Supply Chain Resilience – Influence of Supply Chain Capabilities and Strategies on Agility and Robustness

Christoph Alexander Pickert[1] and Nattharika Rittippant[2]

Abstract

The increasing complexity of supply chains as well as a strong focus on operational efficiency resulted in supply chains which are increasingly prone and vulnerable to disruptions. As a result, the concept of supply chain resilience, which is the ability of a supply chain to resist external shocks and return quickly to its desired state, emerged. This research explores the resilience domain by investigating the effects relational competencies have on supply chain resilience and performance. We distinguish between a proactive and reactive dimension of resilience: robustness and agility. Survey data from Thai manufacturing companies are collected and the conceptual framework is preliminary tested using exploratory factor analysis. The paper contributes in terms of proposing and preliminary testing the conceptual model linking antecedents and consequences of a firm's supply chain resilience. It extends the theoretical models and frameworks of previous researchers by incorporating the influence of supply chain strategies. It also provides an explicit distinction between agility and robustness and the influence of these dimensions on the performance of the supply chain. By assessing the impact certain organizational capabilities have on the resilience of a supply chain, practitioners will be able to understand how to establish a more resilient supply chain.

Keywords: agility, robustness, supply chain management, supply chain resilience

Introduction

In March 2011 TOYOTA and a big number of other companies, which were focusing on tightly managed supply chains and disciplined operations received a wake-up call, when an earthquake reaching the magnitude of 9.0 on the Richter scale in conjunction with an enormous tsunami struck Japan. While worldwide news coverage was focusing on the impending danger of the melting down nuclear power plant of Fukushima, companies such as TOYOTA slowly began to realize the degree to what this natural disaster compromises its global business. The company has focused for years on an efficiency driven operation management and a tightly managed supply chain. Thus, slack and waste were removed from its operations. The just-in-time delivery became standard and inventory levels were reduced to a minimum. However these practices enabled TOYOTA to become the bestselling car manufacturer worldwide. The company was now more prone to supply chain disruptions than it has ever expected. A reduction of its supply base, single sourcing initiatives and minimum buffer stocks which have been effective in a stable environment now caused severe problems. The shutdown of a few auto-part suppliers grounded TOYOTA's assembly lines

[1] School of Management Technology, Sirindhorn International Institute of Technology, Thammasat University, 131 Moo 5, Tiwanont Road, Bangkadi, Muang 12000 THAILAND, Tel: 662-501-3505 Ext. 6003, Fax: 662-501-3505 Ext. 6014.

[2] Assistant Professor, School of Management Technology, Sirindhorn International Institute of Technology, Thammasat University, 131 Moo 5, Tiwanont Road, Bangkadi, Muang 12000 THAILAND, Tel: 662-501-3505 Ext. 6003, Fax: 662-501-3505 Ext. 6014, E-mail: natthari@siit.tu.ac.th.

worldwide within a few days and lead to a global decline in March production of about 30%. It took TOYOTA more than six months to recover from the disruption and return to the pre-disaster stage by delivering products in required volumes (Marchese and Lam, 2014; SC Digest, 2012).

The unexpected, disruptive events such as natural disasters constitute frequent reminders that companies operate in an increasingly unpredictable and risky environment. The recent disruptions include natural disasters such as Hurricane Katrina 2005 and Thailand flood 2011, diseases such as bird flu 2005 and swine flu 2009, terrorist attacks in New York 2001, as well as economic recessions or the global financial crisis 2008 (PWC, 2013; Soni, Jain and Kumar, 2014). The increasing global interconnectedness and complexity of supply chains, shortened product life cycles, as well as the strong focus on operational efficiency, make supply chains increasingly prone and vulnerable to disruptions (Bogataj and Borgata, 2007; Myers, Borghesi and Russo, 2006). Owing to these developments, the concept of supply chain resilience, which describes the ability of a supply chains to resist external shocks and return quickly to its desired state, emerged and has increasingly become more important among professionals and researchers (Marchese and Lam, 2014; Wieland and Wallenburg, 2013).

For companies, the implication is very clear: The competitiveness of an organization will heavily depend on the extent to which it can keep pace with the trend of designing and operating more robust and anticipatory supply chains. The need exists to develop more resilient supply chains, but it is still unclear for managers how the resilience can be achieved and how different capabilities foster or decrease resilience in a supply chain network (Ponomarov and Holcomb, 2009). Supply chain resilience is difficult to measure in terms of the return of investments. It is important for practitioners to have a clear understanding of the cause and effect relationships within the field of resilience. Practitioners need improved knowledge to analyze the factors that determine the resilience of supply chains against disruptions (Sheffi and Rice, 2005; Tang, 2006).

Hence this study examines the issue of resilience, which is of great importance in the field of supply chain management. In order to do so, we examine the causal effects certain organizational capabilities have on resilience and the impact resilience has on the performance of a supply chain. A purposefully distinction is made between the proactive (robustness) and reactive (agility) component of Resilience.

Literature Review

Due to the fact that Resilience is an emerging field in the Supply Chain Management (SCM), a generally accepted and commonly used definition for this multi-disciplinary and multi-faceted does not exist (Hohenstein, Feisel, Hartmann and Giunipero, 2015). Rice and Caniato (2003, p. 25) took the first attempts to explain the resilience within the field SCM and developed their definition from an organizational point of view. According to their definition, resilience in SCM can be regarded as the "ability to react to an unexpected disruption, such as one caused by a terrorist attack or a natural disaster, and restore normal operations." In contrast Christopher and Peck (2004) as well as Sheffi and Rice (2005) define resilience as the ability of a system to withstand external shocks and quickly restore the initial state or even achieve a more aspirational state in the aftermath of a disturbance. An extensive and theoretically founded definition of resilience has been established by Ponomarov and Holcomb (2009), who followed a multidisciplinary approach. According to Ponomarov and Holcomb (2009, p. 131) supply chain resilience is defined as "The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function." This study furthermore follows the concept of a separation of resilience into a proactive and reactive dimension as proposed by Wieland and Wallenburg (2013). These two dimensions are classified as agility and robustness. Agility is defined as a concept, which is mainly based on flexibility and responsiveness (Braunscheidel and Suresh, 2009) and marked by obligatory information enrichment consultative forecast mechanism in order to react quickly to changing requirements or scenarios (Fernie, Sparks and McKinnon, 2010). By establishing visibility and flexibility as well as a high degree of connectedness between supply chain partners, agility constitutes an important element of the resilience capabilities by enabling a supply chain to quickly and efficiently respond to changes (Christopher and Peck, 2004; Braunscheidel and Suresh, 2009). Robustness in contrast is defined as the proactive dimension of resilience (Shukla, Lalit and Venkatasubramanian, 2011) and as "the ability of a supply chain to resist change without adapting its initial stable configuration" (Wieland and Wallenburg, 2012, p. 890). The requirements of a resilient supply chain, to be relatively resistant to external disruptions (Meepetchdee and Shah, 2007) and to master a variety of situations without showing significant adverse effects (Harrison, 2005) are, thus, expressed by its robust capabilities.

The literature related to the resilience domain of supply chains is extensive and covers several different areas of academic research. A strong scientific interest in the study of supply chain resilience could be observed after major disruptions such as the 9/11 terrorist attacks or the tsunami in Thailand, which significantly affected the global economy (Christopher and Peck, 2004; Rice and Caniato, 2003; Sheffi and Rice, 2005). In the light of following disorders such as Hurricane Katrina or the nuclear catastrophe in Fukushima, it is not surprising that the resilience of supply chains is increasingly considered in scientific publications. According to Hohenstein et al. (2015) these developments show that the exploration of resilience will likely be intensified over the next years as supply chain resilience proved to be an important factor for companies' competitiveness.

Although an extensive body of literature exists on the topic of resilience, the majority of the published research on this topic concentrated on defining the concept of resilience (Sheffi and Rice, 2005), highlighting its importance (Hendricks and Singhal, 2005; Hendricks, Singhal and Zhang, 2009) or identifying certain characteristics, which have influence on the resilience of a supply chain (Thun and Hoenig, 2011). Most of the studies however examine certain characteristics, fostering SC-Resilience in an isolated research setup and do not link them with other important factors. Therefore, there is still a lack of understanding concerning the most important elements of the supply chain resilience and the relations between them (Wieland and Wallenburg, 2013). Moreover, only a small number of papers exist that deals with the identification and examination of antecedents and relates those capabilities with the results of resilience (Carvalho, Barroso, Machado, Azevedo and Cruz-Machado, 2011). According to Ponomarov (2012), the literature also lacks theoretical justification for the established frameworks of resilient supply chains. Obvious gaps are the missing conceptualization of the complex cause-effect relationships between the different characteristics fostering resilience and the analysis between antecedents and outcomes of supply chain resilience, as well as a need for an empirical testing of proposed conceptual models (Ponomarov, 2012; Wieland and Wallenburg, 2013).

Hypothesis Development

The basis of this work is constituted by previous studies, which are investigating and considering supply chain capabilities in the context of a resource-oriented perspective (Zhao, Droge and Stank, 2001; Lynch, Keller and Ozment, 2000). In the existing literature, several logistics and supply chain-related functions are discussed and analyzed, which contribute to improvements in company performance and thereby create a sustainable competitive advantage (Lynch, Keller and Ozment, 2000; Zhao, Droge and Stank, 2001; Esper, Fugate and Davis, 2007; Olavarrieta and Ellinger, 1997). Christopher and Peck (2004, p. 13) came to the conclusion that resilience should be purposefully designed in a supply chain and that certain capabilities should be implemented in order to improve the supply chain resilience. This paper, therefore, investigates how certain supply chain capabilities affect the resilience of a supply chain and subsequently the firms' performance.

Antecedents of Supply Chain Resilience

In order to achieve a high degree of agility and robustness, a company needs visibility to improve the identification of potential changes as well as speed to be able to respond quickly (Christopher and Peck, 2004). Therefore, achieving this visibility is an important precondition for enabling companies to recognize and accurately respond to changes. Barratt and Oke (2007) showed that visibility can be facilitated by investments in information management capabilities. Information sharing can foster both the visibility of changes or disruption as well as the speed managers can respond to them (Holweg and Pil, 2008; Wieland and Wallenburg, 2013).

In order to cope with the complexity and uncertainty in today's business environment, as well as to enhance efficiency and effectiveness, companies now apply cooperative organizational structures (Achrol and Louis, 1988; Stank, Davis and Fugate, 2005). According to the resource dependency theory, stronger relationships enable companies in uncertain times to skim off required resources from supply chain partners in order to effectively use resources and maintain competitiveness (Fynes, Burca and Marshall, 2004). Within a supply chain, forming closer long-term relationships with partners, such as key or lead suppliers, can be regarded as an option of creating governance mechanisms and to reduce uncertainty. In this way, a strategic supply chain orientation is becoming increasingly significant (Ponomarov, 2012).

In order to reduce risk and disruption vulnerability, the members of a supply chain must be able to proactively anticipate possible changes and implement reliable solutions and strategies that prevent their supply chains from the negative effects in the future (Hendricks, Singhal and Zhang, 2009; Zsidisin and Wagner, 2010). Thus, the anticipation and preparedness and the strategies fostering these capabilities are essential factors of resilient supply chains (Wieland and Wallenburg, 2013).

Furthermore risk management capabilities play an important role with regard to resilience as the creation of a risk management culture in the organization can enhance or even facilitate the resilience component in the supply chain (Christopher and Peck, 2004).

According to Wieland and Wallenburg (2012), risk management at supply chain stages can mitigate cascading failures of the supply chain. Strong risk management capabilities foster the implementation of proactive risk measures and support organizational learning from previous events (Lin and Wang, 2011; Schmitt, 2011).

Effects of Supply Chain Resilience on Supply Chain Performance

If a disruption has occurred at some point of the supply chain, agility ensures an adequate response and adaptation to the disturbances and enables a supply chain to start the recovery as soon as possible (Hohenstein et al., 2015). A rapid response to a disturbance allows a supply chain to quickly recover and can reduce the total negative effects of a disruption considerably (Manuj and Mentzer, 2008). The more time a company needs to react and to carry out its countermeasures, the longer disruption may exert its negative influence on the performance of a supply chain (Blackhurst, Craighead, Elkins and Handfield, 2005). Furthermore, Blackhurst, Kaitlin and Craighead (2011) highlighted the positive effect the agile components of resilient capabilities have on the performance of a supply chain by considerably reducing the recovery time after a disturbance occurred.

According to Yang, Aydin, Babich and Beil (2009), it is essential for organizations how potential disturbances can be anticipated and to find ways how to effectively prepare and deal with prospective disruptions. For reducing the associated risks of disruptions by means of a robust supply chain design, companies should implement robust strategies such as slack capacities, redundancies or safety stocks in their supply chain, which will decrease the impact of negative effects on the performance (Hendricks, Singhal and Zhang, 2009; Zsidisin and Wagner, 2010). Hamel and Välikangas (2003) emphasized the significance of forward-looking capabilities that can identify trends and risks that may sustainably affect the profitability of the core business. By anticipating future uncertainties, which is an important part of a proactive supply chain strategy, positive effects on the overall performance of a supply chain can be achieved accordingly (Hallikas, Karvonen, Pulkkinen, Virolainen and Tuominen, 2004).

Conceptual Framework

Based on the literature review, a conceptual model linking antecedents of resilience and their influence on agility and robustness as well as the influence of those two factors on the performance of the supply chain is developed. Figure 1 illustrates our conceptual model and hypotheses.

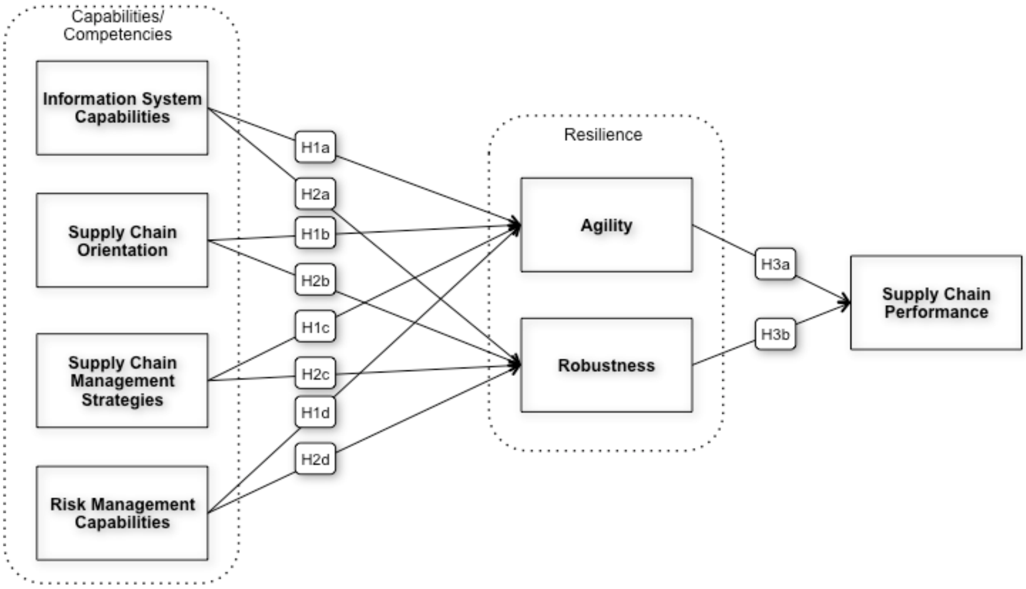

Figure 1. Conceptual Model

Methodology

Data Collection

Survey data from Thailand based companies was collected by conducting a web-based survey and preliminary analyzed using exploratory factor analysis (EFA). According to the recommendations of Ponomarov (2012), the target groups were senior-level employees of companies working in the field of supply chain management or with direct involvement in company decision-making processes. The survey was conducted in Thailand and 137 usable responses have been collected for 5 months between December 2014 and April 2015.

Data Analysis

As preparation for the model estimation, the collected data is first reviewed for missing values and outliers. In Addition the data is subsequently tested for multi-normal distribution, as the Maximum Likelihood (ML) method is desired for the estimations. The missing values showed no systematic failures and the overall number of missing values is comparatively small. Thus, the Full Information Maximum Likelihood (FIML) estimation was used to estimate the missing values (Arbuckle, 1996). In order to identify outliners in the data set, the Outliner Labeling Rule analysis according to Hoaglin, Iglewicz and Tuckey (1986) was applied. The analysis conducted with a g-value of 2.2 as proposed by Hoaglin and Iglewicz (1987) showed no considerable outliners in the dataset, which is not unusual as all variables were operationalized using a 5-point Likert Scale. In order to assess the normal distribution of the dataset, Kolmogorov-Smirnov test (KS) and Shapiro-Wilk test (SW) were applied as well as kurtosis, skewness and critical ratios were considered. The assessment on the indicators level overall suggest only a moderate violation of the assumption of normal distribution. Thus, a model estimation based on the ML-method can be applied in the further steps of this study, as the ML-method should only be rejected if an extreme violation of the multi-normal distribution assumption exists (Bollen 1989). In order to assess the reliability and validity, testing of reflective measurement models exploratory factor analysis was conducted.

Results

The KMO criterion of 0.864 and the rejection of Bartlett's tests indicate sufficient correlations of the reflective measurement indicators, thereby supporting the adoption of the concept of multiple items. Most of the communalities show high values with values > 0.5 and, thus, can be considered adequate (Weiber and Mühlhaus 2014). Only the values for the items for Supply Chain Orientation (SCO) show slightly lower values but are still close to 0.5. However, Lean Supply Chain Strategy shows a significantly lower value of 0.093. With correlations in the range of about 0.6 to 0.9 on the propagated factor and values in the range of less than 0.3 for the other factors, the EFA provides that all constructs are one-dimensional and a high suitability for the subsequent analysis steps is generally given.

Table 1 shows the detail EFA results of the rotated factor matrix by applying Direct Oblimin rotation. The positive and negative prefixes of the factor loadings can be ignored as long as the indicators, which are strongly loading on one factor, show the same prefixes. Negative values only indicate that the indicators are located in a negative quadrant after rotation. In summary it can be stated that the hypothetically assumed structure of seven factors can be confirmed on the basis of the EFA. The Lean Supply Chain Strategy has been excluded and Integrated Environment Supply Chain Orientation is considered as an item of Information System Capabilities. Table 1 indicates that seven factors could be extracted, which explain most of the variance in the collected data. Therefore, the analysis indicates that the factors of the proposed framework are in accordance with the underlying data and that the survey items are appropriate measures for these factors. However, it should be emphasized that the EFA only proves that the survey items are valid measurements of their assigned factors. In order to test the validity and reliability of the conceptual model, more sophisticated quantitative techniques such as Structured Equation Modeling should be applied.

Table 1. Exploratory Factor Analysis Results

	Factor						
	RMC	IMC	SCS	RBN	SCP	AGT	SCO
RiskAssessment	.906	-.081	.069	-.112	.117	-.148	-.021
RiskMonitoring	.857	.066	-.092	.149	-.078	-.009	-.001
RiskMgtTeam	.780	.099	-.076	-.031	.012	.086	.030
RiskIdentify	.765	-.047	.043	-.111	-.176	.000	.007
RiskImplement	.717	-.022	.004	-.139	-.103	.054	.030
JointPlanning	.084	.884	-.086	.003	.041	-.010	.036
InfoAccuracy	-.006	.793	.093	-.063	-.018	-.121	.080
ExtInfoSharing	.078	.777	.087	.021	-.076	-.052	.066
IntInfoSharing	-.091	.755	-.039	-.063	-.126	-.076	-.125
IntegratedDB	-.087	.661	.031	-.001	-.229	-.212	.030
IntegratedEnvir	.061	.559	-.083	.023	-.044	-.095	.158
SlackCapability	.167	.164	-.801	-.067	.078	.006	-.087
SafetyStock	.045	.057	-.785	-.040	-.074	-.075	-.068
FlexSupply	-.040	-.035	-.761	-.029	.025	-.113	.025
FlexTransport	-.090	-.054	-.659	-.193	-.095	-.035	.131
Postponement	.030	-.095	-.631	-.111	-.063	-.076	.229
LeanStrategy	-.079	.139	.182	-.040	.112	.048	.021
GrantTime	-.017	-.034	-.044	-.867	-.098	-.075	.012
RetainStability	.044	-.028	-.038	-.795	-.084	-.116	.006
FlexSC	.058	.040	-.049	-.734	-.073	.027	.016
CarryOutFunc	.167	.144	-.083	-.685	.119	.015	-.097
Connectedness	.110	-.031	-.169	-.529	-.074	-.027	.155
CustResponse	.060	.032	-.031	-.120	-.763	.012	-.051
CustShipment	-.013	.080	-.193	.109	-.727	-.088	.030
QuantMaintain	.104	.041	-.053	.025	-.694	-.079	.055
OnTimeDelivery	.021	.014	.021	-.152	-.657	-.030	-.018
FixManufTime	.087	.143	.102	-.102	-.627	.027	-.004
CustService	-.018	.039	-.109	-.039	.017	-.810	-.055
ManufLeadTime	.062	.072	-.089	.088	-.034	-.783	-.035
RestorProdFlow	.104	.097	.045	.056	-.117	-.756	.108
DeliveryReliabil	-.077	.077	-.051	-.124	.012	-.736	-.005
MktResponsive	-.010	.110	-.024	-.166	.009	-.624	.073
CustCollaborat	.081	.035	.065	-.032	.010	.039	.725
CustObjective	.019	-.109	.058	-.033	-.019	-.143	.621
TopManagement	-.024	.159	-.113	.013	-.010	.142	.599
TrustCustomer	-.054	.050	-.069	.040	.027	-.031	.556

Conclusion

This paper contributes with a quantitative study to an improved understanding of the supply chain resilience. A conceptual model was developed in an attempt to explain the complex phenomenon of the supply chain resilience. Our exploratory factor analysis provides the preliminary results of factor loadings. It could be shown that the theoretically derived factors are supported by the collected data and that the survey items provide a good reproduction of the identified factors. The study limitations include the small sample size and generalizability issue due to the fact that we only collected the data from manufacturing companies in Thailand. Further analysis to prove the model using a more sophisticated tool such as structural equation modeling is recommended. Larger sample size to include firms from other countries for cross comparison should be further pursued.

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