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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

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Abstract

This study investigates the role of supply chain risk management (SCRM) in mitigating the effects of disruptions impacts on supply chain resilience and robustness in the context of COVID-19 outbreak. Using structural equation modeling on a survey data from 470 French firms, the results confirm the basic tenets of resource-based view and organizational information processing theories regarding the combination of dynamic resources to face disruptions' uncertainty. Furthermore, the findings reveal the mediating role of SCRM practices and the prominent role they play in fostering supply chain resilience and robustness. Overall, by providing empirical assessment of a comprehensive SCRM framework, this research contributes to the extant literature and suggests further avenues for research.

Keywords: Disruption impacts, supply chain risk management practices, supply chain robustness, supply chain resilience, COVID-19, epidemic.

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1. Introduction

According to several scholars (Fahimnia et al., 2018, Ivanov, 2018, Choi et al., 2001, Xu et al., 2020) supply chain (SC) risks can be categorized into operational and disruption risks. The operational risks relate to ordinary disturbances in the SC operations such as lead-time and demand fluctuations, whereas the disruption risks concern mainly events with low frequency and high impacts (Hosseini et al., 2019; Kinra et al., 2019). Epidemic outbreaks constitute a special case of SC risks in terms of duration (long term), high uncertainty and ripple effects propagation (Ivanov, 2020). Research on the epidemic's effects on SCs have emerged during the last decade (Natarajarathinam et al., 2009; Scott and Ruttner, 2019; Ivanov, 2020) highlighting the variety of their threats to the firms' viability. SC disruptions caused by pandemics can threaten SC resilience and robustness as demonstrated by several studies (e.g. Kumar and Chandra's research (2010) on the impacts of the avian flu on US companies; Le Hoa Vo and Thiel's study (2011) on the effects of avian flu on the chicken meat SC).

Recently, the Coronavirus (COVID-19) outbreak has affected numerous global SCs availability (Araz et al., 2020). The disruptions effects of COVID-19 impacted the global economy and paralyzed several industries (Ivanov, 2020). According to Fortune (2020), more than 94% of top 1000 companies have been negatively affected by this outbreak. Furthermore, the COVID-19 is directly causing disturbances in supply and demand at the global and local scales (Ivanov, 2020). Hence, Ivanov and Dolgui (2020) call for more empirical research on SC resilience and robustness to elucidate how firms facing COVID-19 threats might develop survival mechanisms to mitigate the epidemic's threats. Likewise, van Hoek (2020) highlights SC managers' difficulties to operationalize the concepts of risk management and SC resilience and urges researchers to conduct empirical research to examine how SC managers are dealing with COVID-19 challenges.

While robustness relates to SCs' ability to maintain its planned performance following a disruption (or a series of disruptions) impacts (Nair and Vidal, 2011; Simchi-Levi et al., 2018), resilience concerns the ability of SCs to recover their performance after having absorbed the disruption effects (Spiegler et al., 2012; Hosseini et al., 2019). The COVID-19 outbreak has put the resilience and robustness of SCs to the test in several industries with shortages in supply, lack of reactivity and production stops (Ivanov and Dolgui, 2020). Therefore, there is a need to assess how firms might deploy SC risk management (SCRM) processes to cope with the disruption impacts of COVID-19 outbreak. SCRM has been investigated extensively in prior studies (e.g. Ho et al., 2015; Wieland and Wallenburg, 2012; Kern et al., 2012; Kırılmaz and Erol, 2017) but the interactions of SC risk processes with SC disruptions, SC resilience and SC robustness have not been examined sufficiently. Addressing those questions is relevant since SCs are designed to be global and lean which increases their vulnerabilities in the current epidemic context (Ivanov, 2020). This study is an attempt to contribute to this line of research.

Regarding our field of study, we decided to conduct our research on French firms for several reasons. First, France is the world's 7th largest economy and is highly developed (World Bank, 2019). Second, French companies are connected with global SCs importing and exporting all throughout the globe (French Ministry of the Economy, 2018). Third, according to the World Bank logistics performance index, France is positioned among the first countries in Europe (World Bank, 2019).

Consequently, this study seeks to investigate the following research questions:

RQ1. Do COVID-19 disruption impacts affect supply chain risk management practices, supply chain robustness and resilience of French companies?

*RQ2***.** Do supply chain risk management practices of French companies impact their supply chain robustness and resilience?

RQ3. Can supply chain risk management practices of French companies mitigate the COVID-19 disruptions impacts on their supply chain robustness and resilience?

Resource-based view (RBV) and organizational information processing (OIP) theories with their emphasis on the resources and capabilities to mitigate risks along SCs are used as the main theoretical foundation of this research. To answer the research questions, data collected from a survey of 470 SC professionals were analyzed using partial least square structural equation modeling.

The contributions of this research are manifold. First, we answer the call of many scholars for more empirical research on SCRM in COVID-19 context (Ivanov, 2020; Ivanov and Dolgui, 2020; van Hoek, 2020), and on testing concepts of RBV and OIP in SCRM (e.g. Hart and Dowell, 2011; Shi et al., 2012; DuHadway et al., 2019). The combination of RBV and OIP theories sheds light on how firms deploy SCRM practices to deal with disruptions impacts which extends the propositions of previous conceptual studies (e.g. DuHadway et al., 2019; Ivanov, 2020). In addition, the results provide further insights on the impacts of implementing SCRM on both of firms' SC resilience and robustness. Also, by assessing the combinations of SCRM practices, the findings help identify the key processes that firms might deploy to improve both of their SC resilience and robustness.

The paper is structured as follows. In the next section, the framework inspired from RBV, dynamic capabilities and OIP theory is presented along with the research model and hypotheses. Following this, we describe the methodology for the survey analysis. Next, we present the main findings in the fourth section. Finally, the conclusions and implications deriving from the study are discussed in the last section.

2. Theoretical framework and conceptual background

To theoretically investigate the role of SCRM practices in reducing disruption impacts on SC resilience and robustness, we draw on RBV and OIP theories.

2.1. Resource based view theory and dynamic capabilities concept

The RBV is a theoretical approach that emerged as a response to the turbulence in the business environment resulting from globalization, technological innovations, and economic crises (Wernerfelt, 1984; Barney, 2012). According to RBV, firms can achieve competitive advantages if they possess valuable, inimitable and non-substitutable resources (Barney, 1991; Hart, 1995). Resources can be classified as: physical capital resources, human capital resources and organizational capital resources (Barney, 1991). The coordination of all these resources can improve the firms' performance and competitiveness (Hart and Dowell, 2011; Graham and Potter, 2015; Kauppi and Hannibal, 2017).

Since SCM seeks to optimize firms' resources and performance, numerous scholars in the field have based their research on RBV (Defee and Fugate, 2010; Burgess et al., 2006; Halldorsson et al., 2007). Accordingly, RBV was deployed in SCM research to investigate information management in the SC (Huo et al., 2016), distribution logistics (Yang and Lirn, 2017), sustainable SCM (Shibin et al., 2017; Carbone et al., 2019), alliances in SC networks (Steiner et al., 2017), blockchain (Treiblmaier, 2018; Yu et al., 2018), SCRM (Fan and Stevenson, 2018), learning in a SC (Yang et al., 2019) and network design for SMEs (Partanen et al., 2020). Despite its popularity, RBV theory was criticized by some scholars for the ambiguity of the resources' concept and its static approach of firm's operations (Priem and Butler, 2001 a, b). Hence, the concept of dynamic capabilities has been developed to reflect the dynamic challenges faced by firms (Winter, 2003).

2.2.Dynamic capabilities concept

Dynamic capabilities are defined as the ability to integrate, build and reconfigure internal and external skills to respond to a rapidly changing environment (Teece et al., 1997). Dynamic capabilities are considered as repetitive behaviors that are learned and based in part on tacit knowledge which allow firms to build competitive advantage (Winter, 2003). The concept of dynamic capabilities has been the subject of severe criticism (Williamson, 1999; Barreto, 2010). Dynamic capabilities are sometimes considered as an abstract concept lacking specific components (Pavlou and El sawy, 2011), difficult to measure (Mulders and Romme, 2009) and can only be observed *a posteriori* (Easterby Smith et al., 2009). Despite those limitations, numerous scholars have extensively made use of RBV and dynamic capabilities concept in the context of SC (e.g. Aslam et al., 2020; Chowdhury et al., 2019; Dubey et al., 2019; Gruchmann and Seuring, 2018; Hong et al., 2018; Hsin-Lu, 2011, Riley et al., 2016; Wamba et al., 2017; Yao and Fabbe-Costes, 2018; Yu et al., 2019).

Beyond firm's boundaries, several scholars deploy the dynamic SC capabilities' concept in their investigation of how SC partners mobilize cross-organizational processes to create and/or modify capabilities following market shifts (Beske, 2012; Defee and Fugate, 2010; Aslam et al., 2020). RBV and dynamic capabilities constitute a relevant framework to examine how firms coordinate their resources and capabilities in response to SC risks (Ojala and Hallikas, 2006; Tsai et al., 2008; Fan and Stevenson, 2018; Chowdhury and Quaddus, 2017). In this optic, firms need to realign their resources and processes (Sirmon et al., 2007; Eddleston et al., 2008; Blackhurst et al., 2011) to quickly adapt to changes resulting from disruptions' threats.

2.3.Organizational information processing theory

OIP theory provides additional insights on how organizations might deal with unpredictable SC disruptions (DuHadway et al., 2019). OIP theory was inspired by the paper of Galbraith (1974) on organizational design. Accordingly, firms should develop capabilities to meet

increasing requirements for information processing due to mounting uncertainty or equivocality. Hence, the more an organization develops its ability to process information (i.e. enhancing its quality and flow), the more it can deal with uncertainty (Wu et al., 2013; Tushman and Nadler, 1978; Cegielski et al., 2012).

SC disruptions constitute a major source of uncertainty and equivocality due to the amount of information to be collected, treated and interpreted (Wu et al., 2013). Consequently, processing information becomes indispensable for developing SC risk practices (DuHadway et al., 2019; Wu et al., 2013). Furthermore, the level of uncertainty parallels the magnitude of SC disruptions (Ellis et al., 2011). Therefore, firms need to build structural practices to meet the information processing requirements generated by increased uncertainty (Bode et al., 2011; Azadegan et al., 2020). Organizations that successfully build these capabilities can enhance their competitiveness and performance (Hazen and Sankar, 2015; Carnovale and Yeniyurt, 2015; Wu et al., 2013).

OIP tenets can also be applied in the context of SCs, since information processing capabilities can improve the ability of firms to manage their SC networks (Hult et al., 2004; Carnovale and Yeniyurt, 2015). Consequently, OIP framework can shed light on how firms formalize processes to gather and interpret information in order to enhance their preparedness and mitigate disruptions impacts (Bode et al., 2011; Pettit et al., 2013). In this optic, SCRM practices can be conceptualized as capabilities/resources that firms learn, deploy, share and develop. The goal of SCRM is to improve firm's performance, by maintaining SC robustness and enhancing SC resilience. In situations of high uncertainty such as the COVID-19 epidemic, the ability of firms to reconfigure their capabilities is crucial for their survival and growth (Chowdhury and Quaddus, 2017; Sirmon et al., 2007). Along the lines of several scholars (e.g. Blackhurst et al., 2011; Chowdhury and Quaddus, 2017; Helfat et al., 2007; Marsh and Stock, 2006), we argue that firms who are able to restructure and redeploy their

resources in a turbulent environment, are more capable of developing capabilities that mitigate SC disruptions impacts.

By proactively configuring and managing resources, i.e. SCRM practices, firms can mitigate SC disruptions and therefore might succeed in maintaining their planned SC performance (robustness) or recover their performance after having absorbed the disruption effects (resilience).

3. Hypotheses development

3.1. SCRM practices and disruptions impacts

Disruptions are the manifestations of SC risks, hence the need for strategies to treat such disruptive events (DuHadway et al., 2019). SCRM is a multifaceted concept and scholars diverge widely regarding its definition. For the most part, SCRM practices seek to reduce SC vulnerability and mitigate disruptions impacts (Ho et al. 2015; Norrman and Jansson, 2004; Tang, 2006; Wieland and Wallenburg, 2012). Drawing on extant literature, Fan and Stevenson (2018) provide a comprehensive framework of SCRM comprising the identification, assessment, treatment, and monitoring of SC risks. Thus, the goal of SCRM processes is to limit the effects of SC disruptions that hinder the continuity of material and information flows within the SC (Bode et al., 2011; Chowdhury and Quaddus, 2017; Craighead et al., 2007). Facing the various threats of risks and disruptions, firms tend to develop specific SCRM practices that involve four interconnected processes (Fan and Stevenson, 2018; Kırılmaz and Erol, 2017; Wieland and Wallenburg, 2012).

Risk identification

The first step in SCRM practices concerns the identification of risks (Kleindorfer and Saad, 2005; Wieland and Wallenburg, 2012) through regular screening of potential SC risks (Buhman et al., 2005). Since the severity of disruptions impacts depends on early detection of

its probability, firms must deploy risk identification to discover the sources of SC risks accurately (Craighead et al., 2007; Chowdhury and Quaddus, 2017). Due to the complexity of SCs and the resources constraints, firms must collect data on their critical processes, flows and partners in the SC to optimize the efficiency of SCRM (Kleindorfer and Saad, 2005; Wieland and Wallenburg, 2012). Therefore, risk identification plays a crucial role and influences the outcomes of the subsequent processes in SCRM (Fan and Stevenson, 2018; Wieland and Wallenburg, 2012).

Risk assessment

Risk assessment can be identified as the evaluation of risk's occurrence including an estimation of its impact (Kleindorfer and Saad, 2005; Schmitt and Singh, 2009; de Souza et al., 2009; Wieland and Wallenburg, 2012; Zsidisin et al., 2004). This process seeks to provide in-depth information about risks antecedents and key vulnerabilities with great emphasis on the inter-relatedness of risks and trigger events (Kleindorfer and Saad, 2005; Manuj and Mentzer, 2008; Wieland and Wallenburg, 2012).

The severity of SC disruptions impacts depends on the risk's events duration and speed of propagation (Braunscheidel and Suresh, 2009; Manuj and Mentzer, 2008; Schmitt and Singh, 2009). Therefore, risk assessment aims to prioritize the identified risks by their likelihood in an appropriate way (Manuj and Mentzer, 2008; Matook et al., 2009; Ritchie and Brindley, 2007; Schmitt and Singh, 2009; de Souza et al., 2009; Wieland and Wallenburg, 2012). In addition, the purpose of risk assessment is to prepare for the next SCRM practices, i.e. mitigation and control of SC risks (Fan and Stevenson, 2018; Wieland and Wallenburg, 2012).

Risk mitigation

Based on data collected in previous SCRM practices, risk mitigation seeks to address SC risks with appropriate measures through mitigation strategies before the disruption occurs or

through contingency plans after the event unfolds (Azadegan et al., 2020; Chopra et al., 2007; Manuj and Mentzer, 2008; Wagner and Bode, 2006). The efficiency of risk mitigation depends on the close collaboration with SC partners and the recognition of SCRM practices' importance within the firm (Berg et al., 2008; Fan and Stevenson, 2018; Wieland and Wallenburg, 2012; Zsidisin et al., 2004). The results obtained by risk mitigation will be useful in the subsequent stage of risk control (Fan and Stevenson, 2018; Wieland and Wallenburg, 2012).

Risk control

Several studies highlight the role of risk control in reducing the frequency and impacts of SC risks; hence the need to evaluate the performance of SCRM practices (Berg et al., 2008; Manuj and Mentzer, 2008; Wieland and Wallenburg, 2012). Risk control is ensured through systematic processes, preparedness, risk awareness of employees, articulated procedures and elaborated plans (Berg et al., 2008; Manuj and Mentzer, 2008; Matook et al., 2009; Wagner and Bode, 2008; Zsidisin et al., 2004).

Given the fact that COVID-19 SC disruptions have damaged the availability of several SCs (Araz et al., 2020; Ivanov, 2020), and the way firms manage their processes including their SCRM processes, we propose the following hypothesis:

H1. Disruptions impacts influence significantly and negatively supply chain risk management practices, i.e. Risk identification (H1a), Risk assessment (H1b), Risk mitigation (H1c) and Risk control (H1d).

3.2.Disruptions impacts, supply chains robustness and resilience

SCs environments generate many causes of uncertainties and vulnerabilities for firms (Chapman et al., 2002; Peck, 2005; Svensson, 2004). The multiplicity of crises (financial, economic, social, ecological and political) has drawn the attention of scholars to the necessity of investigating SC resilience and robustness. SCs' resilience and robustness have been

conceptualized in several studies on firms' responsiveness to risks by dynamic adaptation to situations (Dolgui et al., 2020; Pettit et al., 2019; Scholten et al., 2019). In the context of COVID-19 outbreak, firms' survival, and growth in a turbulent period have become a pressing issue for scholars (Ivanov, 2020; Ivanov and Dolgui, 2020) and practitioners (van Hoek, 2020).

Numerous definitions of SC resilience exist. For instance, it is defined by Rice and Caniato (2003) as the ability to respond to an unexpected disturbance and then restore operations to normal, for Sheffi (2005) it relates to the containment of disturbances and subsequent recovery and Pettit et al. (2013) consider SC resilience as the capability to anticipate and overcome SC disruptions. A more complete definition has been offered by Yao and Fabbe-Costes (2018, p. 260): *"Resilience is a complex, collective, adaptive capability of organizations in the supply network to maintain a dynamic equilibrium, react to and recover from a disruptive event, and to regain performance by absorbing negative impacts, responding to unexpected changes, and capitalizing on the knowledge of success or failure"*.

Robustness is a common topic in SCM research due to the ever-increasing volatility in SCs (Christopher and Holweg, 2011) and its direct influence on business performance (Wieland and Wallenburg, 2012; Ivanov and Dolgui, 2020). SC robustness is considered as a proactive strategy to cope with changes, turbulences or disruptions (Chowdhury and Quaddus, 2017; Durach et al., 2015; Wieland and Wallenburg, 2012 and 2013). Tang (2006, p. 36) defines a "robust strategy" as a strategy which will *"enable a firm to manage regular fluctuations efficiently under normal circumstances regardless of the occurrence of major disruptions"* and *"will help a firm to sustain its operations during a major disruption"*.

The main difference between the concepts lies in the fact that robustness relates to firm's ability to maintain its planned performance following a disruption (or a series of disruptions) impacts (Nair and Vidal, 2011; Simchi-Levi et al., 2018), whereas resilience concerns the

ability to recover the performance after having absorbed the disruption effects (Spiegler et al., 2012; Hosseini et al., 2019).

Drawing on the aforementioned arguments, we propose the following hypotheses:

H2. Supply chain resilience is negatively influenced by disruptions impacts

H3. Supply chain robustness is negatively influenced by disruptions impacts

3.3.Disruptions impacts, SCRM practices, supply chains robustness and resilience

Several scholars hint at the link between firms' SCRM practices and SC robustness and resilience (Ambulkar et al., 2015; Bode et al., 2011; Chowdhury and Quaddus, 2017; DuHadway et al., 2019). In order to develop SC robustness, firms need to set up measures to reduce SC vulnerability which involves scanning for risks and dealing with them before their occurrence (Azadegan et al., 2013; Tang, 2006). Also, firms who analyze their network to identify sources of risks, can withstand better the disruption effects and recover faster (Ivanov and Sokolov, 2013). Overall, firms who learn from their SC environment how to identify threats, can build proactively capabilities that improve their responsiveness to SC disruptions (Blackhurst et al., 2011; Bode et al., 2011; DuHadway et al., 2019; Ramaswami et al., 2009). Leveraging and reconfiguring resources becomes a key factor to recover from disruption and maintain performance. Therefore, in a situation of disruption such as COVID-19 epidemic, firms' reconfiguration and deployment of resources/capabilities through SCRM help them cope with disruption impacts and maintain SC resilience and robustness.

In high disruption impact situations, the firm's ability to reconfigure resources might act as a mechanism to develop resilience and robustness to SC disruptions.

Having argued above that SCRM practices are influenced by disruption impacts (hypotheses 1a, 1b and 1c), and SC resilience and robustness have been linked above to disruptions impacts (hypotheses 2 and 3), we suggest that disruption impacts can have indirect implications on firms' SC resilience and robustness through SCRM practices.

In other words, disruption impacts affect SCRM practices, which in turn influence SC resilience and robustness. Based on the previous arguments, and considering the various SCRM practices, our study tests the following hypotheses:

H.4. Supply chain resilience is influenced positively by supply chain risk management practices i.e. Risk identification (H4a), Risk assessment (H4b), Risk mitigation (H4c) and Risk control (H4d).

H.5. Supply chain robustness is influenced positively by supply chain risk management practices i.e. Risk identification (H5a), Risk assessment (H5b), Risk mitigation (H5c) and Risk control (H5d).

The research model is summarized in Figure 1.

--- insert Figure 1 ---

4. Research method

4.1. Research design

The data were collected through a survey administered in 2020 to a random sample of 3411 companies in France. The survey was first tested by 8 academics and 7 SC managers to ensure that all measurement items were clear. After integrating final improvements, the survey was administered via e-mail to managers and executives with a letter presenting the goal of the study. We received 470 completed surveys, indicating a 13.77% response rate. According to Dillman (2000), a response rate ranging from 6% to 16% is considered acceptable. The collected responses exceed the sufficient range for partial least squares structural equation modelling (PLS-SEM) analysis (Chin, 2010). Furthermore, we conducted "a priori" and post-hoc power analyses using the G*Power tool to assess the adequacy of the sample size (Faul et al., 2009). Following the recommendations of Cohen (1988), the analyses were based on minimum values, i.e., a minimum R^2 value of 0.10, a statistical power of 80%, and five predictors for SC robustness and SC resilience constructs. The "a priori" G*Power estimation

indicated that a sample size of 134 was required. The post-hoc G*Power estimation for a minimum R^2 of 0.10, a sample size of 470, and five predictors revealed that the statistical power reached through the study's sample size was 0.99, which is well above Cohen's (1988) recommendations.

We performed an analysis of non-response bias to check the validity of the data. Following Werner et al. (2007), we determined the differences between early and late respondents and found that no difference was significant (respectively, N=280 and N=190) in terms of firm sector, turnover and employees' number (t=.630; p=.428; t=.749; p=.387; and t=.106; p=.745 respectively). Thus, non-response bias was not problematic in our study.

Moreover, in line with Podsakoff et al. (2003), we tested for common method bias ex ante and post ante. Regarding ex ante analysis, data were carefully collected from respondents who possessed relevant knowledge in the subject area of SCRM (the executives, the operations management and purchase directors). Furthermore, the anonymity of respondents was guaranteed, and the designed questions were formulated in a direct manner to avoid ambiguity. In addition, the independent and dependent constructs of the survey were separated and double-barreled questions were avoided. Following data gathering, we performed post-hoc analysis to check for common method bias (CMB) using Harman's (1967) one factor test. The eigenvalue unrotated exploratory factor analysis solution revealed five factors, with the highest portion of the variance explained by a single factor being 35.13%. This result showed that CMB was unlikely to be an issue for this study, as most of the variance was not due to a single factor (Fraj et al., 2015). Finally, we performed the latent factor test to provide additional support to common method bias absence (Podsakoff et al., 2003). Consequently, we introduced a latent factor to the original measurement model and the comparison of the results obtained between the structural models with and without the latent

factor revealed no significant differences. A summary of the sample characteristics is provided in Table 1.

--- insert Table 1 ---

4.2. Construct measures

All measures were adapted from validated instruments in prior literature. In our research, we mobilize seven constructs: *COVID-19 Disruption impacts, Identifying SC risk, Assessing SC risk, Mitigating SC risk, Controlling SC risk, SC Robustness* and *SC Resilience.*

Disruption impacts items were adapted from several studies (Ambulkar et al., 2015; Bode et al., 2011; DuHadway et al., 2019). The scale measures how SC disruptions reported by the respondents impacted their firm's overall efficiency of operations (disrupt1), delivery reliability to customers (disrupt2), and procurement costs of supplies (disrupt3). The measurement items were measured using a seven-point scale (1 = not at all, 7 = a large extent).

Drawing on prior studies (Chowdhury and Quaddus, 2017; Kern et al., 2012; Wieland and Wallenburg, 2012) SCRM practices were measured based on four processes, namely: risk identification, risk assessment, risk mitigation and risk control.

For SC Risk identification, the respondents were asked to indicate to what extent they are informed about risks in their SC (identify1), how they search for short term risk (identify2), their data gathering (identify3) and their definition of early warning indicators (identify4).

SC Risk assessments consists of five items related to identifying the sources of SC risks (assess1), the evaluation of supply risks probability (assess2), the analysis of risks' impacts (assess3), the classification of supply risks (assess4), and the evaluation of SC risks urgency (assess5).

SC Risk mitigation is composed of three items that measure the respondents' reactive strategies to SC risks (mitigate1), the evaluation of such reactive strategies (mitigate2) and the importance of SCRM practices (mitigate3).

SC Risk control is measured using four items related to respondents sensibilization of employees to the perception of SC risks (control1), the professional design of risk management processes (control2), minimization of SC risks' occurrence probability (control3), and minimization of the SC risks impacts (control4).

All SCRM practices were measured each on a 7-point Likert-type scale (1 = strongly disagree, 7 = strongly agree).

Based on previous studies (Ambulkar et al., 2015; Bode et al., 2011; Wieland and Wallenburg, 2012) SC resilience was operationalized using four items measured on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree). The items measure the ability of the SC to cope with changes due to a SC disruption (resil1), the ability to adapt to a SC disruption (resil2), the ability to provide a quick response (resil3), and the ability to maintain high situational awareness (resil4).

Drawing on extant literature (Ambulkar et al., 2015; Bode et al., 2011; Chowdhury and Quaddus, 2017), SC robustness was operationalized using four items measured on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree). The items measure the ability of the SC to retain the same stable situation as it had before some changes occur (robust1), the ability to develop a reasonable reaction to disruptions (robust2), the adaptations of the firm through developing a wide variety of possible scenarios (robust3), and the capacity of the firms' SC to functions despite some damage done to it (robust4).

We also controlled for the size of the firm which was measured using the annual sales (Azadegan et al., 2020). Large firms tend to have access to a greater number of resources and better control of their SCRM practices (Ambulkar et al., 2015; Bode et al., 2011). However,

smaller firms, may have the ability to be nimble in the face of adversity, due to the shorter chain of command (Chowdhury and Quaddus, 2017; Ramaswami et al., 2009).

A summary of the items constructs is provided in Appendix A.

4.3. Data analysis

For this study, we employed variance-based, structural equation modeling (partial least squares: PLS-SEM) using SmartPLS (v. 3.2.6) (Ringle et al., 2017). This method was preferred to investigate our research questions because PLS is a predictive method that deals with complex models (Sarstedt et al., 2017; 2020), which is the case of this study with seven constructs. In addition, PLS-SEM offers more flexibility by avoiding inadmissible solutions and factor indeterminacy issues (Fornell and Bookstein, 1982).

Moreover, PLS-SEM approach is useful for theory development when models are complex and in an explorative stage (Nitzl, 2016). This is the case of research on SCRM which has been somewhat arbitrary when it comes to theoretical foundations (Fan and Stevenson, 2018). Furthermore, the use of broader theories is rather scarce in the empirical studies on SCRM (Fan and Stevenson, 2018; Prakash et al., 2017). Accordingly, our research model should be investigated in a rather data-driven manner (Chenhall, 2012; Nitzl, 2016) in adequacy with prediction-oriented PLS-SEM approach (Hair, et al., 2019).

In this study, the model was analyzed following a two-step approach: (i) assessment of the reliability and validity of the measurement model, and (ii) examination of the structural model (Chin, 2010).

5. Results

5.1. Measurement model assessment

Assessing the research model involves deciding whether the constructs were reflective or formative. In numerous studies (e.g. Chowdhury and Quaddus, 2017, Ambulkar et al., 2015;

Wieland and Wallenburg, 2012) the constructs of disruption impacts, SCRM practices, SC resilience and robustness were considered reflective. The conditions listed by Jarvis et al. (2003) and Chin et al. (2010) also reinforce the same perspective. Thus, in reflective constructs, *"changes in the underlying construct are hypothesized to cause changes in the indicators"* (Jarvis et al., 2003, p. 200), i.e. the variations in the latent construct will cause all of its measures to reflect such change.

The adequacy of the measurement model of all constructs was assessed through (i) item loadings and composite reliabilities, (ii) convergent validity (AVE), and (iii) discriminant validity (Table 2). Thus, the reliability of the items was established, as all outer loadings were above the 0.70 threshold and both Dillon-Goldstein's rho (composite reliability) and Cronbach's α values were above the lower limit of 0.60 (Hair et al., 2017). Furthermore, the convergent validity values of all constructs were above the threshold of 0.50 (Table 2).

--- insert Table 2 ---

To check discriminant validity, we followed two approaches. First, we checked Fornell and Larcker's (1982) criterion, which requires the square root of AVE for each construct to be higher than its correlation with all other constructs. Table 3 indicates that this criterion was met for all constructs. Second, we used Henseler et al. (2016) heterotrait-monotrait ratio (HTMT) approach. HTMT values for the constructs ranged from 0.013 to 0.869 (see Table 2), which were below the limit of 0.90 (Henseler et al., 2016). Moreover, we assessed the HTMT inference through the bootstrap method to control if HTMT was significantly different from 1. The confidence intervals (not presented) for each combination of constructs in the model indicate that value 1 falls outside the confidence ranges (HTMT < 1). Thus, the results of the three criteria used in this study (Fornell-Larcker, $HTMT_{.90}$, and $HTMT_{inference}$) corroborate the discriminant validity of the constructs.

--- insert Table 3 ---

We assessed the quality of the structural model (Table 4). SC disruption impacts explain three practices of SCRM that have a substantial R^2 (0.56, 0.57 and 0.54) according to Hair et al. (2017); whereas one of them (identify) has a limited R^2 (0.051). The four SCRM practices explain 0.285 of SC resilience and 0.200 of SC robustness.

Also, the predictive relevance of the model was supported, as the Stone-Geisser Q^2 values were larger than zero (The four SCRM have values of Q^2= 0.029, 0.402, 0.426, 0.391 respectively, Q^2= 0.189 for SC resilience, and Q^2= 0.102 for SC robustness).

SmartPLS 3.0 provides an index of overall model quality to validate the research model. This index is called the standardized root mean square residual (SRMR) and a value less than 0.08 is considered a good fit (Hu and Bentler, 1998). Since SRMR=0.06 this indicates significant model quality. Moreover, the normed fit index (NFI) was 0.951 (> 0.90), indicating good model fit (Hair et al., 2019).

--- insert Table 4 ---

5.2. Structural model analysis

The results of the PLS structural model analysis are depicted in Table 5. The two analyses (i.e., correlations and PLS path coefficients) are used collaboratively to explain the relationships among variables. We used the bootstrap resampling method that stabilizes the β coefficient estimates to calculate the error and thereby determine the significance of these coefficients.

--- insert Table 5 ---

The results show negative and significant direct relationship between disruptions impacts and SC risk identification, SC risk assessment and SC robustness. Such findings demonstrate the negative impact of COVID-19 on firms SCRM practices and their ability to regain their performance. Therefore, H1a, H1b and H3 are supported. Conversely, no significant direct

effect of distribution impacts was found either on SC resilience or SC risk mitigation and control. Hence, H1c, H1d and H2 were rejected.

Moreover, the findings indicate the positive and significant effect of all SCRM practices on SC resilience; whereas for SC robustness, only SC risk identification and control had positive and significant effect. Consequently, H4, H5a and H5d are supported. On the other hand, we found no significant direct effect of SC risk assessment and mitigation on SC robustness. Therefore, H5b and H5c were rejected.

Also, the results reveal a difference in terms of firms' size regarding their SC risk identification (β=0.118, $p < .05$) and mitigation (β=0.077, $p < .05$).

Regarding indirect effects, we adopt the approach of Zhao et al. (2010) and Nitzl et al. (2016) to characterize the mediation relationships between constructs (Table 4). Specifically, there are two types of nonmediation:

- Direct-only nonmediation: The direct effect is significant but not the indirect effect; and
- No-effect nonmediation: Neither the direct nor indirect effect is significant.

Moreover, there are three types of mediation:

- Complementary mediation: Both of the direct and indirect effects are significant and point in the same direction;
- Competitive mediation: The direct and indirect effects are both significant and point in opposite directions; and
- Indirect-only mediation: The indirect effect is significant but not the direct effect.

Hence, mediation may not exist at all (i.e., direct-only non-mediation and no-effect non-mediation) or, in case of a mediation, the mediator construct accounts either for some (i.e., complementary and competitive mediation) or for all of the observed relationship between two latent variables (i.e., indirect-only mediation). Overall, the results show a negative and

significant indirect relationship between disruptions impacts and SC risk assessment (complementary mediation) and SC resilience (indirect mediation). Furthermore, the findings reveal positive and significant indirect effects between SCRM practices and SC resilience (complementary mediations) and robustness (complementary and indirect mediations).

5.3. Additional analysis

To further explore the model results, we conducted an additional analysis, i.e., importance-performance map analysis (IPMA) to determine the constructs with major role in predicting SC resilience and robustness. The results in Table 6 show that risk assessment has the biggest performance in both of SC resilience and robustness. However, it is risk identification and control that have the biggest importance in building SC robustness with respective values of 0.317 and 0.257. This means that one-unit rise in SC risk identification from 57.203 to 58.203 would improve robustness by 0.317 points and one-unit rise in SC risk control would raise SC robustness by 0.257 points. Consequently, companies wishing to improve their SC robustness would have to focus on how they identify and control SC risks. Regarding SC resilience, SC risk identification and control are important, but the greatest importance is obtained by risk mitigation. That means that the priority in SC resilience for companies should be enhancing risk mitigation.

--- insert Table 6 ---

6. Discussion

This study analyzed the role of SCRM in absorbing disruptions impacts and building SC resilience and robustness. COVID-19 seems to affect negatively how firms identify and assess SC risk due to the amplitude of sudden disturbances at the global scale that few firms were able to predict in advance. The findings indicate that COVID-19 disruption impacts have affected mainly SC robustness thus creating a short-term negative effect. However, SC

resilience was not directly affected by disruption impacts as most of the firms seem to think that they have been able (or will be able) to recover and regain their previous SC performance level.

SC resilience and robustness require different combinations of resources, capabilities and processes. In the context of Covid-19, this difference can be explained by the specificities related to SC resilience and robustness. As stipulated by Ivanov (2020) and Ivanov and Dolgui (2020), SC robustness can be built without structural changes, whereas SC resilience is a disruption driven concept that needs specific adaptations by firms. Thus, the findings reveal that the four SCRM practices influence positively SC resilience, whereas only SC risk identification and control have direct positive effects on SC robustness.

The findings reveal that all SCRM practices influence positively SC resilience which corroborates the proposition of DuHadway et al. (2019) regarding recovery efforts needed for SC resilience. However, only SC risk identification and control have a direct positive effect on SC robustness. Such results offer more nuances to prior literature on SCRM practices (Ambulkar et al., 2015; Kern et al., 2012; Wieland and Wallenburg, 2012).

Thus, our study indicates which SCRM practices affect positively SC robustness following the sudden Covid-19 outbreak (i.e. SC risk identification or being informed about potential threats and SC control or how SC risk processes are designed). Moreover; the indirect effects highlighted in our study underline the mediating effects of SCRM practices that help firms to restore SC operations, contain disturbances and recover their planned performance. Consequently, our study provides further support to the RBV and dynamic capabilities approach by identifying the key SCRM processes to rely on in order to enhance SC resilience and robustness as dynamic capabilities.

Furthermore, the findings corroborate the suggestions of OIP theory regarding the importance of processing information to deal with uncertainty. Indeed, as the results indicate, SC risk

identification plays a major role in SC resilience and robustness (having the biggest β, t and importance values). Thus, the way SC risk is identified influences how firms might assess, mitigate and control the threats. Positive indirect effects emerge when firms initiate efficient SC risk identification because of the interconnectedness of SCRM practices (Fan and Stevenson, 2018; Wieland and Wallenburg, 2012).Despite the insignificant direct effect of SC risk assessment and mitigation on SC robustness, positive indirect effects of such practices indicate that firms confronted with the unprecedented threats of current COVID-19 situation, were forced to 'improvise' new measures of risk assessment and processing. Ultimately, the combination of such practices contributed to generate a positive impact of SC risk control on SC robustness.

Finally, the findings provide additional insights regarding the firms' size and their SCRM practices. Specifically, we have found a positive impact of size on SC risk identification and mitigation. Hence, the larger the firm, the more its ability to initiate SC risk identification and mitigation. Firms with large size are able to use resources, capabilities and processes, whereas SMEs are often affected by shortages in resources when they want to deploy strategic initiatives (Chowdhury and Quaddus, 2017; Ramaswami et al., 2009). Conversely, no significant direct effect of size on SC risk assessment and control was found but the indirect effects were significant. Such results suggest that: (i) regardless of size, firms tend to adopt similar approaches to evaluate the potential threats of COVID-19 and minimize its impact or (ii) due to the rapid COVID-19 outbreak small and large firms did not have sufficient time to deploy adequate SC risk assessment and control practices. Such findings shed light on the differences in SCRM practices based on firm's size and provide foundation for further research avenues.

7. Conclusion

In this paper, we empirically investigated the links between disruptions impact, SCRM and SC resilience and robustness. The results provide several insights for theory and practice.

7.1. Theoretical implications

71.1 Theoretical implications for SCRM research

This research tested a comprehensive framework of SCRM practices which reinforces prior theorization of risk management in SCs (Fan and Stevenson, 2018; Kern et al., 2012; Wieland and Wallenburg, 2012). Such holistic approach of SCRM practices enables a systematic examination of their impact instead of focusing on isolated practices of risk management or on investigating merely upstream processes. The findings illustrate the need for SCRM deployment as policies and decision support mechanisms to predict and deal with SC epidemic outbreaks along the lines of prior studies in the field (e.g. Calnan et al., 2018; Esra Büyüktahtakin et al., 2018). In addition, the findings offer empirical evidence of the interconnectedness of SCRM practices in a sequential path that firms might adopt to deal with SC risks.

The positive impact of SCRM practices supports the general tenets of RBV and OIP theories which extends the past work of several researchers (e.g. Ambulkar et al., 2015; Bode et al., 2011; Kırılmaz and Erol, 2017; Wieland and Wallenburg, 2012). Thus, our study demonstrates the potential of combining RBV and OIP theories to underline how SCRM practices at various stages in the SC can be deployed to absorb disruptions impacts.

Our findings also indicate the pivotal role played by SC risk identification and how it can influence the outcomes of SCRM management practices. In this optic, it should be noted that the collaboration with partners in the different SC stages and knowledge exchange in the identifying sources of threats can greatly influence the outcome of SCRM practices. Consequently, our study points towards the need for relational governance with the SC

members (suppliers, customers and other stakeholders) to generate better outcomes of SCRM practices.

7.1.2. Theoretical implications for research on SC resilience and robustness

This study is an attempt to contribute to SC resilience and robustness' literature and respond to the call of several scholars for more empirical research on the topic (van Hoek, 2020; Ivanov, 2020; Ivanov and Dolgui, 2020). This research also contributes to organizational theory by highlighting the applicability of RBV, dynamic capability view and OIP theories to SCRM. Thus, linking RBV, OIP and dynamic capabilities with SC robustness and resilience is an attempt to provide a clear view of how these concepts interact and how they can be assessed. In doing so, we provide additional insights to prior studies on SCRM and SC disruption (Ambulkar et al., 2015; Chowdhury and Quaddus, 2017; Ivanov, 2020).

Overall, the pivotal role of information gathering and processing in OIP theory (Galbraith, 1974) was found to influence SC robustness and resilience and consequently can be particularly useful in explaining firms' behavior during COVID-19 pandemic. In this perspective, SCRM practices can be seen as a way to reduce the usual information gap existing in disruption situations, since SC disruptions (similar to the COVID-19 epidemic context) generate ambiguity (Azadegan et al., 2020). Additionally, from an RBV and dynamic capabilities perspective, better information about resources availability is required to enhance firms' information processing capability. Thus, the combination of those theoretical perspectives in an uncertain SC context suggests that firms who master information processes of their SCRM may better improve their SC resilience (and somewhat robustness) resources and capabilities.

Finally, by investigating the disruption impacts of COVID-19, we highlight the responses of firms to the epidemic and how it affects both of their SC resilience and robustness. Therefore,

we provide a broader outlook of SC resilience and robustness assessment which extends the findings of extant literature.

7.2. Practical implications

Our findings might incite firms to voluntarily adopt SCRM initiatives or develop existing practices because of their potential benefits on SC resilience and robustness. The results provide guidance to firms about the specific conditions for SCRM practices in order to enhance their outcome. The priority of firms should be to develop efficient and updated risk identification measures because they affect the other SCRM processes. Thus, the results indicate that firms need to develop interconnected SCRM practices in order to improve their SC robustness and resilience. However, looking at COVID-19 impacts on firms' performance and financial capabilities (Gereffi, 2020), not all of them may have the necessary resources and capabilities to do so. This may create a decision dilemma for SC managers who will need to justify investigating in SCRM processes. Indeed, SCRM is often seen as an efficient tool when facing high-frequency-low-impact events (Blackhurst et al., 2005, Braunscheidel and Suresh, 2009, Norrman and Jansson, 2004) but wrongly less efficient for high-frequency-low-impact events such as epidemic outbreaks (Sodhi et al., 2012). COVID-19 disruption impacts highlight the need for network collaboration and more inter-organizational sharing of resources and capabilities. Ultimately, for firms wanting to enlarge the scope of their SCRM practices, they should try to build cooperation with other SC members to prepare for different disruptions impacts scenarios that a single firm cannot mitigate. In this optic, our results provide foundation to argue for more involvement of SC partners in firms' SCRM practices.

7.3. Limitations and further research directions

As with any research, our study is subject to several limitations that offer an opportunity for further research. First, our study adopts a cross-sectional design and investigates mainly the context of French firms. Therefore, future studies in other countries might provide data

regarding the similarities and/or differences with other contexts. Second, we have collected data at one point of time and we had no access to longitudinal data needed for investigating causality over a longer period of time. Consequently, conducting a longitudinal research might provide useful insights regarding the interaction between SCRM practices, disruption impacts, SC resilience and robustness in the long run.

Third, we focused on SC robustness and resilience as the dependent variables, whereas recent studies (Ivanov, 2020; Ivanov and Dolgui, 2020) deployed both concepts as two dimensions of SC viability. Therefore, future research might investigate the outcomes of SC resilience and robustness and particularly how both concepts might influence firms' performances (financial, operational and social). Finally, future research might be conducted to investigate in depth the conditions of developing SC resilience and robustness. More specifically, further research might examine how information processing influences both of SC resilience and robustness to complement recent studies deploying OIP theory in SCRM (e.g. Azadeghan et al., 2020; DuHadway et al., 2019).

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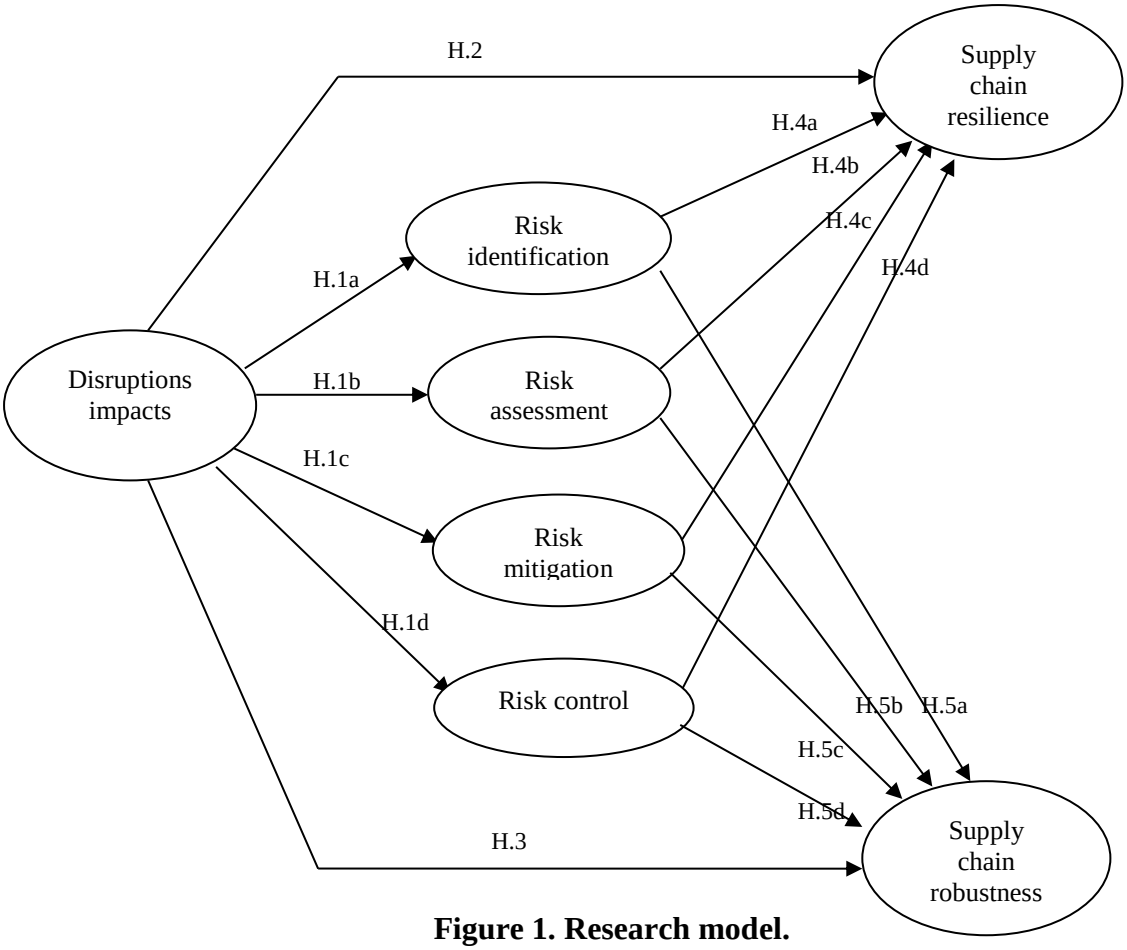

Figure 1. Research model.

Characteristics of respondents (sample=470)	Number	Percentage
Sector		
Manufacturing	215	45.7%
Energy	17	3.6%
Transport	25	5.3%
Chemicals, pharmaceuticals	77	16.4%
Retail	106	22.6%
Services and humanitarian	30	6.4%
Sales (in millions €)		
<50	89	18.9%
[50-249]	107	22.8%
[250-499]	49	10.3%
[500-999]	42	8.8%
≥1 000	183	39.1%
Experience/age of company (in years)		
< 10	30	7.3%
[10–19]	31	7.5%
[20-29]	45	10.9%
[30-39]	35	8.5%
[40-49]	72	17.5%
≥50	198	48.2%
Number of employees		
<50	35	7.4%
[50 – 249]	86	18.3%
[250-999]	82	17.4%
[1000-4999]	86	18.3%
≥5000	181	38.5%
Respondents' job titles		
Vice President (SCM, Operations, Purchasing)	37	7.9%
SC Management Director	125	26.8%
Operations Director	30	6.4%
Purchasing Director	7	1.5%
SC Manager	207	43.9%
Purchasing Manager	13	2.8%
Purchasing team member	7	1.5%
SC team member	44	9.3%

Table 1 Descriptive Statistics

Construct/Items	Loadings	Composite Reliability	Cronbach's Alpha (α)	Average Variance Extracted (Ave)
SC Disruption Impacts		0.829	0.710	0.630
Impact1	0.908			
Impact2	0.894			
Impact3	0.616			
SC Risk Identification		0.877	0.812	0.641
Ident1	0.724			
Ident2	0.785			
Ident3	0.869			
Ident4	0.818			
SC Risk Assessment		0.929	0.904	0.723
Assess1	0.836			
Assess2	0.831			
Assess3	0.888			
Assess4	0.854			
Assess5	0.843			
SC Risk Mitigation		0.901	0.835	0.753
Mitigate1	0.884			
Mitigate2	0.898			
Mitigate3	0.819			
SC Risk Control		0.916	0.876	0.731
Perfrisk1	0.792			
Perfrisk2	0.836			
Perfrisk3	0.898			
Perfrisk4	0.889			
SC Resilience		0.908	0.865	0.711
Resil1	0.845			
Resil2	0.863			
Resil3	0886			
Resil4	0.776			
SC Robustness		0.832	0.745	0.559
Robust1	0.686			
Robust2	0.683			
Robust3	0.852			
Robust4	0.836			
Control				
Size	1.00	1.00	1.00	1.00

Table 2 Estimation of the measurement model parameters

	SC Disruption impact	Identify	Assess	Mitigate	Control	SC Resilience	SC Robustness	Size
SC Disruption Impact	**0,794**	-0,123	-0,055	0,126	-0,148	0,238	0,321	-0,016
Identify	0,158	**0,801**	0,750	0,796	0,676	0,513	0,480	0,156
Assess	0,065	0,869	**0,850**	0,863	0,755	0,391	0,418	0,142
Mitigate	-0,114	0,658	0,751	**0,868**	0,733	0,512	0,421	0,173
Control	0,174	0,801	0,672	0,858	**0,855**	0,568	0,481	0,176
SC Resilience	-0,205	0,437	0,359	0,444	0,505	**0,843**	0,559	0,182
SC Robustness	-0,257	0,390	0,371	0,359	0,420	0,475	**0,748**	0,024
Size	0,030	0,173	0,135	0,190	0,189	0,193	0,061	**1,000**

Table 3 Discriminant validity coefficients*

*Diagonal elements (bold) are the square root of the variance shared between the constructs and their indicators (AVE). Below the diagonal elements are the correlations between the construct's values. Above the diagonal elements are the HTMT values.

Constructs	R^2	Q^2
Distribution impacts	-	-
Identify	0.051	0.029
Assess	0.56	0.402
Mitigate	0.57	0.426
Control	0.54	0.391
SC robustness	0.200	0.102
SC resilience	0.285	0.189

Table 4 Quality of the structural model

Hypothesis test	*Direct effect*	*T value*	*Indirect effect*	*T value*	*Total effect*	*T value*	*Mediation type*
Distribution impact → Identify	-0.137	**2.631****			-0.137	**2.631****	Direct-only nonmediation
Distribution impact →Assess	-0.069	**2.115****	**-0.105**	**2.603*****	-0.036	0.693	Complementary mediation
Distribution impact → Mitigate	-0.068	1.899	-0.026	0.691	-0.095	1.788	No-effect nonmediation
Distribution impact → Control	-0.061	1.763	-0.068	1.799	-0.130	**2.529****	No-effect nonmediation
Distribution impact → Resilience	-0.060	1.276	-0.094	**3.079*****	-0.154	**2.833*****	Indirect-only mediation
Distribution impact → Robustness	-0.264	**5.686*****	-0.040	1.758	-0.303	**6.652*****	Direct-only nonmediation
Identify→ Resilience	0.300	**4.130*****	0.041	0.735	0.342	**6.601*****	Direct-only nonmediation
Assess → Resilience	0.265	**3.363*****	0.318	**6.701*****	0.051	0.717	Complementary mediation
Mitigate → Resilience	0.190	**2.719*****	0.248	**4.722*****	0.437	**7.065*****	Complementary mediation
Control→ Resilience	0.344	**4.687*****			0.342	**4.687*****	Direct-only nonmediation
Identify→ Robustness	0.145	**2.037****	0.174	**3.322*****	0.319	**6.452*****	Complementary mediation
Assess → Robustness	0.098	1.283	0.128	**2.228****	0.226	**3.358*****	Indirect-only mediation
Mitigate → Robustness	0.049	0.587	0.128	**2.222****	0.177	**2.252****	Indirect-only mediation
Control→ Robustness	0.177	**2.278****			0.177	**2.278****	Direct-only nonmediation
Size → Identify	0.118	**2.241****			0.118	**2.241****	Direct-only nonmediation
Size→Assess	0.022	0.615	0.091	**2.226****	0.114	**2.175****	Indirect-only mediation
Size → Mitigate	0.077	**2.085****	0.083	**2.169****	0.159	**3.056*****	Complementary mediation
Size → Control	0.049	1.384	0.115	**3.030*****	0.164	**3.198*****	Indirect-only mediation

Table 5 PLS structural model

***p<0.01, **p<0.05

Constructs	SC Robustness		SC Resilience	
	Importance	Performance	Importance	Performance
Distribution impacts	-0.056	54.397	-0.079	54.397
Identify	0.317	57.203	0.324	57.203
Assess	0.222	63.751	0.148	63.751
Mitigate	0.201	55.323	0.418	55.323
Control	0.257	54.126	0.341	54.126

Table 6 PLS-IPMA results

Appendix A. Construct Items

Construct	Items	Indicator
SC Disruption Impacts	*How did COVID-19 disruption negatively affect…*	
	Impact1	Overall efficiency of operations
	Impact2	Lead time for delivery (delivery reliability)
	Impact3	Purchasing costs for supply
Risk Identification	*To what extent do these statements apply to your supply chain?*	
	Ident1	We are comprehensively informed about basically possible risks in our supply chain
	Ident2	We are constantly searching for short-term risks in our supply chain
	Ident3	In the course of our risk analysis for all suppliers and SC partners, we select relevant observation fields for supply risks
	Ident4	In the course of our risk analysis for all SC partners, we define early warning indicators
Risk Assessment	*To what extent do these statements apply to your supply chain?*	
	Assess1	In the course of our risk analysis we look for the possible sources of supply chain risks
	Assess2	In the course of our risk analysis we evaluate the probability of supply chain risks
	Assess3	In the course of our risk analysis we analyze the possible impact of supply chain risks
	Assess4	In the course of our risk analysis, we classify and prioritize our supply chain risks
	Assess5	In the course of our risk analysis, we evaluate the urgency of our supply chain risks
Risk Mitigation	*To what extent do these statements apply to your supply chain?*	
	Mitigate1	In the course of our risk analysis, we demonstrate possible reaction strategies
	Mitigate2	In the course of our risk analysis, we evaluate the effectiveness of possible reaction strategies
	Mitigate3	Supply chain risk management is an important activity in our company
Risk Control	*To what extent do these statements apply to your supply chain?*	
	Perfrisk1	Our employees are highly sensitized for the perception of supply risks
	Perfrisk2	Our risk management processes are very professionally designed
	Perfrisk3	We have clearly managed to minimize the frequency of occurrence of supply chain risks over the last three years
	Perfrisk4	We have clearly managed to minimize the impact of occurrence of supply chain risks over the last three years
SC Resilience		To what extent do these statements apply to your supply chain?
	Resil1	We are able to cope with changes brought by the supply chain disruption
	Resil2	We are able to adapt to the supply chain disruption easily.
	Resil3	We are able to provide a quick response to the supply chain disruption
	Resil4	We are able to maintain high situational awareness at all times.
SC Robustness	*To what extent do these statements apply to your supply chain?*	
	Robust1	For a long time, our supply chain retains the same stable situation as it had before some changes occur
	Robust2	When changes occur, our supply chain grants us much time to consider a reasonable reaction
	Robust3	Without adaptations being necessary, our supply chain performs well over a wide variety of possible scenarios
	Robust4	For a long time, our supply chain is able to carry out its functions despite some damage done to it