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**Managing Supply Chain Risk: A Supply-Side Perspective**

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### **ABSTRACT**

Supply chain risk management has gained significant attention in the field of operations management. In the past, research focused on initiatives that made supply chains leaner, resulting in efficient but vulnerable operations. In our study, we develop a model for upstream supply chain risk management. We collected survey data of 162 companies for the empirical analysis. In a path analytic model we link the risk management activities – risk identification, risk assessment and risk mitigation – to risk performance. Many studies have stressed the importance of an iterative risk management process that is constantly adapted to the changing environment. Therefore, we include the effect of a continuous improvement process on the risk management activities. The data provides support to all our hypotheses confirming risk management's contribution to risk performance. In times of economic crisis, our results provide managers with an even stronger argument to invest in supply chain risk management initiatives.

### **Keywords:**

supply chain risk management; continuous improvement, structural equations model

## **1. Introduction**

The recent past has seen a growing interest in supply chain management topics within the field of operations management research (Kouvelis, Chambers, & Wang, 2006). Outsourcing, reduction of inventories and increasing inter-firm cooperation are only a few initiatives that helped to make supply chains leaner and more efficient. However, Kleindorfer and Saad (2005) argue that extreme leanness results in a cost-efficient but fragile supply chain. In absence of risk, a lean process may outperform whereas in a world of uncertainty an efficient but susceptible supply chain with a high risk exposure might even threaten the other operations of a company. In fact, the impact of supply chain disruptions on company performance has increased over the past few years (Hendricks & Singhal, 2005). Single sourcing (Hendricks & Singhal, 2005; Tomlin, 2006), low inventories (Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007; Hendricks & Singhal, 2005; Schmitt & Singh, 2009), increased product complexity (Hendricks & Singhal, 2005) and a growing importance of purchasing as a value creation function (Zsidisin, Panelli, & Upton, 2000) allow only little margin for error and leave supply chains highly vulnerable. At the same time, global organizations face an increasingly unstable environment in many of their markets (Manuj & Mentzer, 2008a; Wagner & Bode, 2008). With more sensitive supply chains on the one hand and higher uncertainty in a global business world on the other hand, disruptions hit supply chains more often and severe. The negative consequences are immense when risks are poorly managed or remain undetected (Hendricks & Singhal, 2003).

Thus, managing supply chain risks needs to be a primary objective of any senior executive team by integrating risk management as part of each and every supply chain (Cohen & Kunreuther, 2007; Ghoshal, 1987; Tomlin, 2006). Hendricks and Singhal (2005) show that past supply chain

research heavily focused on cost-efficiency and less on robustness. In a recent survey of Poirier and Quinn (2004), only one third of the responding firms say that they paid “sufficient attention to supply chain vulnerability and risk mitigation actions” (Poirier & Quinn, 2004, p. 31). While the stream of empirical papers in the field of SCM is steadily growing, the few existing empirical studies heavily rely on secondary data or use more than 10-year old data sets (Cheng & Grimm, 2006; Kouvelis et al., 2006). However, extensive research has been carried out on risk management in the field of financial markets (Kouvelis et al., 2006). Seshadri and Subrahmanyam (2005) highlight the potential of applying the concepts of financial risk management in the field of operations management.

Reviewing the literature and combining previous research shows that a common risk management process is generally organized into three steps: risk identification, risk assessment, and risk mitigation (Bode & Wagner, 2009; Kleindorfer & Saad, 2005; Tang 2006). In the past, authors also stressed the importance of an ongoing risk monitoring and iterative risk management process that is constantly adapted to the requirements of a changing environment (Bode & Wagner, 2009; Hendricks & Singhal, 2005; Kleindorfer & Saad, 2005). With no continuous improvement even successful risk management processes will become weak and eventually obsolete when environmental conditions change and new risks arise. Thus, we argue, that in the long run, risk management activities need to go hand-in-hand with a continuous improvement process.

As to the best of our knowledge, there hardly exist empirical studies on the combined contribution of risk identification, risk assessment, risk mitigation on supply chain risk management performance. Hendricks and Singhal (2003, 2005) analyze in their event studies the stock price effect of more than 500 public disruption announcements made by companies.

Wagner and Bode (2006) use a survey-based approach to investigate supply chain vulnerability including several supply chain characteristics. 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 upstream supply chain risk management activities on risk performance.

The remainder of the paper is structured as follows: In section 2 we place our study in the context of supply chain risk management research. Based on a literature review, we develop and operationalize our model in section 3. Sampling and data description are then presented in detail in section 4 together with our measurement and structural model analysis. Section 5 includes the discussion of the study results and the analysis of our findings. We finally discuss the study limitations and opportunities for further research in section 6.

## **2. Upstream Supply Chain Risk Management**

Research on supply chain risk management classifies risks into operational risks and disruptions risks (Tang, 2006) or refers to them as supply-demand coordination risks and disruption risks (Kleindorfer & Saad, 2005). Operational risks include the everyday management of the supply chain whereas disruptions risks are associated with unexpected events including natural disasters (Kouvelis et al., 2006). As a second dimension Tang (2006) suggests structuring the literature on supply chain risk management according to the mitigation approach. Supply management, demand management, product management, and information management can all contribute to a successful mitigation strategy.

Recent research stresses the importance of an integrated and holistic approach in supply chain management because a narrow view on a single focal firm cannot take into consideration the many interrelations of a global supply chain (Buhman, Kekre, & Singhal, 2005; Steele & Court, 1996; Wagner & Bode, 2006).. Research has come up so far with distinct models and management tools for various segments of the supply chain. 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 (Kouvelis et al., 2006; Manuj & Mentzer, 2008b; Wagner & Bode, 2008). Tang's (2006) classification of risk management approaches within the supply chain context also distinguishes supply management and demand management. We follow this argumentation; however, we stress that a holistic view of the supply chain is always necessary. For example, clear knowledge about the demand side impact is necessary when assessing supply side risks regarding a potential negative business impact. Our model focuses on upstream supply chain risk management sometimes also referred to as supply risk management (Wagner & Bode, 2006; Zsidisin, Ellram, Carter, & Cavinato, 2004).

### **3. Conceptual Model**

Our research model includes five constructs and six relationships among them, as shown in Figure 1. The constructs are defined in the subsequent chapters and their operationalization is anchored in the literature. We investigate the effect of risk identification on risk assessment which again is hypothesized to have positive impact on risk mitigation. Risk mitigation then directly contributes to risk performance. Additionally, we examine the impact of a continuous improvement process on the risk identification, risk assessment and risk mitigation activities.

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Insert Figure 1 about here  
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### *3.1 Risk Identification*

The critical first step of every risk management process is the identification of risks (Kleindorfer & Saad, 2005). The identification of risks is triggering the risk management process. Risk identification aims to discover all relevant risks. This implies that an early judgment is needed to decide whether a risk is considered to be relevant – and thus will be further assessed – or not. Therefore, risk identification needs to follow a holistic approach (Buhman et al., 2005), screening the whole supply chain regularly for weak signals within the supply chain and the environment. The target of this step is to identify as broadly as possible all potential threats and all relevant vulnerabilities within the upstream supply chain. We see the scope of risk identification in analogy of a research process. Basic research at the very beginning needs to be broad in order to discover various opportunities. In the stage of applied research, however, efforts need to focus on a deep understanding for a very specific object of research. Risk identification – like basic research – as the very first step in risk management is targeted to broadly discover all potential risks. Risk assessment – in analogy to applied research – then aims to evaluate and understand each relevant risk in detail.

Craighead et al. (2007) argue that disruption severity is influenced by the time it takes for a company to learn about a risk or to predict a disruption. Companies need to develop the ability to predict disruptions early, so that risks can be duly assessed and mitigation efforts can take effect. By carefully scanning these early warning signals, relevant risks are recognized early and mitigation actions can be initiated in time (Craighead et al., 2007; Hendricks & Singhal, 2003; Tomlin, 2006; Zsidisin et al., 2004). A totally undirected search for new risks, however, does not

use limited resources in the most efficient way. Due to resource constraints it is therefore necessary to define observation fields and discover potential sources of risks and vulnerabilities. Due to the complexity of supply chain operations, this requires knowledge about a company's most critical components, processes and suppliers in order to focus resources on the most fragile areas of the supply chain (Hallikas, Virolainen, & Tuominen., 2002; Kleindorfer & Saad, 2005; Steele & Court, 1996). The operationalization of the risk identification construct including detailed item description with their respective loadings can be found in the appendix Table A.1.

It is importance to notice that only risks that are identified in the first step can be assessed and managed in the subsequent process (Berg, Knudsen, & Norrman, 2008). Thus, risk identification is crucial for the overall risk management process. We expect that excellent activities for identifying risks lay the foundation for duly assessing the risks in the next step. Thus, we derive our first hypothesis:

***Hypothesis 1: Risk identification activities have a positive impact on risk assessment.***

### *3.2 Risk Assessment*

Step two of the risk management process is risk assessment. Almost every definition of risk assessment in the literature includes an evaluation of likelihood of occurrence and an estimation of the possible impact in case the risk event unfolds (Hallikas et al., 2002; Harland, Brenchley, & Walker, 2003; Kleindorfer & Saad, 2005; Manuj & Mentzer, 2008a, 2008b; Ritchie & Brindley, 2007; Schmitt & Singh, 2009; Souza, Goh, & Meng, 2009; Steele & Court, 1996; Yates & Stone, 1992; Zsidisin et al., 2004). Risk assessment processes in the field of supply management are no exemption here. The main purpose of risk assessment is thus to provide the necessary

information about a risk identified in order to effectively avoid it, reduce its likelihood and impact, accept its occurrence or prepare contingency plans (Baird & Thomas, 1985).

Risk assessment 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 (Harland et al., 2003; Kleindorfer & Saad, 2005; Manuj & Mentzer, 2008b; Ritchie & Brindley, 2007). The resulting business impact of a disruption highly depends on the occurrence speed of a specific risk and its duration (Braunscheidel & Suresh, 2009; Hendricks & Singhal, 2003; Manuj & Mentzer, 2008b; Schmitt & Singh, 2009). Therefore, the result of risk assessment activities provides a clear classification of all relevant risks and puts them into a prioritizing order. For the process to be effective, it needs to be kept simple. Graphical illustration can help to map risks in an appropriate way to show where, when, and with what likelihood and impact risks might occur (Hallikas et al., 2002; Harland et al., 2003; Manuj & Mentzer, 2008b; Matook, Lasch, & Tamaschke, 2009; Norrman & Jansson, 2004; Ritchie & Brindley, 2007; Schmitt & Singh, 2009; Steele & Court, 1996; Souza et al., 2009; Yates & Stone, 1992). Detailed understanding of the specific risk is necessary to initiate the right mitigation activities. Thus we expect that outstanding risk assessment activities contribute to a better risk mitigation and therefore we hypothesize:

***Hypothesis 2:** Risk assessment activities have a positive impact on risk mitigation.*

### *3.3 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 and executed. This involves the generation as well as the assessment of diverse mitigation strategies (Chopra, Reinhardt, & Mohan, 2007; Kleindorfer & Saad, 2005; Manuj & Mentzer 2008b; Wagner & Bode, 2006). Kleindorfer and Saad (2005) argue that prevention is better than cure, which requires risk managers to act fast and treat urgent risks first. Literature states, that early and effective mitigation can only be achieved through close collaboration with supply chain partners. Risk mitigation needs to be supported from various functions within the firm. Top management attention is necessary to stress the importance of this risk management activity and to strictly ensure holistic thinking, decision making and fast action (Berg et al., 2008; Chen & Paulraj, 2004; Kleindorfer & Saad, 2005; Zsidisin et al., 2004).

Risk mitigation aims to reduce the probability of risk occurrences and lessen the negative impact of a risk. These actions can be preventive measures before the risk unfolds as well as contingency plans in the event a risk already occurred (Tomlin, 2006). Whereas risk identification and risk assessment indirectly contribute to risk performance by supporting risk mitigation with the right information at the right time, our risk mitigation construct is directly linked to risk performance. Therefore, we state our third hypothesis:

***Hypothesis 3: Risk mitigation activities have a positive impact on risk performance.***

### *3.4 Continuous Improvement Process*

Continuous monitoring and improvement needs to be part of every iterative risk management process. We argue in line with previous research that risk management activities need to be

performed regularly and frequently (Giunipero & Eltantawy, 2004; Kleindorfer & Saad, 2005). Even after a successful mitigation activity for an occurred risk, continuous monitoring is necessary to control the risk, analyze the mitigation effectiveness and adjust measures if necessary at each step of the supply risk management process (Craighead et al., 2007; Giunipero & Eltantawy, 2004; Matook et al., 2009; Norrman & Jansson, 2004; Rees & Allen, 2008;).

Like every process, supply chain risk management has to adapt to new situations over time and strive for continuous improvement. The utility of current risk management activities needs to be assessed regularly and corrections have to be made on an ongoing basis. Clear knowledge about a firm's risk management effectiveness can be a strong incentive for employees' risk awareness and financial investments (Hendricks & Singhal, 2003; Kleindorfer & Saad, 2005;).

Risk monitoring and continuous improvement help to optimize effectiveness and efficiency of all previous risk management steps. 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. Therefore we expect a positive relationship between continuous improvement process and risk identification. Thus, we hypothesize:

***Hypothesis 4a:*** *A continuous improvement process has a positive impact on risk identification.*

By continuously evaluating the effectiveness of risk management activities and adjusting processes according to best practices and past experience we expect a positive influence of a continuous improvement process on risk assessment. Thus, we derive our hypothesis:

***Hypothesis 4b:*** *A continuous improvement process has a positive impact on risk assessment.*

A continuous improvement process includes ongoing observation of mitigated risks and assessment of effectiveness of risk mitigation measures taken. Thus, a company can learn and develop skills to mitigate risks in the most effective way. Therefore, we hypothesize:

***Hypothesis 4c:*** *A continuous improvement process has a positive impact on risk mitigation.*

### *3.5 Risk Performance*

Measuring 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 a further development of the risk performance construct. Risk management aims to reduce the frequency and impact of supply risks, therefore performance evaluation should measure such reduction (Berg et al., 2008; Hendricks & Singhal, 2003; Manuj & Mentzer, 2008b;). To measure a reduction of frequency and impact we focused on a time horizon of three years, as previously used by Hendricks and Singhal (2005).

A well managed risk can unfold with only little negative impact on the business. Good risk performance is indicated by well defined procedures on how to deal with risk. With a systemic process, clear responsibilities and elaborated contingency plans, companies are able to accommodate risks according to their daily routines without unplanned firefighting actions (Berg et al., 2008; Hendricks & Singhal, 2003; Kleindorfer & Saad, 2005; Norrman & Jansson, 2004; Matook et al., 2009; Steele & Court, 1996; Wagner & Bode, 2008; Zsidisin et al., 2004). This

especially requires preparedness and risk awareness of every employee within the firm beyond the supply management staff (Hallikas et al., 2002; Manuj & Mentzer, 2008b).

## **4. The empirical study**

### *4.1 Sample and Data Collection*

To capture a broad picture of supply chain risk performance, the conceptual model was tested using information from a wide sample of firms. A mailed survey was the most appropriate instrument to apply and test our theory. Data collection focused on large and mid-sized companies in the industrial sector. In according to Simonin (1997) only companies with revenues above EUR 50 million were selected. Large and mid-sized companies seem most appropriate for this study because they are more likely to have complex governance systems and standardized processes in place (Bonaccorsi, Giannangeli, & Rossi, 2006; Simsek, Veiga, Lubatkin, & Dino, 2005). Contacts were obtained from the professional address provider who offered the largest available research sampling frame of valid addresses within Germany including contact details of a supply management executive. The measurement items were drawn from relevant literatures. Respondents indicated their perception for each measurement item on seven-point Likert-type scales. The face validity of the survey items was assessed by iteratively refining the item wording and terminology with a panel of 22 experts (individually discussed with eleven senior managers and eleven academic domain experts). After revising according to their comments the survey instrument was sent out to 1,146 addresses. Data collection took place during a period of three months.

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, with a standard deviation of €18.8 billion. The mean number of employees is around 14,000, with a standard deviation of 45,000. We also calculated the value added for each company, finding a mean value added of 55% of total sales. Thus, the sample fulfills the initial requirement of large and mid-sized industrial companies, with a purchasing function of relevance. We targeted high level managers, since they typically form more reliable sources of information than less-senior colleagues (Miller & Roth, 1994). The survey respondents held titles as chief purchasing officer, purchasing officer, supply manager, supply risk manager. More than 60% of the respondents were (chief) purchasing officers with purchasing responsibilities within their respective business divisions. Respondents had substantial work experience within the field of supply management, averaging more than 12 years.

To detect non-response bias, the data was tested for differences between early respondents and late respondents. Fifty percent of returned questionnaires arrived within ten days after start of the data collection period. Those eighty-two data sets were considered early respondents, whereas the remaining eighty respondents are tested as late respondents. A t-test showed no significant differences between early and late respondents at the 0.05 significance level (Armstrong & Overton, 1977). Therefore, non-response bias is not a problem in this study.

Although it is common in management research to use key informants as a source, the collected data is prone to some common method bias. In line with previous studies in this field, we addressed this potential problem in several ways. We followed the recommendations made by Podsakoff, Mackenzie, Lee, and Podsakoff (2003) for questionnaire design and data collection. We designed the survey instrument separating the measurement items in the questionnaire

(Drolet & Morrison, 2001; Podsakoff & Organ, 1986) and guaranteed response anonymity. Furthermore, high ranking informants – like in the current study – are considered to be a more reliable source (Bagozzi & Phillips, 1982; Phillips, 1981). To further limit the risk of common method bias, we evaluated for the risk performance constructs the actual number of risk events with in twelve months and its impact based on the supply chain level rather than solely relying on respondents' perception.

#### *4.2 Measures*

We operationalized the variables using multi-item reflective measures. Based on our literature review of section 3, 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. For a detailed list of indicators and constructs with their respective literature sources, the reader is referred to Table A.1-A.5 in the appendix.

#### *4.3 Analytical Method*

We analyzed the measurement model and structural model using partial least squares (PLS), specifically SmartPLS (Version 2.0 M3 Beta: Ringle, Wende, & Will, 2005), a powerful multivariate analysis technique. We believed that PLS was the most appropriate analytic technique for our study for several reasons. This distribution-free method weights indicator loadings on constructs in context of the theoretical model rather than in isolation (Hulland, 1999). As a variance based method, PLS places minimal demands on measurement scales and distributional assumptions using least-squares estimation (Chin, 1998a; Fornell & Bookstein, 1982; Wold, 1982). PLS is most appropriate in examining data where the sample size is

relatively small (Hulland, 1999; Mitchell & Nault, 2007). Designed to explain variance, PLS is more suitable for predictive applications and theory building (Chin, 1997). To ensure proper use of this technique we followed the general procedures described by Chin (1998a) and Hulland (1999).

#### *4.4 Measurement Model*

Construct validity is assessed by its three sub-dimensions: content validity, convergent validity and discriminant validity. The first, content validity was addressed by rigorously anchoring every item and every construct in the literature and test its validity within focus group workshops.

We used three measures to assess convergent validity, reliability and internal consistency: significant path coefficients with values higher than 0.7, composite reliability and average variance extracted (AVE). Table 1 shows the loadings for each measurement item on their construct. To test their statistical significance we used bootstrapping (Efron & Tibshirani, 1993). We followed the procedure as in Johnston, McCutcheon, Stuart, and Kerwood (2004), generating 1000 samples of randomly selected cases and then calculated path coefficients and T-statistics for each sample. The cross-loading results confirm further the validity of the measurement model.

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Insert Table 1 about here  
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A standardized loading of 0.7 is the commonly applied threshold for item loadings on established scales (Fornell & Larcker, 1981). All measurement items are highly above the threshold and thus form a very strong measurement model.

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Composite reliability and average variance extracted for the five latent constructs are shown in Table 2. 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 (Chin, 1998b). The composite reliability of our measure shows values of 0.884 and above, suggesting that each scale has excellent reliability.

The high values for average variance extracted indicate that the items share far more than half of the variance of the respective constructs. Each construct easily exceeds the commonly applied threshold of 0.5 (Chin, 1998b; Fornell & Larcker, 1981).

We assessed discriminant validity in order to address the potential problem of having one construct overlap 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 (Carmines & Zeller, 1979). Cross loadings are presented in Table 1 with each item loading highest on its respective construct. Additionally, following the procedures outlines in Fornell and Larcker (1981), we calculated the squared correlations between the constructs which are presented in Table 3. Discriminant validity is obtained when all values for squared correlations are significantly different from 1 (Anderson & Gerbing, 1988). For all our constructs, squared correlation is much less than 1. Thus this criterion for discriminant validity is satisfied for all our constructs (Hulland, 1999), indicating that each construct is sufficiently distinct from each other. A more stringent criterion is formulated by Fornell & Larcker (1981), advising values for squared correlations to be smaller than the average variance extracted of the respective construct

shown in Table 2. All our constructs even satisfy this more stringent criterion with squared correlations between the constructs being smaller than their respective values for average variance extracted. Thus, we conclude that all our study constructs show sufficient discriminant validity.

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#### *4.5 Structural Model*

The results of the structural model are reported in Figure 2. 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 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 involve in identifying supply risks are found to perform equally strong risk assessments. Therefore, our hypothesis H1 is supported by the model.

Likewise, the path coefficient from risk assessment to risk mitigation is highly positive and also 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, too. Hence we find support for 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), giving the notion that organizations with superior risk mitigation activities perform generally better in managing risks. This lends support to hypothesis H3.

The path coefficients from the construct of continuous improvement process to the three other 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 excel also in their 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; thus, hypothesis H4b is supported.

It can also be stated that the above mentioned companies are most likely to excel in their risk mitigation actions as well as is shown by the path coefficient from continuous improvement process to supply risk mitigation ( $\gamma_{4c}=0.234$ ;  $p<0.001$  level); therefore lending support to our hypothesis H4c.

## **5. Discussion and Implications**

Throughout this paper, we addressed the need for professional supply chain risk management activities along the risk management process – risk identification, risk assessment, and risk mitigation. We argued that companies with higher competencies in these three process steps of 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 risk. To the best of our knowledge, this is the first empirical study on the process dimensions of upstream supply chain risk management and thus remarkably contributes to theory and practice in several ways.

Through extensive literature research we significantly elaborate the existing theory. Our detailed operationalization of constructs notably sheds light on the problem of measuring risk management efforts. With our scales demonstrating excellent consistency, partial least squared analysis succeeds to explain between 46% and 75% of the observed variances in our model. The well selected items provide a sound starting point for further empirical research in this area.

As research on risk identification and risk assessment is scarce (Kouvelis et al., 2006), 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 risk management concept where risk identification, risk assessment, and risk mitigation can only be successful when closely linked together. The high variances explained by our model support the notion that accurate risk assessment is only possible with excellent prior risk identification just as risk mitigation is

impossible without prior risk assessment. Activities 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 (Berg et al., 2008; Craighead et al., 2007; Zsidisin et al., 2000).

Additionally, our results lend support to the application of traditional risk management constructs in the area of supply chain risk management. Even though the complexity of supply chains might lead to differing activities from traditional risk management, the basic risk management process is still suitable. Our study provides significant insights on how risk management tools and methods derived from previous studies can contribute to risk performance. Kouvelis et al. (2006) argue, that despite the surge of academic interest in supply chain risk management, implementation still lacks behind. Well defined measurement methods and clear evidence can help to translate risk management practices into a business case and justify investments. Our results provide managers with a strong argument to invest in supply chain risk management projects (Chen & Paulraj, 2004).

The empirical results do not only support the sequence of risk identification, risk assessment, and risk mitigation, but also sound 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 for risk identification and risk assessment. Clear definition of scope and boundaries between the process steps are necessary in order to identify which supply chain risk activities yield the highest benefits for companies.

The very 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

initiatives need to be living processes, iteratively executed on a regular basis. The link is strongest from continuous improvement to risk identification which is in line with our expectations based on the current world economy. The increased speed of changes in the economic environment – strongly underlined by the current crisis – inevitably results in the need to continuously adapt internal processes to external changes. The strong effect of continuous improvement activities on risk identification supports the view of a dynamic environment where activities need to be readjusted regularly. The impact of continuous improvement on risk mitigation is still significant, but to a much lower degree. This lends support to the notion, that risk identification activities need to adapt more frequently to environmental changes and new risk, whereas risk mitigation strategies are rather constant.

## **6. Limitations and Future Research Directions**

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

Even though our sample covers a variety of industrial firms, the data was gathered solely within Germany which limits the generalizability of the results. Like most studies in the past, we surveyed high-level supply chain professionals from individual firms, who are capable of reliable assessments and are generally considered as a reliable source. While mainly relying on the manufacturer's perceptions is a potential limitation of our study, it also offers opportunity for further research. It would be informative to replicate this study within an international setting

surveying multiple sources and informants within the individual companies and also across the supply chain.

Our study clearly shows the strong relationship among the 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. An interesting question that arises from our finding is what specific risks are behind the analyzed data. Qualitative research is needed to go deeper into the variety of different risks that require distinct mitigation strategies.

Though our model notably shed light into the effect of upstream supply chain risk management activities to its risk performance, it would be interesting to investigate what other factor 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. This would provide even more detailed knowledge about risk management's effect on risk performance. Furthermore, future studies should analyze how risk performance impacts supply performance and how supply performance, in turn, is related to company performance. 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.

Given the calamitous events in recent years (such as hurricane Katrina or the Northeastern electrical power outage), much research remains to be done to further develop supply chain wide risk management programs that are rigorously linked to performance. Especially during the economic crisis risks like supplier bankruptcy are expected to increase (Chang, 2003). Thus, the

current economic situation emphasizes the importance of robust supply chains and duly executed risk management.

FIGURE 1  
Conceptual Model of Upstream Supply Chain Risk Management

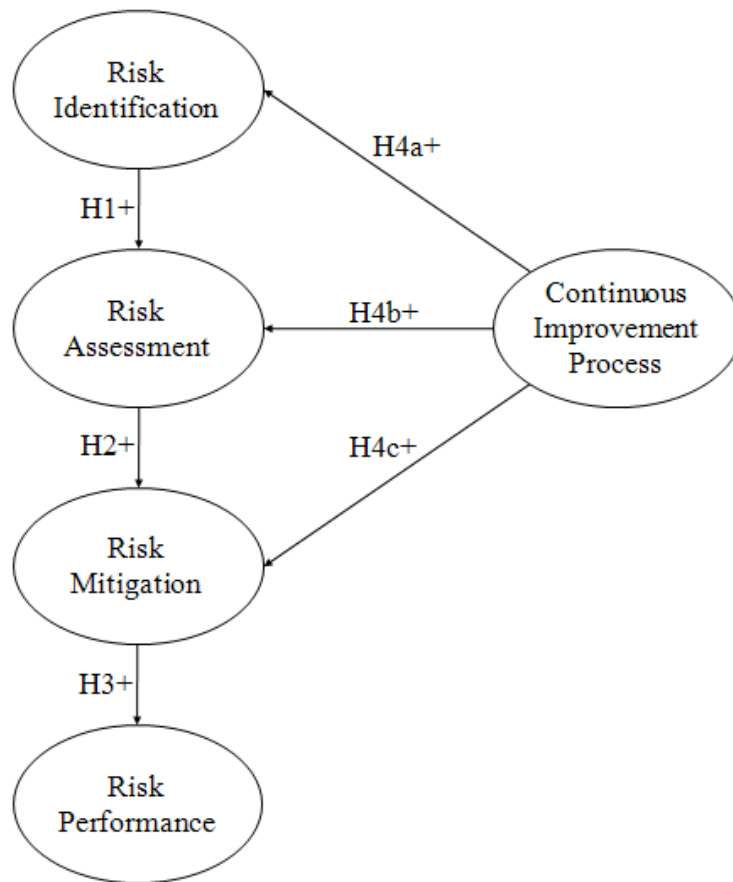


FIGURE 2  
Structural and Measurement Model

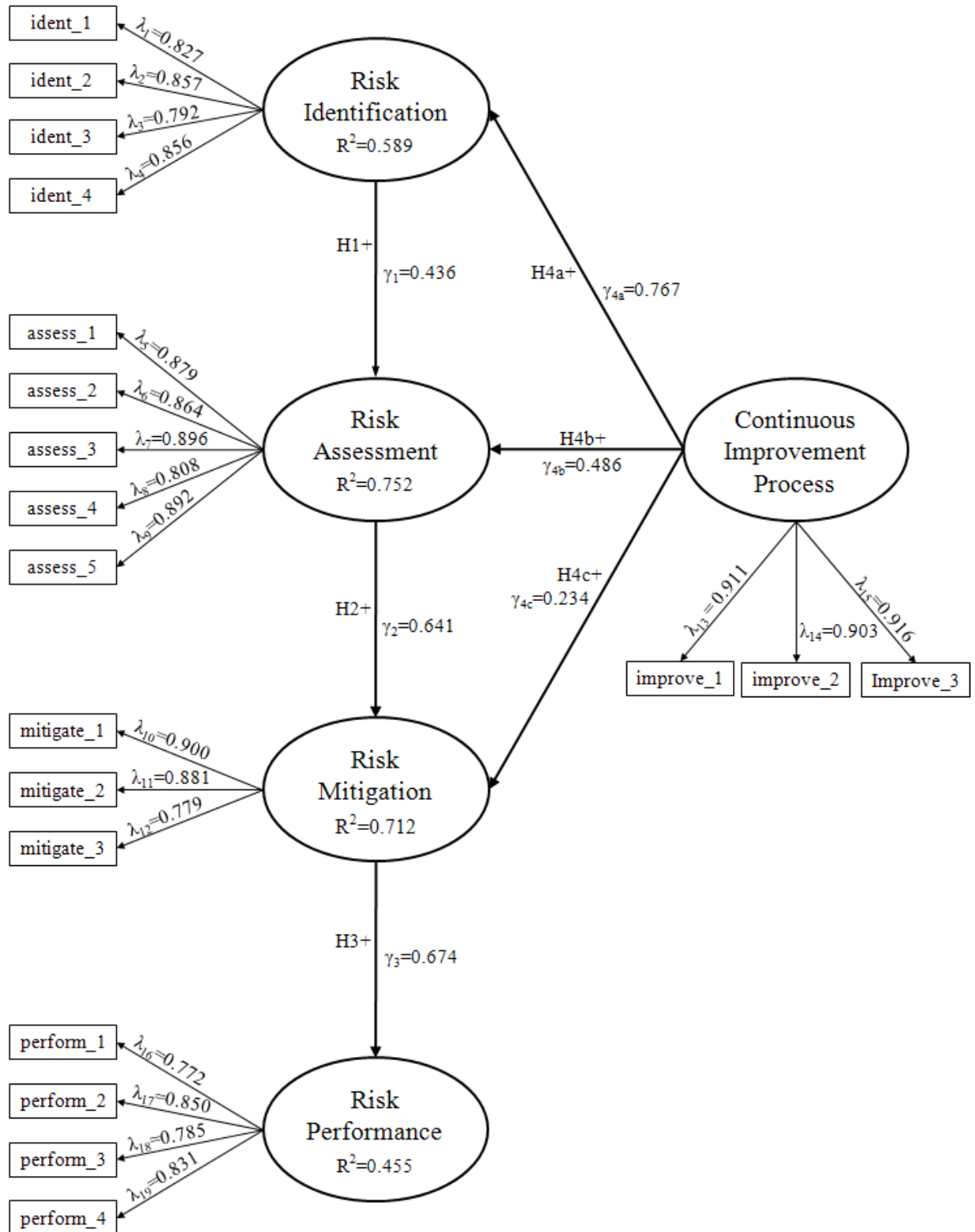


TABLE 1  
Cross Loadings

	Identification	Assessment	Mitigation	Continuous Improvement Process	Performance
ident_1	<b>0.827</b>	0.654	0.586	0.613	0.530
ident_2	<b>0.857</b>	0.728	0.613	0.670	0.558
ident_3	<b>0.792</b>	0.627	0.579	0.561	0.519
ident_4	<b>0.856</b>	0.685	0.652	0.705	0.631
assess_1	0.750	<b>0.879</b>	0.712	0.681	0.575
assess_2	0.690	<b>0.864</b>	0.718	0.687	0.587
assess_3	0.660	<b>0.896</b>	0.735	0.691	0.476
assess_4	0.735	<b>0.808</b>	0.691	0.759	0.604
assess_5	0.677	<b>0.892</b>	0.758	0.741	0.557
mitigate_1	0.648	0.790	<b>0.900</b>	0.663	0.544
mitigate_2	0.583	0.709	<b>0.881</b>	0.680	0.484
mitigate_3	0.632	0.631	<b>0.779</b>	0.603	0.691
improve_1	0.737	0.750	0.672	<b>0.911</b>	0.649
improve_2	0.692	0.793	0.717	<b>0.903</b>	0.626
improve_3	0.665	0.694	0.685	<b>0.916</b>	0.691
perform_1	0.520	0.516	0.586	0.520	<b>0.772</b>
perform_2	0.715	0.655	0.676	0.751	<b>0.850</b>
perform_3	0.421	0.407	0.386	0.459	<b>0.785</b>
perform_4	0.433	0.437	0.441	0.523	<b>0.831</b>

TABLE 2  
Composite Reliability and Average Variance Extracted

	Composite Reliability*	Average Variance Extracted**
Risk Identification	0.901	0.695
Risk Assessment	0.939	0.754
Risk Mitigation	0.890	0.730
Continuous Improvement Process	0.935	0.828
Risk Performance	0.884	0.657

Notes. Individual item loadings and critical ratios are reported in the appendix.

\* Composite reliability is a measure of the internal consistency of the construct indicators.

\*\* Average variance extracted reflects the overall amount of variance in the indicators accounted for by the latent construct.

TABLE 3  
Squared Correlation Matrix for Latent Multiple-Item Constructs

Construct	Number of items	(1)	(2)	(3)	(4)	(5)
(1) Identification	4	1				
(2) Assessment	5	0.655	1			
(3) Mitigation	3	0.532	0.694	1		
(4) Continuous Improvement Process	3	0.589	0.674	0.578	1	
(5) Performance	4	0.452	0.416	0.455	0.517	1

## APPENDIX

The operationalization of the latent constructs is summarized in this appendix. The survey used a seven-point Likert-type scale asking respondents to indicate to what extent they agree with the following statements. The scale ranged from “does not apply” (1) to “applies completely” (7). All constructs were operationalized using multi-dimensional reflective items.

TABLE A.1  
Risk Identification

Parcel	Item	Standard loading	Critical ratio*
ident_1	We are comprehensively informed about basically possible risks in our supplier network	0.827	26.962
ident_2	We are constantly searching for short-term risks in our supplier network	0.857	41.999
ident_3	In the course of our risk analysis for all suppliers, we select relevant observation fields for supply risks	0.792	21.935
ident_4	In the course of our risk analysis for all suppliers, we define early warning indicators	0.856	36.684

TABLE A.2  
Risk Assessment

Parcel	Item	Standard loading	Critical ratio*
assess_1	In the course of our risk analysis for individual suppliers or supplier groups we look for the possible sources of supply risks	0.879	44.142
assess_2	In the course of our risk analysis for individual suppliers or supplier groups we evaluate the probability of supply risks	0.864	35.805
assess_3	In the course of our risk analysis for individual suppliers or supplier groups analyze the possible impact of supply risks	0.896	57.952
assess_4	In the course of our risk analysis for all suppliers, we classify and prioritize our supply risks	0.808	26.786
assess_5	In the course of our risk analysis for individual suppliers or supplier groups, we evaluate the urgency of our supply risks	0.892	43.882

TABLE A.3  
Risk Mitigation

Parcel	Item	Standard loading	Critical ratio*
mitigate_1	In the course of our risk analysis for individual suppliers or supplier groups, we demonstrate possible reaction strategies	0.900	62.592
mitigate_2	In the course of our risk analysis for individual suppliers or supplier groups evaluate the effectiveness of possible reaction strategies	0.881	36.596
mitigate_3	Supply Risk Management is an important activity in our company	0.779	21.123

TABLE A.4  
Continuous Improvement Process

Parcel	Item	Standard loading	Critical ratio*
improve_1	We control our risk management methods in Purchasing and Supply Management and adapt these to changing conditions	0.911	62.108
improve_2	We control the progress of measures taken for critical supply risks	0.903	45.872
improve_3	We control the fundamental effectiveness of our activities for identifying and analyzing supply risks	0.916	68.216

TABLE A.5  
Risk Performance

Parcel	Item	Standard loading	Critical ratio*
perform_1	Our employees are highly sensibilized for the perception of supply risks	0.772	21.442
perform_2	Our risk management processes in purchasing are very professionally designed	0.850	34.907
perform_3	We have clearly managed to minimize the frequency of occurrence of supply risks over the last three years	0.785	15.394
perform_4	We have clearly managed to minimize the impact of occurrence of supply risks over the last three years	0.831	18.580

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