Abstract: - Since the prevailing business environment is becoming ever more dynamic and uncertain, especially on the supply side, a growing number of academics and practitioners have been drawing attention to supply chain risks. This development has been triggered particularly by the growing number of catastrophic events, such as natural and man-made disasters, which disrupt supply chains around the globe. Therefore, we focus on such external supply chain risks which are characterized by low probability and high impact and can even devastate an enterprise if there is no risk management [1]. We investigate approaches for firms to enhance their supply chain flexibility and to mitigate supply chain disruptions. In addition, we analyze the influence of supply chain flexibility and risk management on firm performance using partial least squares (PLS) analysis.

Key-Words: - Supply chain flexibility, supply chain risk management, diversification, supply chain performance, catastrophic events, supply chain management

1 Introduction
The prevailing business environment is more international and dynamic than ever and characterized by increasing uncertainty [2]. Therefore, managers need to develop strategies to deal with different types of risk [see 3, 4]. Unpredictable catastrophic events, such as Fukushima or the Thailand flood in 2011, which lead to an infrequent but increasing amount of disruptions [5, 6], expose firms to dramatic financial and operational risks [7]. Furthermore, the frequency of these natural and man-made disasters and the resulting economic loss are increasing [see 8, 1]. The result of this growing complexity of supply chains [9] as well as trends influencing supply chains, such as globalization, just-in-time, and increasing product variety [see 10, 11], is that supply chains are more vulnerable than ever [12]. However, most company strategies focus on recurrent low impact events or gradual climatic change impacts, but ignore sudden catastrophic events [7, 13] even though the probability of being affected by such an event – at least indirectly somewhere in the firms’ ecosystem – should not be underestimated [5, 14].

Since catastrophic events occur suddenly, leaving little time for adaptation [15], it is essential that supply chains become more resilient [16], i.e. having the capacity to adapt existing resources and skills to sudden changes or shocks [17]. Sheffi and Rice [18] distinguish between two main strategies for developing resilience, building redundancies or enhancing flexibility. Since redundancies in the sense of extra inventory are expensive and only pay off if a disruption occurs, research proposes flexibility as a major success factor for business continuity, mitigating effects of supply chain disruptions and quick recovery, allowing firms to use alternate suppliers, transportation routes and manufacturing sites with relative ease [14].

2 Theoretical Background and Hypotheses
Since there is no general flexibility theory [19], we base our research mainly on two theoretical approaches explaining the analyzed relations, namely contingency theory, and the dynamic capabilities approach. Contingency theory argues, that firms have to consider the context in which they act...
to ensure high performance [20] as performance is a result of the interaction between firms and their environment. Consequently, especially in dynamic and uncertain environments, firms need to be flexible with regard to environmental conditions and have to apply risk management strategies in order to react appropriately in the face of a catastrophic event, in order to minimize its effect on the supply chain [21]. Dynamic capabilities (DC), i.e. the ability of a company to reconfigure its capabilities in response to changing environments [22], are of particular importance in rapidly changing and disruptive environments [23], because they help firms to cope with changing conditions. Consequently, flexibility has been proposed as a DC [24, 2].

The effect of risk on different aspects of firms’ strategies as well as on performance is discussed intensively in the risk management literature [25, 20]. In contrast to previous research, we argue that not risk itself, but rather perceptions of risk exert a substantial impact on the strategy of a firm, as firms with higher risk perceptions spend more time on strategies to reduce or cope with risks.

Firms can diversify facilities, sourcing options and logistics [6] to reduce the risk of catastrophic events. Since multiple sourcing reduces dependency, it is regarded as the best way to manage procurement disruptions [26]. This coherence is already established [7, 27]. Furthermore, Contractor [28] argues that geographical diversification can reduce risk, and Ponomarov and Holcomb [11] argue that logistic processes and capabilities can be used to cope with increasing supply chain risks. Additionally, risk perceptions influence supply chain risk management processes [12]. Therefore, we propose that risk perception in the case of supply-chain design mainly impacts sourcing, geographical and transport diversification as well as supply chain risk management:

H1: The higher the level of perceived risk with regard to catastrophic events,
- the lower the sourcing dependency (H1a)
- the higher the degree of geographical diversification (H1b)
- the higher the degree of transport diversification (H1c)
- the more distinct the strategic supply chain risk management (SSCRM) (H1d).

As proposed in real options theory, diversification leads to flexibility [29]. Real options theory means that diversification enables capacity adjustment within a firms’ portfolio. Furthermore, Swafford et al. [30], for example, propose supply chain processes, i.e. geographical diversification of production, sourcing dependency and transport diversification, as the key antecedents of a firms’ supply chain flexibility (SCF). Consequently, we formulate:

H2: The higher the degree of geographical diversification, the greater the level of SCF.
H3: The higher the degree of transport diversification, the greater the level of SCF.

Flexibility positively affects performance, especially in dynamic and uncertain environments [31], because high flexibility allows firms to respond quickly to market changes [9]. In addition, Sheffi [32] argues that supply chain flexibility raises resilience in the face of serious disruptions, as well as less serious day-to-day ones. Therefore, we propose:

H5: The greater the level of SCF, the greater the overall supply chain performance (SCP).

The importance of supply chain risk management is often underrated in the literature [20]. In conceptual research, literature generally agrees that supply chain risk management has a positive effect on performance in turbulent environments [12], because it can minimize risks and improves performance as argued in contingency theory. Thus, we formulate:

H6: The more distinct the SSCR M, the greater the overall SCP.

Catastrophic events lead to highly dynamic environments, because their occurrence is uncertain. Following the dynamic capabilities approach, the advantages of flexibility increase with growing dynamics and uncertainty [33]. Furthermore, SSCR M focuses on a structured consideration and treatment of supply chain risks. Following contingency theory, SSCR M is more relevant for SCP in more dynamic and uncertain environments. Therefore, we propose:

H7a: The influence of SCF on SCP for firms affected by a catastrophic event is greater than for those that are not affected by such an event.

H7b: The influence of SSCR M on SCP for firms affected by a catastrophic event is greater than for those that are not affected by such an event.

3 Methodology and measures
To test our hypotheses, we conducted two studies, a qualitative pre-study of international consumer and industry goods manufacturers, as well as specialized consulting firms, and a questionnaire survey with 147 respondents out of 2,500 questionnaires (response rate: 6%) that could be used for data analysis. Remarkably, about 52% of the companies in the
quantitative survey were affected by a catastrophic event in the last three years.

We used 7-point Likert scales to measure the indicators of all variables [see 34]. For model testing, we applied partial least squares structural equation modeling (PLS-SEM) [see 35] and chose SmartPLS [see 36, 37, 38]. We adapted existing scales to our research context in terms of our qualitative study and the pre-test.

Risk perception is conceptualized as the perceived relevance of threats posed by catastrophic events and measured by two reflective items, e.g. “The risk associated with catastrophic events is threatening our very existence” [see 39]. Geographical diversification is defined as the spreading of business units of manufacturing firms. We used a reflective four-item scale, e.g. “We have a high geographical distribution of our employees”. Based on the results of our pre-study, we excluded sales concentration [see 40] and replaced it by an indicator measuring the diversification of the manufacturing units [see 41]. Sourcing dependency in our context captures single sourcing of products with no alternatives available and was measured using a reflective two-item scale, e.g. “We frequently use single sourcing” [see 4]. Similarly, transport diversification is operationalized as having alternative transport solutions for the required products available, thus enabling firms to change the mode of transportation rapidly. We measured it by two reflective items, e.g. “We frequently use different means of transport”, compiled in our pre-study on the basis of Swafford et al. [30]. Degree of SSCRM was basically adapted from Wagner and Bode [4] and adjusted to our research context. SCF is defined as the ability to switch rapidly from one plant to another, from one part to another or change capacity when necessary [31]. We measured it by six formative items, e.g. “We can switch quickly from one product to another” [see 42, 30, 2]. Finally, SCP was operationalized using two general reflective items, e.g. “Overall performance of the supply chain in the last three years has surpassed that of our competitors” [43]. Furthermore, a dichotomous variable – “affected by a catastrophic event” – is integrated in the model [see 4].

The reliability and validity assessment of the reflective measured constructs is presented in Tables 1 and 2. All constructs comply with the relevant requirements [44]. Convergent validity is given as factor loadings of each item were acceptable [45, 46, 47]. Discriminant validity of the constructs is tested according to Fornell and Larcker’s [48] suggestions. Each construct yields a sufficient level of discriminant validity (see Table 2).

Table 1: Reliability and validity assessment of the constructs

<table>
<thead>
<tr>
<th>Items</th>
<th>Cronbach's Alpha</th>
<th>Composite reliability</th>
<th>AVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Risk perception</td>
<td>0.79</td>
<td>0.846</td>
<td>0.79</td>
</tr>
<tr>
<td>(2) Geographical diversification</td>
<td>0.9062</td>
<td>0.9331</td>
<td>0.78</td>
</tr>
<tr>
<td>(3) Sourcing dependency</td>
<td>0.9075</td>
<td>0.9558</td>
<td>0.92</td>
</tr>
<tr>
<td>(4) Transport diversification</td>
<td>0.7684</td>
<td>0.8962</td>
<td>0.81</td>
</tr>
<tr>
<td>(5) Degree of SSCRM</td>
<td>0.8849</td>
<td>0.9087</td>
<td>0.59</td>
</tr>
<tr>
<td>(6) Supply chain performance</td>
<td>0.8339</td>
<td>0.9232</td>
<td>0.86</td>
</tr>
</tbody>
</table>

In order to assess the formative measurement model of SCF, external validity was tested by correlating the formative constructs with one global item (“We can react quickly to unforeseen events”) that is theoretically related to SCF. External validity is satisfactory (r=0.76; p<0.001) and multi-collinearity can be excluded (maximum variance inflation factor VIF=1.8; condition index CI=12.1 [49].

Table 2: Correlations and discriminant validity of the constructs

<table>
<thead>
<tr>
<th>Items</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Risk perception</td>
<td>0.79</td>
<td>0.03</td>
<td>0.0004</td>
<td>0.0009</td>
<td>0.04</td>
<td>0.01</td>
<td>0.0001</td>
</tr>
<tr>
<td>(2) Geographical diversification</td>
<td>0.17</td>
<td>0.78</td>
<td>0.0004</td>
<td>0.06</td>
<td>0.12</td>
<td>0.08</td>
<td>0.01</td>
</tr>
<tr>
<td>(3) Sourcing dependency</td>
<td>-0.02</td>
<td>-0.02</td>
<td>0.92</td>
<td>0.36</td>
<td>0.11</td>
<td>0.44</td>
<td>0.18</td>
</tr>
<tr>
<td>(4) Transport diversification</td>
<td>0.03</td>
<td>0.25</td>
<td>-0.60</td>
<td>0.81</td>
<td>0.21</td>
<td>0.34</td>
<td>0.08</td>
</tr>
<tr>
<td>(5) Degree of SSCRM</td>
<td>0.21</td>
<td>0.35</td>
<td>-0.33</td>
<td>0.46</td>
<td>0.59</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>(6) Supply chain flexibility</td>
<td>0.10</td>
<td>0.29</td>
<td>-0.66</td>
<td>0.58</td>
<td>0.41</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>(7) Supply chain performance</td>
<td>-0.01</td>
<td>0.12</td>
<td>-0.42</td>
<td>0.29</td>
<td>0.37</td>
<td>0.51</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Note: SCF is a formative construct. Diagonal terms (in bold) are the average variance extracted (AVE). The lower triangle of the matrix provides the correlations. The upper triangle of the matrix provides shared variances.

4 Hypothesis Testing and Discussion

Fig. 1 shows the results of the PLS analysis. With an R² of .54 for SCF and .29 for SCP the model fit is sufficient. In addition, the effect sizes (f²) and prediction accuracy, measured by Stone-Geisser-Test (Q²), are acceptable [46].

Hypothesis 1a could not be supported as the coefficient is not significant. The coefficients of Hypotheses 1b, 1c and 1d are positive and, except for transport diversification, significant (0.17, p<0.05; 0.03, n.s.; 0.21, p=0.01). Hypotheses 2, 3 and 4 could be approved. The results show significant effects of all relevant path coefficients (0.23, p<0.01; -0.54, p<0.01; 0.2, p<0.01). Hypotheses 5 and 6, proposing positive links between SCF and SCP, as well as SSCRM and SCP, could also be confirmed as the coefficients are positive and significant (0.43, p<0.01; 0.2, p<0.01). To test
Hypotheses 7a and 7b we analyzed the relationship between SCF and SCP, as well as SSCRM and SCP for the two groups separated by our dichotomous variable. The coefficients for both groups are positive and significant. However, no moderating effect could be established using the corrected Mann-Whitney-Wilcoxon-Test [50, 51, 37]. Anyhow, we found a difference in the effect sizes of SSCRM on SCP between the two groups (unaffected firms: $f^2=0.07$; affected firms: $f^2=0.18$).

**Fig. 1: Path model**

Our analysis demonstrates that SCF exerts a major influence on SCP and increases firms’ SCP, irrespective of the dynamism of the environment and the product that is manufactured. However, there are no significant differences with regard to the influence of SCF, as well as of SSCRM on SCP in different environments which could have different causes. First of all, catastrophic events are only one aspect of a dynamic environment. Additionally, our current environment could already be highly dynamic and uncertain. Furthermore, sample size is limited due to the two distinct groups of respondents.

Our study identified a significant positive relationship between SSCRM and SCP. Since SSCRM is expensive, this result also indicates that today’s environment is already dynamic, on both the supply- and demand-sides.

While risk perception has significant effects on SSCRM and geographical diversification, the correlation between risk perception and transport diversification as well as between risk perception and sourcing dependency could not be confirmed. Since sourcing often relies on the constrained possibility of procuring a specific resource, sourcing decisions are not affected significantly by risk perceptions. In addition, some products cannot be delivered with different transportation forms such as by air, because of their size or weight, or by ship because of delivery time issues.

Concerning the question of how to achieve SCF, we demonstrate that the three elements, namely sourcing, production and logistics, have significant effects on SCF and can explain more than half the variance of SCF. Sourcing strategies, with the greatest influence on SCF, will become an issue of particular interest in the future.

**5 Conclusion**

On the one hand, the results of this study indicate that supply chain disruptions are not as rare as commonly assumed. On the other hand, the impact of a catastrophic event and an associated disruption of supplies can threaten the very existence of a firm. Therefore, internationally active firms should intensify their focus on handling severe supply chain disruptions caused by catastrophic events.

The main managerial implication of this paper is that in the present international business environment, SCF and SSCRM contribute to achieving competitive advantages. SCF, thereby, can be achieved by diversification of sourcing, production and transport activities. Therefore, proactive planning and an integration of SCF and SSCRM in corporate strategies and organizational design are indispensable.
References:


