capability also proactively reduces vulnerabilities by identifying potential risks and assessing their impact and likelihood before they occur. Therefore, it is hypothesized that:

H3. SCR capability has a significant mediating role between SCRM capability and AP.

2.3. Supply chain robustness capability and agility performance

The SCM literature has viewed SCRob as a proactive rather than reactive strategic investment (Durach et al., 2015; Wieland & Wallenburg, 2012) and defined it as a capability to maintain performance during volatile phases (Meepetchdee & Shah, 2007). Indeed, GSC robustness is the capability to "resist or avoid change." Both dimensions of this definition (resilience and avoidance) are evident in terms of supply chain performance outcomes in the face of disruption. In other words, a robust supply chain will not experience significant performance degradation in response to disruptions (Mackay et al., 2020).

Furthermore, robustness is an adaptive capability (Walker et al., 2004) that allows systems to detect and respond to perturbations (Erol et al., 2010). In other words, robustness refers to the degree of sensitivity of the GSC to perturbations (Zhou et al., 2017). Robustness ensures that a GSC has a capability to "yield" to a perturbation (Haimes et al., 1998). In other words, the perturbation will "consume" or absorb the existing robustness capability up to a certain point, beyond which the supply chain's performance suffers degradation.

Generating or reconfiguring a GSC's robustness capability requires additional financial investments (Wieland & Wallenburg, 2012) induced by the integration of redundancies, including multiple suppliers and unused production or transportation capacity resources (Hohenstein et al., 2015). Robustness is the capability to proactively manage perturbations in the GSC, which helps stabilize the performance of the supply chain and its partners (Wieland & Wallenburg, 2012).

A robust supply chain is designed to maintain supply chain performance during periods of perturbation caused by unavoidable risks (Kouvelis et al., 2006). This research argues that the SCRob capability can absorb any performance degradation caused by perturbations, which can make it unnecessary to generate or reconfigure SCR capability (Mackay et al., 2020). Therefore, it is hypothesized that:

H4. SCRob capability has a direct positive effect on the AP.

2.4. Supply chain resilience capability and agility performance

Like robustness, resilience is also considered an adaptive capability (Walker et al., 2004) that allows systems to detect and respond to perturbations (Erol et al., 2010). The concept of "resilience" is an emerging theme in the SCM literature. While there are many definitions of the concept, the essential attributes of resilience can be reduced to a capability to withstand the effect of a perturbation-to the point where the threshold toward the failure pool is not exceeded-and to recover within an acceptable time frame (Haimes, 2009; Dubey et al., 2021) and within elastic limits (Rice & Caniato, 2003). Resilience has been refined in this research as an operational decision to ensure GSC recovery (Munoz & Dunbar, 2015). Indeed, resilience should be combined with strategic SCRM capability (Wieland & Wallenburg, 2013; van der Vegt et al., 2015) as an operational means to address problems arising from poor risk management practices (Kamalahmadi & Parast, 2016).

This research argues that resilience emerges when robustness is exceeded, and therefore any investment in the resilience capability of a highly robust GSC becomes wasteful. The decoupling point between "useful" and "useless" resiliency initiatives requires knowing the magnitude of a disruption and the corresponding robustness capability (Mackay et al., 2020). Therefore, it is hypothesized that:

H5. SCR capability has a direct positive effect on the AP.

3. Research methodology

Initially, survey data were collected and then confirmatory factor analysis (CFA) was used to assess the validity and reliability of the measurement models corresponding to each construct in the research model. CFA, as a technique for examining relationships between proposed item measures and an associated latent construct (Kim & Mueller, 1978), is an appropriate tool because the associations between proposed item measures and constructs have been specified. Since our data are from a sample and not a population, our results will not, therefore, prove causality but rather support the proposed hypotheses. Furthermore, unlike regression, which considers only a single dependent variable and an aggregate error term, SEM is useful for examining causal relationships and dealing with multiple dependent variables as well as the error terms of all dependent and independent variables in a structural model (Kline, 2011). Since this research aims to test multiple relationships between several constructs simultaneously, SEM seems to be an appropriate tool for analyzing our structural model after ensuring acceptable levels of validity and reliability of the measurement scales. Indeed, this section will discuss the method of data collection and sample constitution as well as the development of the measurement model.

3.1. Sample and data collection

The study used a survey to collect data from foreign firms operating in Morocco. Through a pilot test interview, pre-data was collected from three manufacturing firms located in industrial acceleration zones to ensure that the questions were understandable to the respondent without any uncertainty or confusion due to their native language. For the English and Spanish questionnaires, following Craig and Douglas's method (Craig & Douglas, 1999), one professional translator translated the original version of the questionnaire into French and another person then translated it back into English and Spanish. The two translators then agreed on a version of the questionnaire in three languages.

Using a database from the Ministry of Industry and Trade, an online survey was conducted in 2022 to test the hypotheses. The initial sample included informants involved in general management and business functions related to SCM in foreign manufacturing companies based in Morocco. After eliminating mailing errors, the sample contained 750 contacts. Only responses with less than 10% missing values were accepted. The EM algorithm (Dempster et al., 1977) was used for responses with 0.6% missing values. At the end of the survey period, 160 completed questionnaires were well received by respondents, representing a response rate of 21.3%. This is, in effect, a medium sample size (Kline, 2011) and a number of observations greater than the free model parameters as a condition for structural model identification (Fabrigar et al., 2010; Hair Junior et al., 2010; Kline, 2011). Table 1 categorizes the respondent firms by the product sector. Based on a procedure suggested by Armstrong & Overton (1977) regarding the likelihood of late response bias, the results of t-tests suggested no difference at the 0.05 level between early and late respondents, indicating a minimal risk of response bias. Harman's one-factor test was used to check common method bias.

A principal component factor analysis was conducted on all the items in the study, resulting in five factors with eigenvalues above 1. As no single factor was apparent in the un-rotated factor structure, the common method variance problem was not a major issue.

Table 1. Respondents' profile summary.

Structure of the sample	Frequency	Valid %
Firm size (in terms of employees):		
▪ Less than 100;	80	50%
▪ 101-200;	15	9.4%
▪ 200-300;	45	28.1%
▪ 300-400.	20	12.5%
Manufacturing industry type:		
▪ Automotive industry;	46	28.7%
▪ Aeronautics and aerospace industry;	39	24.4%
▪ Food industry;	31	19.4%
▪ Pharmaceutical industry;	23	14.4%
▪ Electronic and electrical components industry;	15	9.4%
▪ Rubber and plastic products industry.	06	3.7%
Respondent designation:		
▪ Top management;	65	40.6%
▪ Middle management;	47	29.4%
▪ Lower management.	48	30%
Respondent experience:		
▪ Less than 3 years;	18	11.3%
▪ 3-6 years;	42	26.2%
▪ 6-9 years;	43	26.9%
▪ More than 9 years.	57	35.6%
Total	**160**	**100%**

3.2. Measurement model

The survey instrument used a seven-point Likert scale (1-strongly disagree or not at all and 7- Strongly agree or a very large extent). After thorough review of the extant literature on the field of SCRM, robustness, resilience, agility performance, the measurement items for the theoretical constructs in the conceptual model are adapted from prior studies. This approach allows for the development of formative and composite measures in the context of this study. Therefore, the measurement items can affect the construct with which they are affiliated and which they measure, just as each construct is reflected and represented by its measurement items (Bollen & Lennox, 1991). The measurement items used in this study are presented in Table 2.

Four items from Donadoni et al. (2018) and Yang et al. (2021) were adapted to measure SCRM reflecting a partner company's capability to prevent, detect, respond to, and restore supply chain risks. SCRob capability was measured by four items adapted from Asbjørnslett (2008), Meepetchdee & Shah (2007) and El Baz & Ruel (2021). SCR capability consists of seven elements adapted from Soni et al. (2014), Jain et al. (2017), Brusset & Teller (2017), and Um & Han (2021). AP is operationalized by four items adapted from Swafford et al. (2008) reflecting the speed at which a firm's supply chain can be responsive to customer expectations.

4. Data analysis and results

4.1. Reliability and validity

This research conducted CFA to determine composite measure reliability (CR), as well as convergent and discriminant validity. The study used CFA because it has an a priori theory of the relationship between measurement items and their constructs, which allows the SEM to be used as an approach to test both the model and the hypotheses. SEM facilitates examination of the overall causal fit of a holistic model (Liao, 2001) as well as mediation effects. All items with a saturation above 0.5 were used from the list of dependent and independent variables for content validity. Table 2 reports the factor loadings, CR and average variance extracted (AVE). The measurement model offered an acceptable fit to the data (x^2/df = 221,934/140 = 1.585, GFI = 0.879, SRMR = 0.066, RMSEA = 0.061, CFI = 0.958). CR showed acceptable internal consistency (CRs > 0.852) while convergent validity was assured, as all the loadings were similar to or greater than 0.5, with acceptable AVE values (> 0.595).

Table 2. Measures, reliability, and validity.

Measures	Factor Loading	Composite Reliability	AVE
Supply Chain Risk Management Capability (adapted from: Donadoni et al., 2018; Yang et al., 2021**):**		0.866	0.620
SCRM1. Preventing supply chain risks (e.g. select a more reliable supplier, use clear safety procedures, preventive maintenance).	0.70		
SCRM2. Detecting supply chain risks (e.g. internal or supplier monitoring, inspection, tracking).	0.69		
SCRM3. Responding to supply chain risks (e.g. backup suppliers, extra capacity, alternative transportation modes).	0.88		
SCRM4. Recovering from supply chain risks (e.g. task forces, contingency plans, clear responsibility).	0.86		
Supply Chain Robustness Capability (adapted from: Asbjørnslett, 2008; Meepetchdee & Shah, 2007; El Baz & Ruel, 2021**):**		0.903	0.701
SCRob1. For a long time, our supply chain retains the same stable situation as it had before disruptions occur.	0.78		
SCRob2. When disruptions occur, our supply chain grants us much time to consider a reasonable reaction.	0.93		
SCRob3. Without adaptations being necessary, our supply chain performs well over a wide variety of possible scenarios.	0.84		
SCRob4. For a long time, our supply chain is able to carry out its functions despite some damage done to it.	0.79		
Supply Chain Resilience Capability (adapted from: Soni et al., 2014; Jain et al., 2017; Brusset & Teller, 2017; Um & Han, 2021**):**		0.911	0.595
SCR1. Ability to cope with changes brought about by supply chain disruption through collaboration with partners to minimize uncertainty.	0.65		
SCR2. Ability to adapt to the supply chain disruption easily through information sharing.	0.80		
SCR3. Ability to maintain high-risk awareness and evaluation at all times.	0.85		
SCR4. Ability to maintain trust with partners to adapt to supply chain disruption.	0.81		
SCR5. Supply chain allows increasing visibility over the supply chain.	0.80		
SCR6. Ability to adapt and cope with changes related to supply chain disruption through a risk management capability.	0.71		
SCR7. Ability to deploy adaptive capability and alternative plans.	0.76		
Agility Performance (adapted from: Swafford et al., 2008**):**		0.852	0.602
SCA1. Speed in reducing manufacturing lead-time during periods of supply chain disruption.	0.72		
SCA2. Speed in reducing development cycle time during periods of supply chain disruption.	0.93		
SCA3. Speed in increasing frequencies of new product introductions during periods of supply chain disruption.	0.88		
SCA4. Speed in adjusting delivery capability during periods of supply chain disruption.	0.50		

Fit indices: x^2/df (chi-square) = 221.934 / 140 = 1.585, the goodness of fit index (GFI) = 0.879, standardised root mean square residual (SRMR) = 0.066, root mean squared error of approximation (RMSEA) = 0.061, comparative fit index (CFI) = 0.958.

All the constructs fulfill Fornell & Larcker (1981) criterion as the square roots of AVEs for particular constructs have higher values than the respective other constructs. Therefore, the study constructs have validated Fornell and Larcker criterion for discriminant validity (Table 3).

4.2. Path analyses

Path analysis is the advanced method of multiple regression analysis. Its implications differ from ordinary least squares analysis. In multiple regression analysis, the number of dependent variables is limited to one, whereas in SEM path analysis, the number of dependent, moderator and mediator variables is not limited. Therefore, SEM path analysis is more sophisticated and has advanced methodological rigor (Fornell & Bookstein, 1982; Wetzels et al., 2009; Wong, 2013). The results related to direct and indirect effects are summarized in Table 4 and Figure 2.

Based on the direct effect of path analysis, it was found that SCRM capability (0.756, $p < 0.001$) has a significant positive relationship with SCRob capability. SCRM capability (0.527, $p < 0.001$) has a positive and statistically significant relationship with SCR capability. SCR capability (0.171, $p < 0.10$) has a positive and statistically significant influence on AP. However, SCRob capability (-0.045, $p > 0.10$) has a negative but directly non-significant relationship with AP. Regarding indirect effects, the effect of SCRM capability on AP was mediated by SCR capability. Therefore, it has (0.056, $p < 0.10$) a positive and statistically significant indirect relationship with AP.

Table 3. Inter-construct correlation estimates and related AVEs.

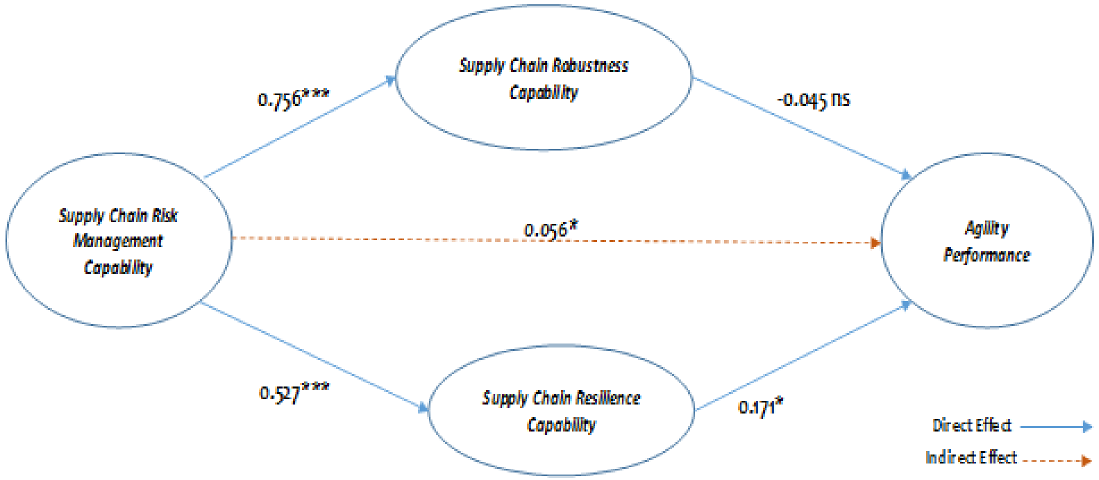
	SCR	SCRM	SCRob	AP
SCR	**0.784**			
SCRM	0.460	**0.774**		
SCRob	0.458	0.747	**0.837**	
AP	0.157	0.123	0.036	**0.769**

Note: Square roots of the AVE are shown on the diagonal.

Table 4. Results of the path analysis and hypothesis testing.

	Paths			Estimates	P	Decisions
H1	SCRM Capability	→	SCRob Capability	0.756	***	Direct Effect Supported
H2	SCRM Capability	→	SCR Capability	0.527	***	Direct Effect Supported
H3	SCRM Capability	→	Agility Performance	0.056	*	Indirect Effect Supported
H4	SCRob Capability	→	Agility Performance	-0.045	ns	Direct Effect Not Supported
H5	SCR Capability	→	Agility Performance	0.171	*	Direct Effect Supported

***p<0.001; *p<0.1. ns: non-significant.



Notes: * indicate alpha level from t-tests: *** for p < 0.001, * for p < 0.10 and ns: non-significant

Figure 2. Research model results.

5. Discussion, implications and conclusion

5.1. Major findings

In support of dynamic capability theory, this study examines how dynamic SCRM capability directly affects operational capabilities, specifically SCRob and SCR, and indirectly affects AP. As such, the main results show that SCRM capability improves, in order of importance, SCRob capability and SCR capability (Direct effects). However, SCRM capability does not directly improve AP, but rather through the exclusive mediation of SCR capability in an environment marked by perturbations in GSCs (Indirect effect).

Furthermore, it is clear from the standardized direct effects obtained that the SCRM capability is strongly correlated with the proactive capability of SCRob relative to its correlation with the reactive capability of SCR during periods of disruptions caused by unavoidable risks. These results argue that SCR emerges when SCRob is exceeded, and therefore investment in these disruptions management capabilities should be rationalized in this order of priority.

By virtue of the results of this study, it is important to note that the SCRob capability can absorb any degradation of the AP caused by perturbations without contributing to its improvement, justifying the lack of a significant effect of this capability on the AP. Indeed, it can be inferred that SCRob is a stabilizing capability for AP, however, SCR is an enhancing capability for AP during periods of GSC perturbations due to uncontrollable events.

5.2. Theoretical and managerial implications

Certainly, there are many implications that can be advanced to fill in the gaps in the literature and provide appropriate guidance for addressing GSC challenges. In particular, the results appear to have comprehensive implications for operations and supply chain practitioners.

First, these results offer guidance on the mechanisms by which supply chain capabilities interact together to contribute to operations continuity and AP stabilization and improvement during periods of unavoidable risks, high vulnerabilities, and GSC disruptions.

Second, the results of this study revealed the importance of a demarcation between risk and vulnerability management and disruption management as well as the mitigation scope of the different supply chain capabilities addressed in this study. Indeed, the SCRM, SCRob and SCR capabilities are considered complementary and inseparable, depending on the nature of the risks and the extent of the disruptions.

Third, the investment in capabilities dedicated to the management of risks, vulnerabilities and disruptions must be progressively implemented in SCRM, SCRob and SCR in order to rationalize the financial costs involved.

5.3. Limitations and future directions

The study has several limitations. First, it did not examine the impact of effective risk, vulnerability, and disruption mitigation capabilities on financial performance alongside agility performance to inform managers about the trade-off between financial cost and agility gain. Second, for the sake of generalization and simplicity, the data was consolidated for all manufacturing activities; however, the results may differ by industry type. Third, the mechanisms by which the capabilities to manage risks, vulnerabilities and disruptions in service supply chains deserve to be studied in a separate research in the future. Fourth, risk, vulnerability and disruption management capabilities should be linked to big data analytics and artificial intelligence, which can be explored in future research. Finally, incorporating other dynamic capabilities and resources related to GSC risks and disruptions management would make the research model more comprehensive and reflective of an integrated vision for researchers and practitioners.

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