Managing Supply Chain Risk: A Supply-Side Perspective

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Abstract: In the past, most research on supply chain management focused on initiatives that made supply chains leaner, faster and more flexible, resulting in highly efficient but more vulnerable operations. Our study draws upon the existing literature to develop a model for upstream supply chain risk management. We collected survey data from 162 companies among several manufacturing industries. In a path analytic model, we link three steps of the supply chain risk management process – risk identification, risk assessment and risk mitigation – with upstream supply chain risk performance. We also include the effect of a continuous risk management improvement process on the risk management activities in order to adapt to the requirements of a changing environment. The data provides robust support to all our hypotheses. The study contributes to the literature by elaborating some theory aspects in more detail and empirically confirming the contribution of upstream supply chain risk management activities to the actual supply chain risk performance. Managers benefit from the insights how risk identification, risk assessment and risk mitigation activities influence risk performance and which role a continuous improvement process can play.

Keywords: Supply Chain Risk Management; Continuous Improvement, Structural Equations Model

I. Introduction

The recent past has seen a growing interest in supply chain management topics within the field of operations management research [33]. The purpose of this paper is to develop and empirically test a model linking supply chain risk identification, risk assessment and risk mitigation to a company's risk performance.

In recent years, popular initiatives like outsourcing, reduction of inventories and increasing inter-firm cooperation among several others created much leaner and more efficient supply chains. However, extreme leanness results in a cost-efficient but fragile supply chain [32]. In the absence of any risk, a lean process may outperform other approaches and in a world of uncertainty, an efficient but susceptible supply chain with a high risk exposure might even threaten the operations of a company. In fact, the impact of supply chain disruptions on company performance has increased over the past few years [29]. Single sourcing [29] [54], low inventories [19] [29] [47], increased product complexity [29] and a growing importance of purchasing as a value creation function [61] allow only little margin for error and leave supply chains highly vulnerable. At the same time, global organizations face an increasingly unstable environment [34] [56]. With more sensitive supply chains on one hand and higher uncertainty in a global business world on the other hand, disruptions hit supply chains more often and severe with immense negative consequences [28]. Thus, managing supply chain risks needs to be a primary objective of any senior executive team by integrating risk management as a part of every supply chain [18] [24] [54]. In a recent survey, only one third of the responding firms report that they paid "sufficient attention to supply chain vulnerability and risk mitigation actions" [43, p. 31].

A literature review combining previous risk management approaches shows that a common risk management process is generally organized into three steps: risk identification, risk assessment, and risk mitigation [6] [32] [53]. Some authors also stressed the importance of an ongoing risk monitoring and an iterative risk management process that is constantly adapted to the requirements of a changing environment [6] [29] [32]. With no continuous improvement, even successful risk management processes will become weak and eventually obsolete when environmental conditions change. Therefore risk management activities need to go hand-in-hand with a continuous improvement process in the long run.

In our study, we first operationalize the constructs risk identification, risk assessment, and risk mitigation through an extensive literature review and link it to risk performance. Furthermore, we include the effect of a continuous improvement process in our model. In a second step, we use partial least squares analysis to evaluate the contribution of these activities on risk performance.

II. Upstream Supply Chain Risk Management

Recent research stresses the importance of an integrated and holistic approach in supply chain management [9] [52] [55]. A common classification is the distinction between upstream and downstream supply chain initiatives. Likewise, risks can occur on the supply side and on the demand side [33] [35] [56]. Tang's (2006) classification of risk management approaches within the supply chain context distinguishes supply management and demand management. We follow this argumentation; although we stress that a holistic view of the supply chain is required. However, supply and demand side focused risk management processes are quite distinctive in their actual implementation and require different kind of constructs and measurement items. This paper focuses on the upstream supply chain risk management which is also referred to as supply risk management [55] [60].

III. Conceptual Model

Our research model includes five constructs and six relationships among them. We investigate the effect of risk identification on risk assessment which again is hypothesized to have a positive impact on risk mitigation. Risk mitigation then contributes to risk performance because only risk mitigation activities can directly decrease the frequency and the impact of actual risk incidents on the operations of a company. Additionally, we examine the impact of a continuous improvement process on the quality of the risk identification, risk assessment and risk mitigation activities.

Risk Identification

The critical first step of every risk management process includes the identification of risks [32] and therefore triggers any further risk management activity. Risk identification aims to discover all relevant risks implying an early judgment if a risk is considered relevant or not. Thus, risk identification needs to follow a holistic approach [9], screening regularly for weak signals within the upstream part of the supply chain and the environment.

Disruption severity is influenced by the time it takes for a company to learn about a risk or to predict the respective disruption [19]. Consequently, companies need to develop an ability to predict disruptions early so that risks can be duly assessed and mitigation efforts can take effect. By carefully scanning the environment for weak signals, relevant risks are recognized in time and mitigation actions can be initiated [19] [28] [54] [60]. Due to resource constraints it is necessary to define observation fields and discover potential sources of risks and vulnerabilities with the least input of resources. Due to the complexity of global supply chain operations, this requires knowledge about a company's most critical components, processes and suppliers worldwide in order to focus the existing resources on the most fragile areas of the supply chain [26] [32] [52]. The quality of the risk identification activities is crucial, because only risks that are identified can be assessed and managed in the subsequent process [5]. Thus, we derive our first hypothesis:

Hypothesis 1*: Supply chain risk identification activities have a positive impact on the supply chain risk assessment.*

Risk Assessment

Step two of the supply chain risk management process is risk assessment. Almost every definition of risk assessment in the literature includes an evaluation of the likelihood of occurrence and an estimation of the possible impact in case the risk event unfolds [26] [27] [32] [34] [35] [46] [47] [51] [52] [58] [60]. The main purpose of risk assessment is to provide the necessary information about an identified risk in order to effectively avoid it, reduce its likelihood and impact, accept its occurrence or prepare contingency plans [4].

The risk assessment process needs to understand the factors leading to the occurrence of a specific risk and provide information on risk drivers and key vulnerabilities in the upstream supply chain. Special attention needs to be paid to interrelatedness of risks and trigger events [27] [32] [35] [46]. The resulting business impact of a disruption highly depends on the occurrence speed of a specific risk and its duration [8] [28] [35] [47]. Therefore, the outcome of the risk assessment activities needs to provide a classification of all identified risks and put them into a prioritizing order. Graphical illustration can help to map risks in an appropriate way and show where, when, and with what likelihood and impact risks might occur [26] [27] [35] [36] [39] [46] [47] [52] [51] [58]. The specific understanding of any identified risk through an in-depth assessment process is thus necessary to initiate the right mitigation activities as prevention or once it occurs. Therefore, we hypothesize:

Hypothesis 2: *Supply chain risk assessment activities have a positive impact on the supply chain risk mitigation.*

Risk Mitigation

Risk mitigation makes use of the data collected in the previous step to address potential risks with the right measures. This includes classic mitigation strategies (before the risk event) as well as contingency plans (after the risk event). For each relevant risk, an appropriate mitigation strategy needs to be developed, evaluated towards their potential value and required investments [17] [32] [35] [55] and finally executed. Effective mitigation strategies can only be developed through close collaboration between supply chain partners and support from various functions within the firm. This requires the support from the senior executives enabling holistic thinking, joint decision making and fast implementation activities [5] [12] [32] [60].

In sum, risk mitigation activities aim to reduce the probability of risk occurrences and reduce the negative impact of an occurred risk [54]. Risk identification and risk assessment indirectly contribute to risk performance by supporting the development of an optimal risk mitigation strategy. However only executed risk mitigation activities have direct impact on the risk performance. Therefore, we hypothesize:

Hypothesis 3: *Supply chain risk mitigation activities have a positive impact on supply chain risk performance.*

Continuous Improvement Process

A continuous monitoring and improvement process is part of any iterative risk management process. Thus we argue that risk management activities need to be repeated regularly and frequently [25] [32]. Even after a successful mitigation activity for an occurred risk, continuous monitoring is necessary to control the risk, analyze the effectiveness of the applied mitigation strategy and adjust measures if necessary at each step of the supply risk management process based on lessons learned [19] [25] [36] [39] [44].

In sum, continuous improvement processes help to optimize the effectiveness and efficiency of the three risk management steps. The ongoing evaluation of a firm's risk management processes helps to shed light on potential areas of improvement and acknowledges the contribution of effective measures of identification as well as lessons learned from earlier incidents. Therefore, we hypothesize:

Hypothesis 4a: *A continuous improvement process has a positive impact on supply chain risk identification.*
Hypothesis 4b: *A continuous improvement process has a positive impact on supply chain risk assessment.*
Hypothesis 4c: *A continuous improvement process has a positive impact on supply chain risk mitigation.*

Risk Performance

Measuring supply chain risk performance continues to present a challenge to researchers as well as practitioners. Berg et al. (2008) conducted a case study about how companies assess the performance of their supply chain risk management programs. We draw upon those insights when measuring risk performance and contribute to the further development of risk performance constructs. Risk management activities finally aim at reducing the frequency and impact of supply risks. Consequently, any risk performance evaluation should measure such reductions [5] [28] [35].

A well identified, assessed and mitigated risk can unfold with only little negative impact on the business. Good risk performance is consequently signaled by well defined procedures on how to manage supply chain risks. With a systematic process, clear responsibilities and elaborated contingency plans, companies are able to accommodate risks according to their daily routines and without unplanned frequent firefighting actions [5] [28] [32] [39] [36] [52] [56] [60]. Such a high supply chain risk management level requires the preparedness and risk awareness of every employee within the firm beyond the purchasing and supply chain management staff [26] [35].

IV. The empirical study

Sample and Data Collection

The conceptual model was tested using information from a wide sample of manufacturing firms. The Data was collected during a time period of three months via a mailed survey which was sent out to 1,146 addresses. We focused on large and mid-sized companies in the industrial sector with revenues above EUR 50 million. The measurement items were drawn from the relevant literature as discussed above. Respondents indicated their perception for each measurement item on a seven-point Likert-type scale. The face validity of the survey items was assessed by iteratively refining the item wording and terminology with a panel of eleven senior managers and eleven academic domain experts. With a sample of 162 completed questionnaires the effective response rate equals 14.1%. The mean sales of the resulting sample is €5.1 billion. The mean number of employees is around 14,000. We also evaluated the degree of value added for each company resulting in a mean value added of 55% of total sales. More than 60% of the respondents were (chief) purchasing officers and hold substantial work experience within the field of supply chain management with an average of more than 12 years. A t-test showed no significant differences at the 0.05 significance level between early and late respondents [2].

Measures & Measurement Model

We operationalized the variables using multi-item reflective measures. Based on our literature review of section III, existing measures were used wherever possible. Newly developed or adapted constructs and items were rigorously anchored in the literature and discussed in several focus group workshops to ensure high content validity.

We analyzed the measurement model and structural model using a partial least squares (PLS) approach, specifically SmartPLS Version 2.0 M3 Beta [45]. PLS is the most appropriate analytic technique for our study for several reasons. First, its distribution-free method weights indicator loadings on constructs in context of the theoretical model rather than in isolation [30]. Second, as a variance based method, PLS also places minimal demands on measurement scales and distributional assumptions using least-squares estimations [15] [22] [57]. Third, PLS is most appropriate in examining data where the sample size is relatively small [30] [38]. Designed to explain variance, PLS is more suitable for predictive applications and theory building [14].

Construct validity is assessed by its three sub-dimensions: content validity, convergent validity and discriminant validity. Content validity was addressed by rigorously anchoring every item and every construct in the literature and testing its validity within several focus group workshops. We assessed convergent validity, reliability and internal consistency. To do so, we checked all path coefficients for significant values higher than 0.7 and assessed composite reliability as well as average variance extracted (AVE) for each construct. To test their statistical significance we used a bootstrapping approach [21] generating 1000 samples of randomly selected cases and then calculated path coefficients and t-statistics for each sample[31]. The cross-loading results confirm further the validity of the measurement model. All measurement items are highly above the common threshold of 0.7 for standardized loadings [23] and thus support the assumption of a valid measurement model.

Composite reliability measures the inter-item consistency. Unlike Cronbach's alpha, composite reliability does not assume equally weighted measures and should have a value of at least 0.7 [16]. The composite reliability of our measure shows values of 0.884 and above suggesting that each scale has an excellent reliability. The high values for the average variance extracted indicate that the items share far more than half of the variance of the respective constructs. Each construct highly exceeds the commonly applied threshold of 0.5 [16] [23].

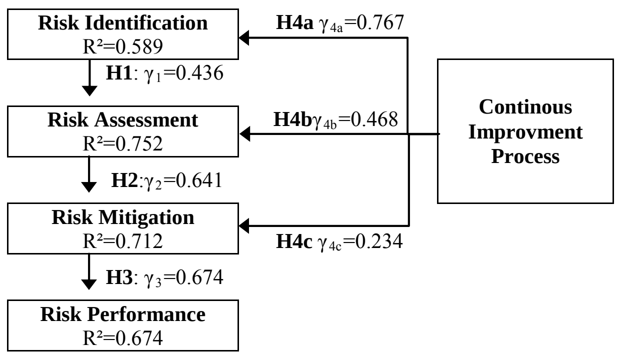
We also assessed discriminant validity in order to address the potential problem of having one construct overlapping with the defined area of another construct. One criterion for adequate discriminant validity is that each item should load highest on the construct it is intended to measure [10]. Additionally, we calculated the squared correlations between the constructs [23]. Discriminant validity is obtained when all squared correlation values are significantly different from 1 [1]. Thus, discriminant validity is given for all our constructs [30] and sufficiently distinct from each other.

Structural Model

Our model explains 46% of the variance observed in risk performance. Additionally, 71% of variance observed in risk mitigation, 75% in risk assessment and 59% in risk identification are explained through our model. All our above stated hypotheses are supported with path loadings being significant at the $p<0.001$ level.

First, the path coefficient from risk identification to risk assessment is strong, positive and highly significant ($\gamma_1=0.436$; $p<0.001$ level). Thus, organizations that regularly and diligently engage in identifying upstream supply chain risks are found to also perform strongly in their risk assessments. Therefore, our hypothesis H1 is supported by the model. Similarly, the path coefficient from risk assessment to risk mitigation is highly positive and significant ($\gamma_2=0.641$; $p<0.001$ level), Thus, it can be stated that firms with due and proper risk assessment tools and activities are most likely to excel in risk mitigation actions. Hence, we find empirical support for our hypothesis H2. The standardized path from risk mitigation to risk performance is also statistically significant with a positive path coefficient ($\gamma_3=0.674$; $p<0.001$ level). This result supports the notion that organizations with superior risk mitigation activities perform generally better in reducing the impact of risks on their supply chain. This lends support to hypothesis H3. The path coefficients from the continuous improvement process construct to the three other risk management constructs are all highly significant and positive. The positive path coefficient from continuous improvement process to risk identification ($\gamma_{4a}=0.767$; $p<0.001$ level) implies that companies that monitor their risk management actions, regularly assess their utility and adjust their risk management processes accordingly are found to have also advanced levels of risk identification activities. Hence, our hypothesis H4a is supported. The path coefficient from continuous improvement process to risk assessment is also showing a positive and significant relationship ($\gamma_{4b}=0.486$; $p<0.001$ level). This implies that a firm's effort to regularly assess and adjust its risk management processes has a positive effect on its risk assessment practices further supporting hypothesis H4b. It can also be stated that companies are most likely to excel in their risk mitigation actions if they invest in a continuous improvement process. The positive and significant path coefficient from continuous improvement process to supply risk mitigation ($\gamma_{4c}=0.234$; $p<0.001$ level) supports our hypothesis H4c.

Figure 1 Structural & Measurement Model



V. Discussion and Implications

Throughout this paper, we addressed the need for professional supply chain risk management activities along the risk management process. We argued that companies with higher competencies in the three process steps of the upstream supply chain risk management show superior performance when it comes to the reduction of the frequency and impact of supply chain risks. Our findings provide evidence that supply chain risk activities support the operational and strategic preparedness of organizations towards a wide range of risks.

Through the literature review, we significantly elaborate on the existing theory. Our detailed operationalization of the constructs sheds further light on the problem of measuring risk management efforts and performances. With our scales demonstrating excellent consistency, the partial least squared analysis explains between 46% and 75% of the observed variances in our model and provides a sound empirical starting point for further large-scale research in this area. As research on risk identification and risk assessment is scarce [33], we put a special focus on these two constructs and clearly demonstrate their importance within the overall risk management process. Our results indicate that all constructs are closely linked to their antecedents, supporting the view of an integrated and holistic risk management concept. Activities also need to be performed sequentially in order to yield visible benefits for companies. These empirical results are also consistent with earlier findings in the case-based literature [5] [19] [61].

Additionally, our results lend support to the application of traditional risk management constructs in the area of supply chain risk management. Our study provides insights on how risk management tools and methods derived from previous studies can contribute to risk performance improvement. Despite the surge of academic interest in supply chain risk management, implementation in practice still lacks behind [33]. Well defined measurement methods and clear evidence can help to translate risk management practices into a business case and justify further investments. Our results provide managers with a strong argument to invest in supply chain risk management projects [12].

The empirical results do not only support the sequence of the risk management process steps but also offer a warning note to researchers. Further attention needs to be paid on the boundaries of the three steps because every company is having slightly different process definitions. Clear definitions of the boundaries between the process steps are necessary in order to identify which activity finally yields the highest benefits for companies.

The strong effect of a continuous improvement process on risk identification, risk assessment, and risk mitigation lends support to the notion that supply chain risk management processes need to get constantly adapted and integrate lessons learned from ongoing experiences. The impact is strongest from continuous improvement to risk identification which is in line with the idea that risk identification is the most undefined process step and can therefore benefit maximally from the integration of lessons learned and continuous improvement efforts.

VI. Limitations & Future Research Directions

Our study lends credence to the notion that effective supply chain risk management processes significantly contribute to risk performance improvements. In addition, our study further elaborates existing theory and provides detailed operationalization of the major risk management constructs. In accomplishing these objectives, however, we have made several research design choices that result in some limitations for our study.

Even though our sample covers a variety of industrial firms, the data was gathered solely within Germany and therefore limits the potential generalization of the study results. An application of the developed constructs should be tested using a broader sample with regards to both global and horizontal diversity. We also surveyed high-level supply chain professionals from individual firms who are capable of reliable assessments and are generally considered as a reliable source. It would be informative to replicate this study within an international setting surveying multiple sources and informants within the participating companies. Our study clearly demonstrates the strong relationship among the analyzed constructs. However, by using a mail survey methodology, we did not have access to the rich qualitative information that led to the perceptions indicated by the respondents on the Likert-type scale. Qualitative research could provide insights into the variety of risks that require distinct assessment and mitigation strategies.

Though our model notably sheds light into the effect of upstream supply chain risk management activities to its risk performance improvement, it would be interesting to investigate what other factors contribute to upstream supply chain risk performance. Further research is needed, possibly using a longitudinal study approach to reveal in detail how frequency and impact of risk events change over time. In addition, future research that incorporates into the analysis both downstream and upstream risk management approaches would provide a valuable contribution to the literature by further developing a holistic model for supply chain risk management.

VII. References

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