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Driving collaborative supply risk mitigation in buyer-supplier relationships

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ABSTRACT
This study develops and tests a theory-driven conceptual model that explains variations in collaborative supply risk mitigation. It is based on data collected from manufacturing firms in Norway. The results show that collaborative risk identification, perception of supply risks, and overall focus on mitigating disruptive risks have a significant direct effect on collaborative supply risk mitigation. Further, an increase in collaborative risk identification strengthens the effect that perceived supply risk has on the level of collaborative risk mitigation, while supplier performance weakens the effect of perceived supply risk on the level of collaborative supply risk mitigation. Finally, the importance-performance map analysis shows that collaborative risk identification and the buying firm's overall focus on mitigating disruptive risks are the most important factors to explain variations in collaborative risk mitigation efforts. On the basis of the results, relevant theoretical implications are discussed and actionable managerial recommendations are provided.

KEYWORDS
Supply risk; collaborative supply risk mitigation; supplier performance; collaborative risk identification

Introduction

The outbreak of the COVID-19 pandemic and its repercussions on supply chains (SCs) has exacerbated concerns about SC risks. This is understandable considering the enormous impact that the pandemic has had on trade and global SCs (ILO 2020). In many ways, the pandemic has proved that SCs need to be more resilient (Linton and Vakil 2020). Even before the pandemic, increased complexity in SCs had attracted considerable interest in supply risk management from academics and practitioners alike. For instance, based on responses from nearly 500 chief procurement officers (CPOs) across the globe, Deloitte (2019) noted that one word to describe the scenario CPOs were facing is *complexity*. They found that most of the respondents (61%) felt procurement-related risks had increased compared with the previous year. Andres and Marcucci (2020) suggest that increased uncertainty and competition in the current global business environment mean businesses are highly exposed to disruptive events. This is a plausible notion because as complexity and uncertainties in SCs increase, so does firms' vulnerability to supply risks and disruptions (Sharma and Sharma 2015). Therefore, effective risk management is essential for preventing and mitigating SC disruptions (Bevilacqua et al. 2020).

One of the approaches to prevent and mitigate supply disruptions is collaborating with suppliers (Remko, 2020). As Andres and Marcucci (2020) suggest, since disruptive events exceed individual actors' capabilities, partners must collaborate to alleviate the negative impacts these may have on business performance. Collaboration with suppliers is vital for addressing the economic aspects of SCs as well as social and environmental issues (Guerrini and Yamanari 2019). This premise is supported by Sharma *et al*. (2020), who identified collaboration with suppliers as one of the essential factors that can enhance the survivability of sustainable SCs during and post-the COVID-19 pandemic. Although the extant literature acknowledges collaboration as a critical factor in handling disruptions, collaborative supply risk mitigation has received limited research attention (Bak 2018; Friday et al. 2018). This is surprising considering the well-known fact that firms no longer compete individually but rather as SCs. Thus, firms that engage in collaborative processes are better positioned to respond to unexpected changes in extreme situations (Andres and Marcucci 2020). Although firms must consider collaboration beyond first-tier suppliers (Mwesiumo et al. In Press), Nejma and Cherkaoui (2020) suggest that collaborative risk mitigation strategies should begin in dyads, namely buyer-supplier links.

Our study contributes to knowledge about collaborative supply risk mitigation by developing and testing a theory-driven conceptual model that explains variations in collaborative supply risk mitigation in buyer-supplier relationships. We apply transaction cost economics (TCE) and relational contracting theory to investigate the role of perceived supply risk, supplier performance and collaborative risk identification as

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drivers of collaborative supply risk mitigation in buyer-supplier relationships. Specifically, we examine the effect of these three variables on the level of collaborative supply risk mitigation. Further, this study implements a contingent approach by investigating the interaction effects of perceived supply risk, supplier performance and collaborative risk identification. This approach is valuable because, as González-Zapatero et al. (2020) note, contingent approaches are crucial for advancing research in supply chain risk management (SCRM). Thus, our study provides actionable theoretical and managerial implications related to SCRM.

In terms of methodology, this study implemented a survey design involving data collection through a self-administered questionnaire. The respondents were managers representing Norwegian firms operating in different industries. The analysis was carried out using partial least squares structural equation modelling (PLS-SEM), a method that has recently become popular in business research, including studies within supply chain management (e.g. Breitling 2019; Gupta et al. 2020; Sislian and Jaegler 2020). PLS-SEM allowed us to estimate the relationships between multi-indicator constructs considered in the study. The remainder of the paper presents theoretical background and hypotheses, with arguments to support tentative answers to the research questions. This is followed by study methodology, analysis, results and discussion.

Theoretical background and hypotheses

This section presents extant literature related to collaborative supply risk mitigation and study hypotheses.

Defining collaborative supply risk mitigation

This paper defines supply risk mitigation as a deliberate activity and process geared towards eliminating or reducing the probability of a risk occurring and its impact. Typical supply risk mitigation strategies include switching suppliers and product substitution (Pellegrino, Costantino, and Tauro 2019), shifting orders among suppliers (Kırılmaz and Erol 2017), and bridging and buffering strategies (Mishra et al. 2016). It also involves multiple sourcing, increasing flexibility, pooling demand, supplier development activities, early supplier involvement in product design, and supplier audits (Hoffmann, Schiele, and Krabbendam 2013; Lampon 2020). Often these activities are deployed as hedging against randomness and hazards (Klibi, Martel, and Guitouni 2010). Although buying firms may be tempted to implement most risk mitigation activities themselves, collaboration with suppliers is critical. Jüttner (2005) argues that the risk mitigation process within a SC must be a coordinated activity because individual firms may be unable to bear the risk or may find it too costly to act alone. Collaboration is vital since most of the supply risk mitigation activities deployed within the buying firm will impact its suppliers (Chen, Sohal, and Prajogo 2013).

According to Sawalha (2014), a collaborative risk strategy involves the coordination of joint efforts before, during and after a major incident, in an attempt to prevent or mitigate its adverse consequences through effective utilisation of technology, unique leadership, teamwork and communication. Therefore, it can be seen as a strategic positioning of resources that aim at obtaining an SC structure that contributes to resilience (Klibi, Martel, and Guitouni 2010). Friday et al. (2018) propose a new definition of collaborative risk management, incorporating insights missing from the SCRM and a buyer-supplier relationship view. They define collaborative risk management as 'an interactive process based on a mutual commitment between firms with a common objective to join efforts and mitigate SC risks and related disruptions, through co-development of strategic relational capabilities and sharing of resources' (p. 238). Thus, collaboration, integration and cooperation emerge as elements critical to achieving supply risk mitigation (Colicchia and Strozzi, 2012; Sawalha 2014). Five hypotheses are developed in the following sections as tentative explanations for the variation in collaborative supply risk mitigation.

Perceived supply risk and collaborative supply risk mitigation

This paper defines perceived supply risk as a buying firm's perception of the magnitude of the likelihood and impact of supply failure. Such failure can be due to a variety of reasons, such as supplier bankruptcy, natural calamities, economic crisis, and supplier's production failure, to name but a few. In TCE (Williamson 1985), these sources of supply failure are viewed as uncertainties that a buying firm has to take into account when engaging with its suppliers. Thus, the buying firm must identify all possible contingencies and draw up contractual clauses to address them. As this is practically impossible, designing a contract that guards against all imaginable future events becomes a challenge (Heckmann and Nickel 2017). As such, formal contracting schemes should be complemented by relational contracting, which can compensate for the limitations of incomplete contracts (Pinnington and Ayoub 2019; Wang et al. 2019). At the core, relational contracting is manifested by relational behaviours between exchange partners. Such behaviours include flexibility (willingness to adapt to change), information exchange (sharing of valuable information), and solidarity (supporting each other regardless of the circumstances) (Brown, Cobb, and Lusch 2006). These behaviours can bridge the gaps in formal contracts and consequently enhance firms' responsiveness (Blanquart and Carbone 2014).

Against this theoretical backdrop, this paper argues that due to uncertainties and complexities inherent in SCs (Sharma and Sharma 2015; Andres and Marcucci 2020), and the difficulty in achieving complete formal contracts (Zhao, Zhang, and Cheng 2020), a perceived high risk of supply failure should lead to a firm's preference to address risks through a relational mechanism. That is, relying on trust, flexibility, solidarity and information sharing instead of strict contractual terms. In essence, this mechanism entails collaboration between the buying firm and its suppliers. As Remko (2020) shows, most of the executives involved in their study recognised the significance of collaborating with suppliers to respond to the ramifications of the COVID-19 pandemic. This recognition aligns with the premise, popular in the literature, that collaborative strategies are vital in managing disruptions (Jüttner 2005; Andres and Marcucci 2020). In line with this notion, we argue that increased concern for potential supply failure should improve buyer-supplier collaborative supply risk mitigation. Based on this rationale, the first hypothesis is proposed:

H1: Perceived supply risk is positively associated with the level of collaborative supply risk mitigation.

Supplier performance and collaborative supply risk mitigation

This paper refers to supplier performance as the buying firm's evaluation of how well the supplying firm accomplishes its tasks (Paparoidamis, Katsikeas, and Chumpitaz 2019). When supplier performance is good, the buying firm's confidence in the supplier is likely to increase, reducing its concerns about potential supply failure (Grötsch, Blome, and Schleper 2013; Heckmann and Nickel 2017). According to TCE, firms strive to minimise transactional costs (Williamson 1985). Examples include costs related to searching for and negotiating with suppliers, monitoring supplier performance, and handling conflicts. Thus, besides competence and power to influence transactions, TCE addresses the efficiency implications of interfirm exchange (Ketokivi and Mahoney, 2020) and suggests that firms ensure efficiency by deploying appropriate governance mechanisms (Mwesiumo, Buvik, and Andersen 2018). Choosing an efficient governance mechanism requires addressing aspects such as creating SC relationships that enable the transfer of components and intermediate products from one production stage to another in an economically efficient way, ensuring that resources are not wasted in the exchange relationship (Ketokivi and Mahoney, 2020).

Since collaborative supply risk mitigation efforts are likely to increase transactional costs related to coordination, TCE predicts that firms would find ways to minimise such costs whenever possible. In the context of SCRM, we propose that firms would begin by assessing their supply situation and invest in collaborative risk mitigation activities only if necessary. Such assessment includes evaluating whether the supplier can be trusted to handle risks (Mwesiumo et al. In Press). Typically, suppliers demonstrate trustworthiness through actions such as making considerable buyer-specific investments. Consistent with this view, we argue that supplier performance can also act to increase the buyer's confidence in the supplier's capability. In line with TCE, increased confidence will lead to reduced collaborative risk mitigation efforts as a way of minimising transactional costs. Moreover, grounded in contingency logic (González-Zapatero et al. 2020), we argue that even when the buying firm perceives supply risk to be high, the supplier's previous performance will reduce the effect that this perception would have on the buying firm's concerns for potential supply failure. Thus, we propose the following hypotheses:

H2: Supplier performance is negatively associated with collaborative supply risk mitigation.

H3: An increase in supplier performance attenuates the association between perceived supply risk and the level of collaborative supply risk mitigation.

Effect of collaborative risk identification

Risk identification is the first step in risk management, the cornerstone of any further steps (Andres and Marcucci 2020). It is a trigger for subsequent risk management activities. As such, collaborative supply risk mitigation can not occur without risk identification. While buying firms can identify risks themselves, the exercise becomes more effective when their suppliers are also involved (Chen, Sohal, and Prajogo 2013; Li et al. 2018). When risk identification and monitoring methods are limited, firms tend to join forces (Bode et al. 2011; Scholten and Schilder 2015). That is, the exchange partners set and pursue joint objectives (Blanquart and Carbone 2014). Accordingly, we argue that collaborative risk identification should increase risk awareness in an exchange relationship and, consequently, increase the likelihood of collaborative risk mitigation efforts. Increased collaborative risk identification should strengthen the relationship between perceived supply risks and concerns for potential supply failure, and eventually increase collaborative risk mitigation efforts. Following this line of reasoning, we propose the following hypotheses:

H4:Collaborative risk identification will tend to increase the level of collaborative risk mitigation.

H5:An increase in collaborative risk identification strengthens the association between perceived supply risk and the level of collaborative risk mitigation.

Methodology

This section presents the methodology of the study. It includes research context, design, data collection method and indicators for the focal constructs and control variables.

Research context, design and data collection

The present study is based on a survey conducted among firms operating in several different industries in Norway. The sample was drawn from among manufacturing firms listed by Proff Forvalt, a database containing credit and accounting information. To select the sample, a stratified sampling technique was applied, whereby all firms in the sampling frame were grouped by industry and then random sampling was applied to each group. The number of firms selected was limited to 200 units per group (stratum). For industries consisting of fewer than 200 units, a smaller quota was used. In addition to the information found in the database, an online self-administered survey was sent via email to all 1407 firms included in the sampling frame. The email was sent to the contact person identified on Proff Forvalt, who was instructed to pass the questionnaire on to the person who could best answer the questions concerning suppliers. Overall, 152 responses were received, indicating a response rate of 11.3%. Seven responses were dropped due to at least one of the following: too many missing values, duplicates, or the respondent firm no longer engaged in manufacturing and thus outside the scope of the study. Finally, 145 valid questionnaires were retained for analysis. The respondents were asked to specify their firm's industry. The industries represented in the sample are: mining and extraction (9), oil and gas (1), fishing (2), textile and clothing (10), paper and paper products (22), rubber and plastic (26), electronics (17), machinery and equipment (16), metal goods (14), chemicals (15), and furniture (10). Three respondents did not specify their industries.

Focal constructs and control variables

This section presents the operationalisation of the study's focal and control variables that lay the ground for the PLS-SEM.

Buyer-supplier collaborative supply risk mitigation. The extent to which the buying firm and their most important supplier collaborate to mitigate supply risk. The construct was measured by using six indicators on a 7-point Likert scale, ranging from 1 = strongly disagree to 7 = strongly agree. The indicators were created based on Zsidisin (2003), Jüttner (2005), and Manuj and Mentzer (2008).

Buyer's supply risk perception. Following Norrman and Jansson (2004), buyers' supply risk perception was operationalised as the likelihood of a particular supply risk occurring and its consequences (risk = probability x consequence). Based on Thun and Hoenig (2011), Zsidisin (2003), and Chopra and Sodhi (2004), five categories of risks were identified and measured: supplier bankruptcy, quality, delays, workforce disputes, and accidents. Each of these was measured on a 7-point Likert scale, ranging from 1 = strongly disagree to 7 = strongly agree. Ultimately, the probability and consequence scores for each risk type were used as a reflective indicator of buyers' supply risk perception, forming a five-indicator latent variable.

Supplier performance. This variable was measured using an index capturing the extent to which the buying firm perceives how well a supplier is doing on a set of performance criteria. We chose to express this construct as an index because supply performance is generally a multi-faceted concept whose magnitude is an aggregation of its various dimensions (Maestrini et al. 2018). A standard procedure as specified by Crossman (2019) was followed to construct the index. First, appropriate items were selected based on insights from Thun and Hoenig (2011). The three aspects considered were delivery delays, quality of supplies, and damage to incoming shipments. Each of these was measured on a Likert scale ranging from 1 = strongly disagree to 7 = strongly agree. Next, the empirical relationship between the dimensions was examined. The correlations between the dimensions indicated their suitability as follows: damage and delay (0.475), damage and quality (0.670) and delay and quality (0.540), all significant at $p > 0.05$. Subsequently, the index was computed as the sum of the scores on the three aspects considered.

Collaborative risk identification. This construct is operationalised as the extent to which the buying firm collaborates with its most important supplier to identify supply risks. Based on Manuj and Mentzer (2008) and Bak (2018), the construct was measured by a single item, on a Likert scale ranging from 1 = small degree to 7 = large degree. The choice of a single-item measure is supported by Bergkvist (2016), who advocates using it when measuring an attribute that is sufficiently narrow and unambiguous.

Control variables. Four control variables were added to the model: the presence of regional production facilities, the size of the buying firm, implementation of lean practices, and the buying firm's overall focus on mitigating disruptive risks. Regional production ('RP') was a dummy variable, representing whether the respondent firm implements a centralised or a decentralised approach to production. It was included because by implementing geographically separate production facilities, the buying firm could spread the risks and hence reduce the need for investing resources to collaborate with suppliers in supply risk mitigation (Chopra and Sodhi 2014). Since implementing risk mitigation activities is costly (Talluri et al. 2013), we included the buying firm's size ('SZ') because we assumed that larger firms have more resources to support collaborative supply risk mitigation than smaller firms. The natural logarithm of the annual revenue was used as a proxy for the firm's size (Lampón *et al*., 2020). The implementation of lean practices ('LE') was included because we assumed that the focus on waste elimination activities would increase the likelihood of the buying firm collaborating with suppliers to mitigate supply risks (Powell and Coughlan 2020). LE was measured on a 7- point Likert scale, ranging from 1 = small degree to 7 = large degree. Finally, the buying firm's overall focus on mitigating disruptive risks ('RF') was included because we assumed it would generally increase the buying firm's likelihood of collaborating with its suppliers in mitigating supply risks. Table 1 summarises the operationalisation of the focal and control variables. Figure 1 presents the study's conceptual model.

Analysis

To test the hypotheses represented by the conceptual model, we conducted partial least squares structural equation modelling (PLS-SEM). This is a composite-based structural equation modelling approach that is increasingly being applied in various fields, including SC (Kaufmann and Gaeckler 2015). Data analysis was conducted using SmartPLS 3. As the multi-item constructs in this study exhibit a composite structure, PLS-SEM was considered an appropriate choice (see Richter et al. 2016; Sarstedt et al. 2016).

Preliminary analysis

Since our conceptual model implies that the hypothesised constructs linearly affect one another, we began the analysis by checking essential assumptions recommended when estimating predictive linear models. To start with, we followed Armstrong and Overton (1977) and assessed non-response bias by conducting a paired samples test to compare responses from early and late respondents. The results showed that responses were not significantly different ($p < 0.01$ level), leading to the conclusion that non-response bias was unlikely. We then checked for the presence of influential observations (observations whose inclusion or exclusion can alter the study's results), normality of the residuals, and heteroscedasticity. Since SmartPLS does not permit conducting such analyses, we used R, an environment for statistical analysis (R version 4.0.2). Accordingly, we first extracted the latent variable scores of the conceptual model (Figure 1) generated by SmartPLS and then conducted further analyses in R.

The presence of influential observations was checked by assessing Cook's distance (Cook, 1977). Three cases turned out to be outliers that could bias our analysis, and were thus excluded from the dataset. The final sample of 142 observations is sufficient according to the recommended PLS-SEM sample size for a statistical power of 80% (Hair et al. 2017). Next, we applied graphical and statistical tests to check the normality of the residuals and heteroscedasticity. As shown in Figure 2, most of the observations lie on the line, suggesting that the normality assumption is fulfilled. Likewise, the charts of residuals versus fitted values and standardised residuals versus fitted values show that the residuals are spread almost equally along with the ranges of predictors, suggesting that heteroscedasticity does not exist. We then deployed the 'gvlma' package (Peña and Slate 2006) to confirm the assumptions through statistical tests. Table 2 shows that all conditions, including normality (checked through skewness and kurtosis) and absence of heteroscedasticity, are met.

Assessing the measurement model

Two of the focal variables in this study are measured using a reflective measurement model. As such, it is important to assess their internal consistency reliability, convergent validity and discriminant validity (Henseler, Hubona, and Ray 2016). Internal consistency reliability is declared when the recommended threshold of Cronbach's alpha (α) is achieved ($\alpha > 0.7$), while convergent validity is established when the average variance extracted (AVE) is higher than 0.5. Hair, Ringle, and Sarstedt (2011) suggest that the loading of each measure must be at least 0.7. Further, it is recommended to retain indicators that load between 0.4 and 0.7 if doing so helps maintaining the construct's content validity (Hair et al. 2017). The items should be removed if keeping them reduces internal consistency reliability or convergent validity needed to reach the recommended thresholds. Table 3 reports the loadings, descriptive statistics, Cronbach's α and AVE values of focal latent variables used in the study.

As shown in Table 3, the values of Cronbach's α and AVE for the multi-item SUPRISK and RISKMIT constructs are higher than 0.7 and 0.5. Most factor loadings were higher than 0.7 except suprisk3 and criskmit1, which loaded at 0.641 and 0.643, respectively. Following Hair et al. (2017), we kept these items to maintain content validity of latent variables because their loadings are

Table 1. Indicators of the focal and control variables.

Variable	Abbreviation	Measures
Collaborative supply risk mitigation (CRISKMIT)		*Do you regularly cooperate with your most important supplier to mitigate risks by:*
	criskmit1	Sharing risks
	criskmit2	Creating contingency plans
	criskmit3	Improving bottlenecks in the supply chain
	criskmit4	Implementing strategically placed safety stocks
	criskmit5	Postponing commitment of resources
	criskmit6	Ensuring high information flow
Buyer's perceived supply risk (SUPRISK)		*Probability × consequence of the following:*
	suprisk1	Supplier bankruptcy
	suprisk2	Quality problems with products from supplier
	suprisk3	Delays in incoming shipments from supplier
	suprisk4	Supplier workforce disputes
	suprisk5	Accidents at supplier's facilities disrupting further operations
		Sum of the scores of the following:
Supplier performance (SUPPF)	suppf1	We rarely experience any delay on our incoming shipments
	suppf2	We rarely experience any quality problems with our incoming shipments
	suppf3	We rarely experience any damage to our incoming shipments
Collaborative risk identification (CRISKID)	criskid	We collaborate with our most important supplier in identifying upstream supply chain risks
Regional production (RP)	regprod	*Does your company implement geographically separated production facilities, for instance, Europe, Asia, USA, so that if one production facility shuts down, other production facilities can absorb productivity loss?*
Size of the buying firm (SZ)	ln_rev	Natural logarithm of annual revenue retrieved from Proff Forvalt
Lean practices (LE)	lean	*To what extent does your company practise a lean manufacturing strategy?*[a]
Focus on mitigating disruptive risks (RF)	riskfoc	*To what extent does your company focus on mitigating disruptive risks?* (Consider high-impact, low-frequency risks that can disrupt your ability to perform core activities over an extended period.)

[a]strategy that focuses on creating cost-effective processes, with high quality achieved through continuous improvement and elimination of activities that do not add value to the product.

higher than 0.4, and their Cronbach's α and AVE values are well above the thresholds.

Conventionally, discriminant validity is assessed by using the Fornell–Larcker criterion and cross-loadings. The discriminant validity is declared when the square root of each construct's AVE is greater than its highest correlation with any other construct and the loadings exceed cross-loadings. Henseler, Ringle, and Sarstedt (2015) introduced the heterotrait-monotrait (HTMT) ratio, which is now considered a superior approach to assessing discriminant validity. With this approach, discriminant validity is declared when the HTMT ratio is significantly smaller than 1. However, according to Voorhees et al. (2016), the best assessment of discriminant validity is achieved with a 0.85 cut-off (HTMT.85). Discriminant validity for the two multi-item constructs in the model (SUPRISK and RISKMIT) was established since all the values of the HTMT ratio are substantially below 0.85. This is also supported by the Fornell–Larcker criterion, as the square root of each construct's AVE is greater than its correlation with the other construct, as shown in Table 4.

Structural model and testing of the hypotheses

Figure 3 presents the structural model corresponding to the hypotheses tested in this study. The interaction effects were estimated using a two-stage approach. First, latent variable scores were computed, and an interaction term created as an element-wise product of the latent variable scores of the independent and moderator variables. Second, the interaction term was used as an independent variable. We chose this approach because, according to Henseler and Chin (2010), it is the most appropriate method for determining whether an interaction leads to a significant additional explanation of the endogenous variable.

The structural model was assessed by examining the magnitude of path coefficients, R^2 values, effect sizes (f^2), predictive relevance and approximate model fit. To assess the predictive relevance, we examined the value of Stone-Gaisser's Q^2. As for the approximate model fit, the standardised root mean residual (SRMR) was examined. Henseler, Hubona, and Ray (2016) recommend a threshold of SRMR<0.08. The values of variance inflation factors (VIF) are well below 3, suggesting the absence of multicollinearity problem (Hair, Sarstedt, and Ringle 2019). To test the hypotheses, we estimated the structural model by bootstrapping 5000 re-samples. Table 5 presents the results of our estimation.

Importance-performance map analysis

In this section, the structural model estimated in the preceding section is further explored through an importance-performance map analysis (IPMA) (Hair et al. 2017). For each predictor of collaborative risk mitigation, IPMA contrasts its total effect (importance measured on a scale from 0 to 100) and the average values of the latent variable scores (performance). Combining these two metrics helps identify areas for improvement by identifying factors according to their importance and performance (Hong, Kwon, and Li 2014). This way, the results of IPMA can guide relevant managerial interventions. The most interesting factors are those with high importance but low performance. Figure 4 shows the results of IPMA for this study.

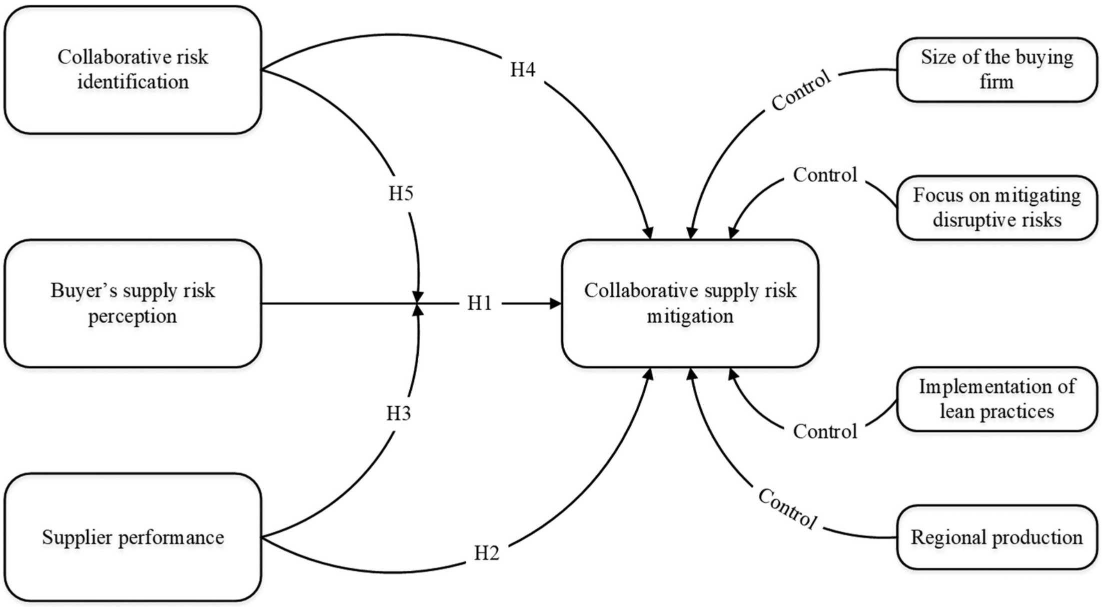


Figure 1. Conceptual model.

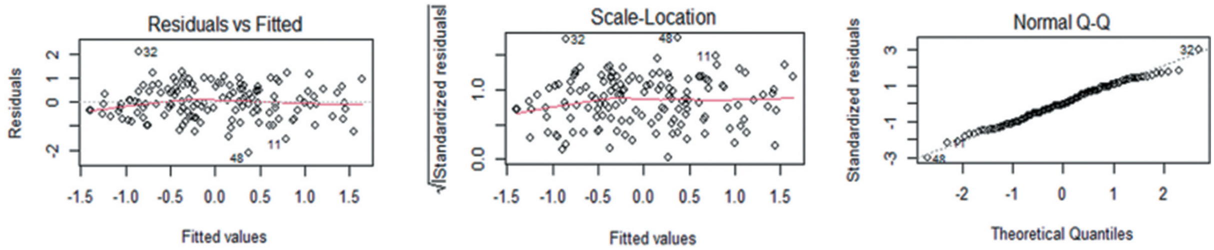


Figure 2. Assessing heteroscedasticity and normality of the residuals.

Table 2. Assessment of the linear model assumptions.

	Value	p-value	Decision
Global stat	2.35844509	0.6701496	Assumptions acceptable
Skewness	0.13713622	0.7111448	Assumptions acceptable
Kurtosis	0.13595126	0.7123397	Assumptions acceptable
Link function	2.03198042	0.1540198	Assumptions acceptable
Heteroscedasticity	0.05337719	0.8172876	Assumptions acceptable

CRISKMIT = SUPPF + SUPRISK + CRISKID + SUPRISK x CRISKID + SUPRISK x SUPPF + RF + LE + SZ + RP + ε

Table 4. Assessment of discriminant validity.

	SUPRISK	CRISKMIT	$\sqrt{AVE}$
SUPRISK	-	-	-
CRISKMIT	(0.387) [0.327][a]	-	0.752
$\sqrt{AVE}$	0.729	-	-

[a](HTMT ratio)[correlation]

Table 3. Descriptive statistics of the focal variables.

Item	Mean	Std dev	Loading	Cronbach's α	AVE
Collaborative supply risk mitigation (CRISKMIT)				0.844	0.566
criskmit1	2.634	1.361	0.643		
criskmit2	2.430	1.406	0.778		
criskmit3	3.331	1.735	0.816		
criskmit4	2.915	1.489	0.740		
criskmit5	2.838	1.564	0.810		
criskmit6	3.937	1.589	0.713		
Buyer's perceived supply risk (SUPRISK)				0.784	0.531
suprisk1	11.204	8.170	0.713		
suprisk2	14.979	8.756	0.728		
suprisk3	14.972	9.428	0.641		
suprisk4	9.021	6.195	0.774		
suprisk5	11.521	8.775	0.780		
Collaborative risk identification (CRISKID)*	3.634	1.750	-	-	-
Supplier performance (SUPPF)*	15.620	3.334	-	-	-

*Single-item constructs. AVE = average variance extracted.

Findings

This section presents the results of the hypotheses test, followed by further exploration of the structural model through an IPMA.

Results of the structural model estimation

The first hypothesis of this study proposed that perceived supply risk is positively associated with the level of collaborative supply risk mitigation. This hypothesis is supported as the corresponding coefficient is positive (0.198) and significantly different from zero (p = 0.006). The second hypothesis proposed that supplier's performance is negatively associated with the level of collaborative supply risk mitigation. Although the results show that the corresponding coefficient is

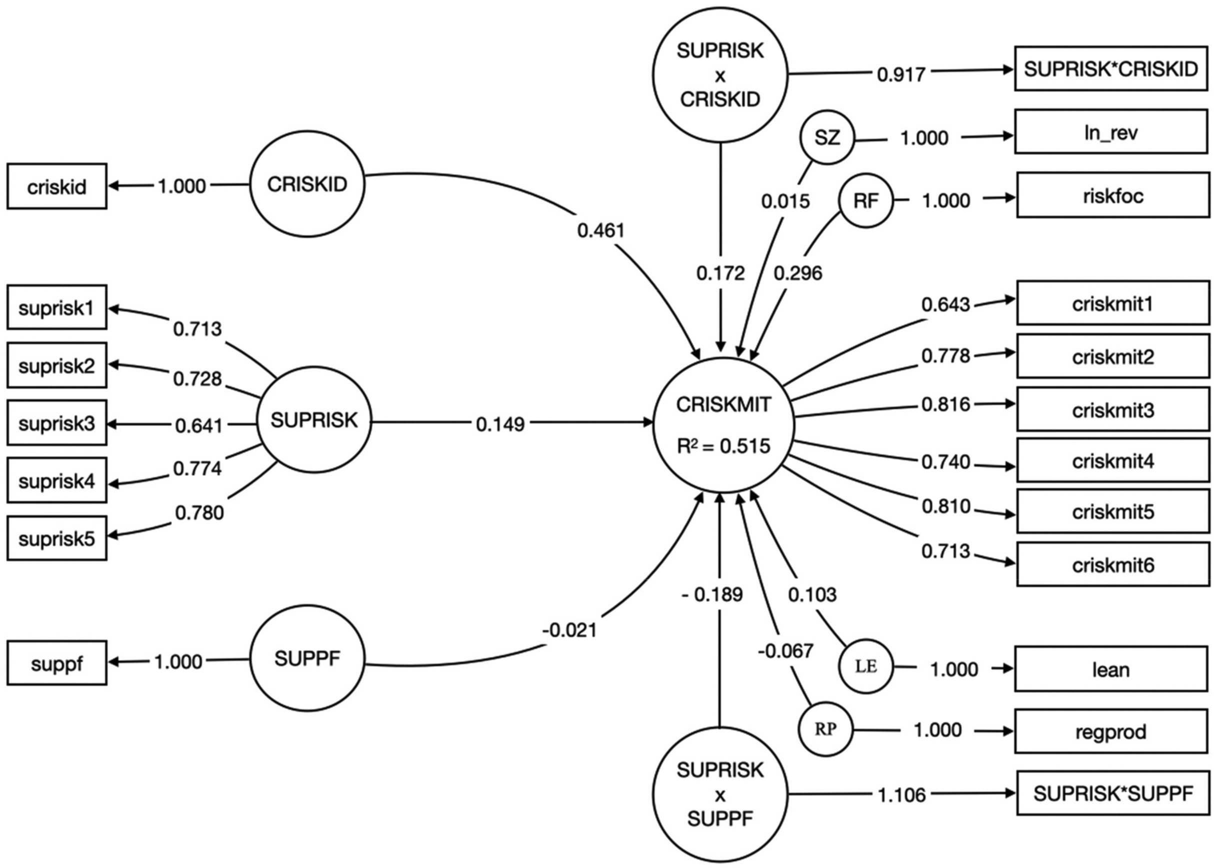


Figure 3. Structural model.

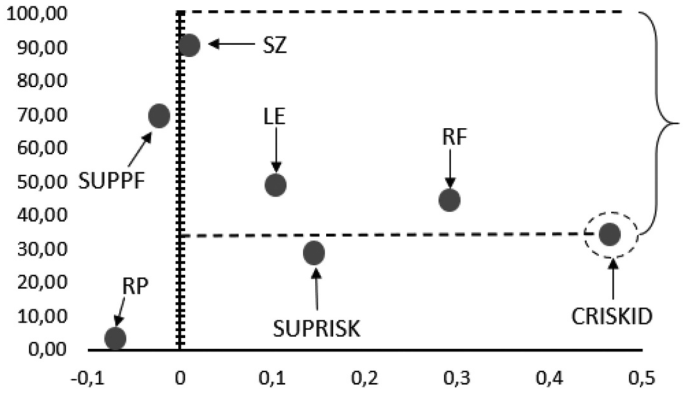
Table 5. Structural model estimation: results.

Path	Path coefficient	f^2	VIF values	t-values	p-values	Significant
SUPRISK	0.149	0.038^S	1.209	2.285^b	0.022	Yes
SUPPF	−0.021	0.001^N	1.100	0.265^{ns}	0.791	No
CRISKID	0.461	0.357^L	1.224	7.249^a	0.000	Yes
SUPPFxSUPRISK	−0.189	0.084^S	1.074	2.570^a	0.010	Yes
CRISKIDxSUPRISK	0.172	0.046^S	1.113	2.309^b	0.021	Yes
RF	0.296	0.157^M	1.153	4.603^a	0.000	Yes
LE	0.103	0.019^N	1.165	1.389^{ns}	0.165	No
SZ	0.015	0.000^N	1.074	0.331^{ns}	0.741	No
RP	−0.067	0.009^N	1.045	1.128^{ns}	0.260	No
R^2	0.515					
Adjusted R^2	0.481					
Q^2	0.270					
SRMR	0.078					

Dependent variable = CRISKMIT; f^2 = effect size; ^{N} Nil effect ^{S} Small effect; ^{M} Moderate effect; ^{L} Large effect ^{a} significant at $p < 0.01$; ^{b} significant at $p < 0.05$; ^{ns} not significant; Q^2 = Stone-Gaisser's; SRMR = standardised root mean residual.

negative (–0.010), suggesting that high supplier performance reduces the level of collaborative supply risk mitigation, this hypothesis is not supported because the corresponding coefficient is not significantly different from zero (p = 0.898). The third hypothesis proposed that supplier performance weakens the effect of perceived supply risk on the level of collaborative supply risk mitigation. This hypothesis is supported as the corresponding coefficient of the moderation effect is negative (–0.169) and significantly different from zero (p = 0.011). The fourth hypothesis proposed that collaborative risk identification is positively associated with the level of collaborative risk mitigation. This hypothesis is supported as the corresponding coefficient is positive (0.447) and significantly different from zero (p = 0.000). Finally, the fifth hypothesis proposed that an increase in collaborative risk identification strengthens the effect of perceived supply risk on the level of collaborative risk mitigation. This hypothesis is supported as the corresponding coefficient is positive (0.163) and significantly different from zero (p = 0.045).

As for the control variables, only the buying firm's overall focus on mitigating disruptive risks is significant as the corresponding coefficient is positive (0.242) and significantly different from zero (p = 0.000). The remaining control variables, namely the presence of regional production facilities, the size of the buying



CRISKID=Collaborative risk identification; RF=Focus on mitigating disruptive risks; SZ=Size; LE=Lean practices; SUPRISK=Buyer's perceived supply risk; RP=Regional production; SUPPF=Supplier performance

Figure 4. Results of importance-performance map analysis.

firm, and implementation of lean practices, do not appear to have a significant effect on the level of collaborative risk mitigation because their corresponding coefficients are not significantly different from zero ($p = 0.893$; 0.216; 0.430, respectively).

Results of the IPMA

As shown in Figure 4, collaborative risk identification ('CRISKID') is the most important factor to explain variations in collaborative risk mitigation efforts, followed by the buying firm's overall focus on mitigating disruptive risks ('RF'). However, the results show that the level of both factors is suboptimal. That is to say, there is still room for improving both collaborative risk identification and overall focus on mitigating disruptive risks. This is because the buyer-supplier relationships considered in this study only perform at 33% in terms of collaborative risk identification and at 47% in terms of overall focus on mitigating disruptive risks. Although the buying firms in our sample seem to consider their suppliers' performance ('SUPPF') as high, this factor is less important in influencing collaborative risk mitigation efforts.

Discussion

This study sought to explain factors that drive variation in collaborative supply risk mitigation. Specifically, we explored the effect of perceived supply risk, supplier performance, and collaborative risk identification on collaborative supply risk mitigation in buyer-supplier relationships. This section presents the theoretical and managerial implications of our findings.

The model tested in this study was conceptualised based on existing theory. The results have shown that all but one of our hypotheses are supported. This demonstrates that the theoretical reasoning used in the study is in line with practice. For instance, the results show that the buying firms and their suppliers increase their collaborative risk mitigation efforts as the level of perceived supply risk rises. Indirectly, this indicates that both parties recognise the limitations of formal contracting and thus act reasonably by deploying a relational contracting mechanism, as manifested by an increased level of collaborative risk mitigation efforts. We can also assume that the study's results suggest that firms have confidence in the potential efficacy of relational norms to address interfirm exchange problems.

Likewise, the positive and significant effect of collaborative risk identification on the level of collaborative risk mitigation confirms its relevance in supply risk mitigation. Theoretically, the results suggest that lack of awareness about potential supply risks inhibits collaborative risk mitigation, but when buying firms begin to collaborate with their suppliers in risk identification, the barrier is eliminated and the awareness thus attained subsequently drives collaborative risk mitigation. The results further confirm the importance of collaborative risk identification, as it reinforces the effect of perceived supply risk on collaborative efforts to mitigate risks. As such, firms appear to act consistently with what would be expected from a rational decision maker.

Interestingly, supplier performance does not seem to reduce collaborative risk mitigation in any significant way. Based on TCE, we expected that since coordinating collaborative efforts entails higher costs, buying firms would try to avoid such costs whenever possible. As such, supplier performance would serve as a cue to the buying firm as to whether it is worth incurring the costs associated with collaborative risk mitigation. Apparently, however, the theory is not supported by our results. It appears that firms pursue collaborative risk mitigation efforts even when their supplier demonstrates good performance. This is interesting because it shows that to the buying firms, the benefits of collaborative risk mitigation outweigh the costs associated with its implementation. Nevertheless, the fact that supplier performance does not seem to have a significant effect on collaborative supply risk mitigation but significantly reduces the effect of perceived supply risk, is also interesting. It suggests that supplier performance purely moderates the relationship between perceived supply risk and collaborative supply risk mitigation. Taken together, the results suggest that buying firms are pragmatic in their approach to collaborative risk mitigation, while recognising that its benefits outweigh the costs.

Regarding managerial implications, the study provides several insights. To begin with, IPMA has shown that collaborative risk identification and the buying firm's overall focus on mitigating disruptive risks play a key role in influencing collaborative risk mitigation efforts. However, more work is required to improve collaborative risk identification and overall focus on mitigating disruptive risks. At the time when the purchasing and supply management function is seeking to gain acknowledgement and respect from the executives (Weissman 2019), it must contribute to the strategic goals of its organisations. One of the ways for making such a contribution can be through forming and maintaining strategic supplier collaborations. As our results show, despite the significance of collaborative risk identification, buying firms engage in this process only to a limited degree. This is surprising, because with the increased complexity of SCs, it is no longer sufficient to focus only on risks associated with first-tier suppliers; instead, buying firms must also address potential risks in the lower tiers (Mwesiumo et al. In Press). Buyer-supplier collaborative risk identification can play a vital role in addressing potential risks in the lower tiers. For instance, the COVID-19 pandemic has led to unprecedented changes within SCs that may be difficult for buying firms to keep track of and manage. By collaborating with first-tier suppliers such changes can be mitigated in order to maintain operations. As our results show, buyers and suppliers who collaborate in identifying risks are more likely to collaborate in mitigating them.

Another interesting managerial insight is related to the revelation that supplier performance does not significantly reduce the level of collaborative risk mitigation between buyers and suppliers; however, it strongly weakens the effect that perceived supply risk has on collaborative risk mitigation. This finding shows that on average the buying firms in our sample recognise the fact that even the best performing suppliers can be exposed to unforeseen events. This is important since most buying firms have recently found that even their best suppliers have been caught off guard by COVID-19. Nevertheless, the significant moderation effect of supplier performance shows that the buying firm's recognition of the potential vulnerability of a supplier, regardless of their performance, is limited by the scope of risks considered by the buying firm. This approach is likely to cause problems when major unforeseen disruptions occur. As such, we recommend that buying firms and their managers should consider expanding the scope of potential risks in their business continuity plans, which, as our result suggest, should lead to increased collaboration with suppliers in mitigating them.

Conclusion

To conclude, this study was designed to contribute to the extant literature by exploring several drivers of collaborative supply risk mitigation. The underlying premise is that the purchasing and supply function should pursue collaborative risk management because SC resilience is crucial to a firm's value creation. This is important especially now when the purchasing and supply function is seeking recognition for its potential strategic role. The results of the analysis confirm the importance of collaborative risk identification, perception of supply risks, overall focus on mitigating disruptive risks and the moderation effect of supplier performance. In light of these findings, we argue that it is high time for the purchasing and supply function within firms to intensify their firms' collaboration with suppliers. Apart from addressing supply risks, collaboration with suppliers may also trigger important innovations that may contribute to increasing revenue for both buyers and suppliers.

To expand on this study, future research can further explore several other facets of collaborative risk mitigation. Firstly, studies may explore the dynamics of buyer-supplier collaboration in risk mitigation. This can include examining how such collaborations emerge, how they are governed, and how they evolve. By examining these issues, future research will help to identify challenges associated with collaborative risk mitigation efforts and provide a basis for appropriate solutions. Secondly, the present study demonstrates that even though collaborative risk identification is a crucial driver of collaborative risk mitigation, the practice is not widespread. It would be interesting to explore ways through which collaborative risk identification can be increased, for instance, through use of digital technologies, such as artificial intelligence, internet of things, big data analytics and blockchain technology, which only recently has entered the sphere of SCRM (see e.g., Marcucci et al. 2021). Thirdly, as the present study shows, risk perception matters in determining the level of collaborative risk mitigation, and future studies may explore the scope of supply continuity plans and how buying firms prioritise different risks, including the calculus behind the priorities.

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