Supply Chain Capabilities, Risks, and Resilience

Xavier Brusset[a], Christoph Teller[b]

[a]*Université de Toulouse, Toulouse Business School, Toulouse, France*
[b]*Surrey Business School, University of Surrey, Guildford, UK*

Abstract

Supply chain resilience is an operational capability that enables a disrupted or broken supply chain to reconstruct itself and be stronger than before. This paper examines resilience using the dynamic capabilities approach, grounded in the Resource-Based View of firms. The purpose of this research is to provide insights for achieving resilience by mapping the relationships between the practices, resources, and processes over which a manager has control. A survey of 171 managers is used to test a conceptual model that proposes relationship between supply chain capabilities and resilience as well as the moderating role of supply chain risks. Variance-based structural equation modeling reveals that only tighter integration between echelons and increasing flexibility lead to added resilience. The perception of supplier risk helps motivate the supply chain manager to enhance integration capabilities and thus achieve higher resilience. Furthermore, the perception of external risks to a supply chain actually reduces the effort of deploying external capabilities to obtain resilience. Overall, the findings strongly support the view that resources, routines, and capabilities provide different results in terms of resilience depending upon supply chain risk factors.

Supply Chain Capabilities, Risks, and Resilience

Abstract

Supply chain resilience is an operational capability that enables a disrupted or broken supply chain to reconstruct itself and be stronger than before. This paper examines resilience using the dynamic capabilities approach, grounded in the Resource-Based View of firms. The purpose of this research is to provide insights for achieving resilience by mapping the relationships between the practices, resources, and processes over which a manager has control. A survey of 171 managers is used to test a conceptual model that proposes relationship between supply chain capabilities and resilience as well as the moderating role of supply chain risks. Variance-based structural equation modeling reveals that only tighter integration between echelons and increasing flexibility lead to added resilience. The perception of supplier risk helps motivate the supply chain manager to enhance integration capabilities and thus achieve higher resilience. Furthermore, the perception of external risks to a supply chain actually reduces the effort of deploying external capabilities to obtain resilience. Overall, the findings strongly support the view that resources, routines, and capabilities provide different results in terms of resilience depending upon supply chain risk factors.

Keywords: Resilience, Supply Chain, dynamic capability, survey

1. Introduction

Supply chain risk management remains a key managerial challenge that affects the performance of organizations (Altay and Ramirez, 2010). Characteristics such as tighter collaboration, increased complexity, reduced inventory levels, and ever-wider geographic dispersion have created greater vulnerabilities (Bode et al., 2011). Supply chain management literature is now beginning to explore how best to build resilience in supply chains, with increasing attention especially toward value chain fragmentation and geographical extension (Gulati et al., 2000). All economic disruptions, whether natural or man-made, carry unforeseen threats to the performance and profitability of supply networks (Hindle, 2008; The Economist, 2009).

In sociology and ecology, resilience characterizes an organization or a social body that is able to rebuild itself after having been substantially affected by an exogenous attack (Berkes et al., 2003). One example from the United States is that of Walmart's operations before and after the passage of hurricane Sandy in 2012 (Creighton et al., 2014). Resilience, as defined by Brandon-Jones et al. (2014), page 55, and Christopher and Peck (2004), page 4, is "the ability of a supply chain to return to normal operating performance, within an acceptable period of time, after being disturbed".

Given the literature and interest in resilience, it is surprising that the management practices required to achieve it are approached from so many different managerial viewpoints (e.g., operations, strategy, information systems, marketing, human resources) as exemplified in Li et al. (2008, 2009). In this paper, we consider the supply chain managers as the central decision-makers and organizers of the management processes within the supply chain. As such,they organize, deploy and control all the necessary investments, assets, resources, routines, processes, and systems to achieve the strategic goal of enabling the supply chain to be resilient. Grounded in the Resource-Based View (RBV) (Wernerfelt, 1984), the dynamic capabilities theoretical framework introduced in Teece and Pisano (1994) yields powerful results

2

which can be brought to bear in the present setting. Teece (2007) defines a dynamic capability as the ability to dynamically integrate, build, and reconfigure lower-order competences to achieve congruence with changing business environments.

We apply this framework here to answer the following questions: (1) Given the risks being faced, what practices does a supply chain manager deploy to obtain such resilience? (2) How do environmental factors related to supply chains influence the effectiveness of these practices? With this dual focus, our research contributes to theory as well as practice by increasing understanding of how to enhance resilience and providing insights to determine the supply chain capabilities required to achieve greater resilience.

We next present a review of the literature and the theoretical underpinning of our paper, from which we derive a conceptual model. Next, we elaborate on the study's methodology, analytical approach, and the results of our empirical study. The concluding sections discuss the theoretical and practical implications of the findings, highlight limitations, and outline directions for future research.

2. Theoretical background and conceptual model

The dynamic capabilities approach has gained wide acceptance as a tool to explain performance across competing firms (Barreto, 2010; Teece et al., 1997). According to this perspective, superior performance stems from two types of organizational capability, namely, dynamic capability and operational capability (Cepeda and Vera, 2007; Helfat and Peteraf, 2003).

The literature has formulated the basic difference between dynamic capability and operational capability (Teece, 2007; Winter, 2003). Dynamic capabilities are a learned pattern of collective activity and strategic routines through which an organization can generate and modify operating practices to achieve a new resource configuration and achieve and sustain a competitive advantage (Teece et al., 1997; Teece, 2007). Barreto (2010) recommends

3

that research should focus on the factors that may help (or hinder) firms to achieve the potential represented by their dynamic capabilities. It is important to recognise that the value of dynamic capabilities is context dependent (Wilden et al., 2013) and not a set recipe or formula for general effectiveness. Organizational response to environmental turbulence is faster as well as more effective (Chmielewski and Paladino, 2007) so ultimately enhances performance. Attaining competitive advantages requires efficient and effective sharing and deployment of resources between partnering organizations and supply chain partners (Rajaguru and Matanda, 2013).

By contrast, Winter (2003) argues that an operational capability provides the means by which a firm functions or operates to make a living in the present. Dynamic capabilities are considered to be of a higher order than operational capabilities, as their role is to contribute to the firm's higher relative performance over time (Drnevich and Kriauciunas, 2011). An operational capability refers to a firm's ability to execute and coordinate the various tasks required to perform operational activities, such as distribution logistics and operations planning, which are processes and routines rooted in knowledge (Cepeda and Vera, 2007). This capability refers to a high-level routine or a collection of routines (named organizational routines or competences in Teece et al., 1997) that can be used to respond to unforeseen events affecting the ability of a supply chain to perform (Barreto, 2010; Eisenhardt and Martin, 2000). For example, given the increasing importance of timely and cost-effective product delivery, supply chain resilience is considered a critical capability to maintain the continuity of operations. Resilience as an operational capability requires both internal processes as well as those relative to the information flow, coordination, and collaboration with upstream and downstream partners.

To build and operate a resilient supply chain, it is helpful to have an in-depth understanding of the lower-order capabilities (or micro-foundations, as described in Teece, 2007) that are required.
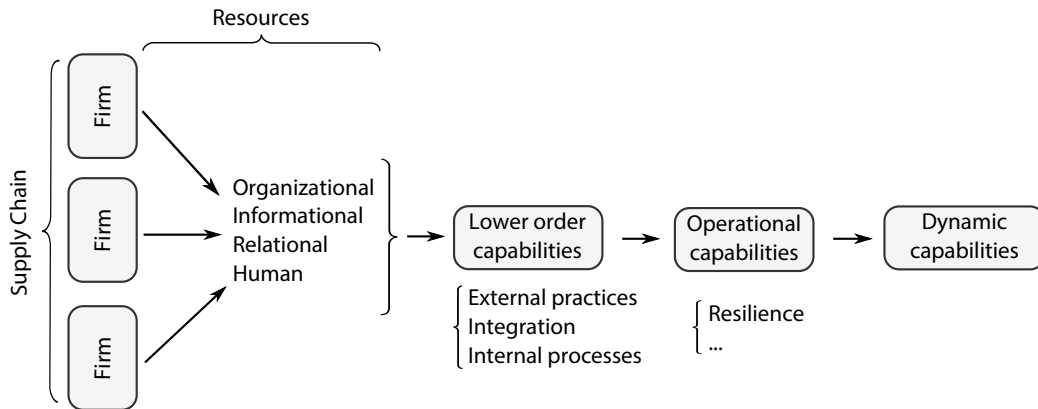
Figure 1: Theoretical model of the Resource-Based-View of a supply chain

Managerial systems, procedures and processes that undergird each class of capability define what Teece (2007) call organizational routines or competences and what Barreto (2010) sees as a requirement for supply chain operations. Henceforth named here lower-order capabilities, they are distinct from the capability itself (Teece, 2007). These lower-order capabilities along the supply chain constitute the practices among the different chain members using which the supply chain is able to absorb or recover from disturbances, and still maintain its ability to deliver value to final customers (Bhamra et al., 2011).

The dynamic capabilities approach makes it possible to characterize the operational capabilities that supply chain managers wish to enhance as well as the routines, procedures, and processes they apply at their firms and across their supply chains (see Figure 1). We now switch focus to the relationship between those lower-order capabilities and the operational capabilities that characterize resilience.

2.1. Resilience in supply chains

An important aspect for all supply chain managers is the capacity of their supply chain to withstand upheavals, disruptions and unforeseen events (e.g., Brandon-Jones et al., 2014; Bhamra et al., 2011). A supply chain

that is still able to perform and deliver products and services under such circumstances is characterized as resilient (Blackhurst et al., 2011). This capacity is defined in Fiksel (2006) and in Pettit et al. (2010) as "the capacity for an enterprise to survive, adapt, and grow in the face of turbulent change". Resilience has broader implications than supply chain risk control. Since supply chains have increased in both length and complexity (Blackhurst et al., 2005), natural catastrophes, wars, strikes and economic upheavals severely impact performance (Chopra and Sodhi, 2004; Wagner and Bode, 2008). Hendricks (2005) states that it is critical for firms to enhance the resiliency (sic) in their supply chains and call for research into specific tactics that help firms develop such capabilities.

Studies are concerned with the ability of the supply chain to return to its original state of operation after being disturbed (Pettit et al., 2010). Today's supply chains are more prone to disruptions caused by natural and man-made events (Wagner and Bode, 2008). Hence, the ability to recover quickly has become a topic of concern for practitioners and academics.

Having described resilience as an operational capability, we now characterize the lower-order capabilities available to the supply chain manager, which, when deployed across all members of the supply chain, should generate this capability. We then stipulate the corresponding hypotheses.

2.2. Lower-order capabilities and hypothesis development

We define lower-order capabilities as the set of physical, financial, human, technological, and organizational resources (Grant, 1991) coordinated by organizational routines (Nelson and Winter, 1982) and deployed in an organization and across organizations.

The literature provides abundant descriptions of the practical managerial routines and processes deployed by a large number of supply chain managers. For the purpose of this study, we centered our attention on the organizational, informational, and human resources across organizations. Even though the relevant literature often does not mention the RBV, the resources mentioned

clearly belong to the class of lower-order capabilities that we identified above. For example, a fully deployed second-generation material requirements planning (MRP II) system is composed mostly of procedures, information systems, and skilled operators, as well as tangible assets (computers, servers and wide area networks). This MRP has to be connected to other firms in the supply chain to exchange forecasts, delivery schedules, and other planning requirements (Akkermans et al., 2003). This lower-order capability, when combined with other similar practices, will contribute to a higher-order operational capability (Su and Yang, 2010). The practices that we consider as having influence on operational capabilities can be grouped as external, integration, and flexibility capabilities, which are described below.

External capabilities: These are the practices that in sum represent Efficient Customer Response policies (Skjoett-Larsen et al., 2003). Partners have to collaborate through systems such as Vendor Managed Inventory (VMI) and Collaborative, Planning, Forecasting, and Replenishment (CPFR) with retailers to enhance close cooperation among autonomous organizations engaged in joint efforts to effectively meet end-customer needs (Faisal et al., 2007).

The flow of accurate and real-time information in the supply chain is considered by many to be as important as the flow of goods. Information sharing can also provide flexibility and improve the responsiveness of the supply chain (Gosain et al., 2005; Agarwal et al., 2006). The information shared may include: end-customer demand, sales forecasts, order status, inventory levels, capacity availability, lead times, and quality. Sharing information can improve transparency, avoid lost sales, speed up payment cycles, create trust, avoid over-production, and reduce inventories (for reviews, see Bhamra et al., 2011; Sahin and Robinson, 2002). Current inter-organizational information systems (IOIS) facilitate the sharing of real-time information in the supply chain and allow organizations to be more effectively coordinated throughout the network. These systems are named Advanced Planning and Scheduling

7

(APS), Collaborative Planning, Forecasting and Replenishment (CPFR), and Efficient Customer Response. IOIS also have implications for the way that supply chains are designed and managed. One important example is the use of vendor managed inventory (VMI) systems where an upstream supplier is able to react directly to the inventory and demand information from a downstream customer by adjusting the quantity and timing of deliveries (Kotzab, 1999). These practices enable a supply chain to be reconfigured when faced with unexpected and disrupting events. As characterized in Faisal et al. (2006) and Faisal et al. (2007), supply chains are affected by "information risks".

Hendricks (2005) empirically documents how glitches in supply chains affect operating performance, naming sources of glitches that run the gamut from parts shortages to reorganizational delays and information technology (IT) problems. Klibi et al. (2010) specifies how resilience in supply chains should be assessed in view of the disruptions being faced. The solutions they propose to enhance resilience require tighter integration of suppliers and distribution networks as well as building redundancy and flexibility. Mandal (2012) specifically identifies IT (an important component of external capabilities) as one of the sources for increased resilience in a supply chain. The resilience provided protects the supply chain against the vagaries of the market. Our first hypothesis is the following.

Hypothesis 1. *There is a positive relationship between the implementation rate of external capabilities (ξ_1) and the level of resilience (η_1) in supply chains.*

Integration capabilities: Supply chain integration has been defined "as the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organization processes. The goal is to achieve effective and efficient flows of products and services, information, money and decisions, to provide maximum value to

8

the customer at low cost and high speed" (Naylor et al., 1999; Frohlich and Westbrook, 2001; Flynn et al., 2010). Even though the integration of manufacturers and clients has been studied in the context of China through the prism of power relationship commitment theory (Zhao et al., 2008), other literature such as Pagell (2004); Lin et al. (2006); Faisal et al. (2007); Rajaguru and Matanda (2013) view this capability as consisting of IT systems and practices that employ both information systems and the corresponding managerial practices and routines to enhance inter-organizational integration and coordination. Such integration of IT with supply chain processes enhances collaboration in the chain through continuous adjustments to the product lineup and inventories as well as sharing forecasts, sales data and inventory levels (Qrunfleh and Tarafdar, 2013, for an appreciation of the impact of Information Systems on supply chain performance). Collaborative platforms provide the possibility of exchanging information in real time (Boyson et al., 2003). The technologies that enable goods to be tracked and traced provide greater control over operations within the chain as well as timely notification and access to detailed information when events occur. This also contributes to suppliers' integration, thus increasing efficiency (Danese and Romano, 2011), especially as service levels can be monitored (García-Dastugue and Lambert, 2003).

Integration provides the capability to reduce the costs and risks of coordination and of transactions by providing managers an opportunity to understand the focal areas that need attention. Hence, they can minimize risks to real-time and free flow of information (Faisal et al., 2007). Mandal (2012) identified the dimensions or antecedents that IT professionals perceive as important for achieving resilience in the Indian context.

Hypothesis 2. *There is a positive relationship between the implementation rate of integration capabilities (ξ_2) and the level of resilience(η_1) in supply chains.*

Flexibility capability: This last set of practices increases the responsiveness of a supply chain to stimuli from end-consumers. It refers to the ability to evaluate and take needs into account quickly (Charles et al., 2011). The forecasting and planning processes within the supply chain are scaled up, resulting in enhancement of the supply chain's reactive capabilities by enabling it to predict final demand changes and adapt to them both in upstream and downstream operations (Olhager, 2013). Such practices, jointly named Sales and Operations Planning (S&Op), provide a vital link between lean manufacturing operations within the supply chain and responsive distribution and differentiation operations (Sauvage, 2003; Faisal et al., 2006).

These practices hold important promise in enabling risk prevention and recovery (Lavastre et al., 2012). By enabling better control of inventories and production schedules, planning and forecasting systems reduce the risks from both upstream and downstream events (Stadtler, 2005). These planning systems have long-, medium-, and short-term horizons and include master planning, requirements planning, and demand and distribution planning. Evidence of the use of such systems and routines to protect the supply chain has been found by Fleischmann and Meyr (2003) and Stadtler and Kilger (2005). This leads us to our third hypothesis:

Hypothesis 3. *There is a positive relationship between the implementation rate of flexibility capabilities (ξ_3) and the level of resilience (η_1) in supply chains.*

Moderating Effects of Supply Chain Risks Using the classification presented in the risk literature review by Heckman et al. (2015), we analyze the risk sources that might affect the supply chain manager's effort to increase the resilience of a supply chain depending on whether the risk source lies within or beyond the supply chain boundaries (Wagner and Bode, 2008; Waters, 2007). Internal risks stem from suppliers and customers. They are

referred to as internal to reflect that they should be within the control of the supply chain manager. External risks are outside her or his control.

External Supply Chain Risks: Chopra and Sodhi (2004) highlight the importance of understanding the nature and effectiveness of supply chain risks to be able to set up or strengthen the firm's capabilities to more effectively manage those risks and thus become more resilient. In terms of risks outside a firm's supply chain, Walters (2006) illustrates the significant impact of external risks—such as economic, social, and political risks for supply chains—on the performance and qualities of a supply chain. We contend that macro-economic, social, and political risks will counteract the efforts deployed by the supply chain manager to increase the resilience of the whole chain. Such external risks can negatively affect how lower order capabilities will develop resilience (Bode et al., 2011; Altay and Ramirez, 2010).

Internal Supply Chain Risks: Supply chains represent vertical inter-organizational networks of firms that are closely linked to their up-stream and down-stream supply chain partners (Carvalho et al., 2012). As such, suppliers as well as customers have an impact on establishing supply chain (management) capabilities (e.g., Teller et al., 2016) as well as on resilience. Hwang et al. (2013) highlight the importance of supplier impact on risks affecting the capabilities of firms, for example, through a lack of reliability, lead times, or delivery problems. Tang (2006) and Chopra et al. (2007) explicitly argue that suppliers represent a source of risks to firms within a supply chain. Walters (2006) provides comparable arguments of customers posing potential risks to their up-stream supply chain partners, for example, if the customer goes into administration, generates variable demand, or has ordering problems. Consequently, risks related to suppliers and customers, that is, risks outside the firm but inside the supply chain affect how firms will be able to garner all the benefits from increasing their lower order capabilities to develop resilience.

To conclude, we propose that supply chain risks related to both external factors and those related to up-stream and down-stream supply chain part-
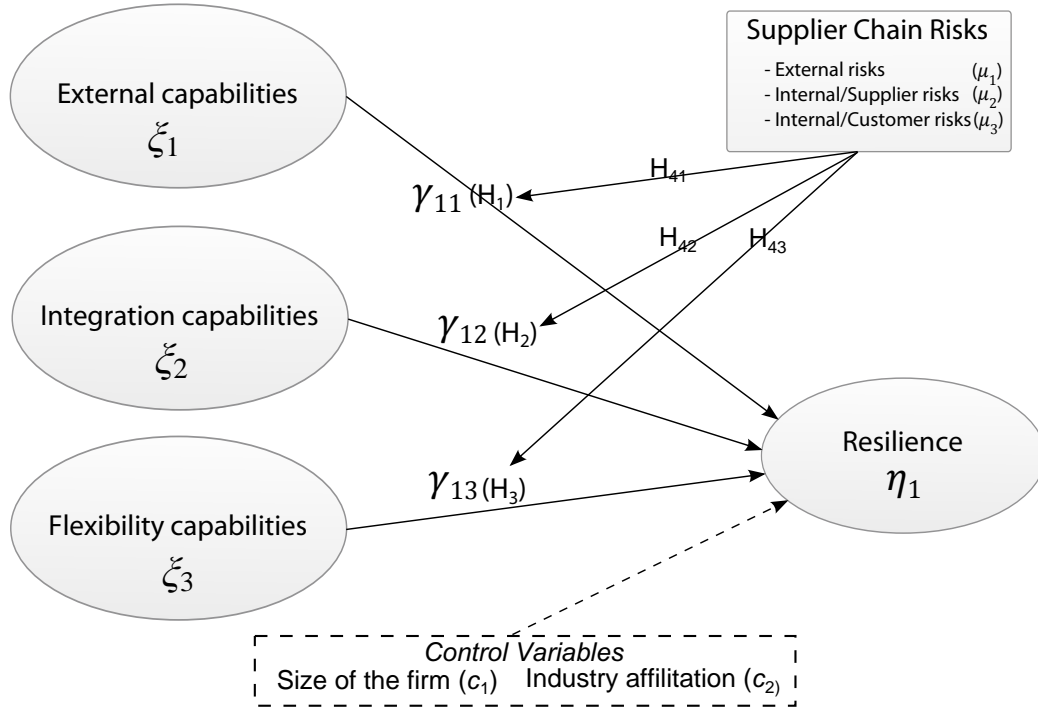
11

Figure 2: Conceptual model.

ners affect the relationship between supply chain capabilities and resilience. We thus propose the final hypothesis H4 as follows:

Hypothesis 4. *Supply chain risks (external risks (μ_1), supplier risks (μ_2), and customer risks (μ_3)) affect the positive relationship between the implementation rate of (external (ξ_1, H_{41}), integration (ξ_2, H_{42}), and flexibility (ξ_3, H_{43})) capabilities and the level of resilience (η_1) in supply chains.*

Our conceptual model comprises all four hypotheses, as depicted in Figure 2. Based on the dynamic capabilities approach, our model proposes the effects of capabilities on the resilience of a supply chain as well as risk factors that influence those effects.

We now turn to the empirical test of our conceptual model.

3. Methodology

3.1. Research design

The design involves a survey among supply chain managers, using a single respondent in each organization as the analysis unit. We considered these managers as key informants (e.g., Campell, 1955) since – due to their role within their organizations – they have the most expertise and access to information on their organizations' capabilities, supply chains, and environments.

Our research views the organization as "embedded in a network of relationships that impact its performance" (Saraf et al., 2007), p. 327. We recognize that a multiple-respondent survey design would have been preferable, but chose a single-respondent design to improve acceptable response rate (Saraf et al., 2007), as suggested by Tang and Tang (2010) for studying inter-organizational phenomena. Even though the study has limited explanatory powers owing to the subjective nature of the data gathered, the use of subjective data is common in this type of research and considered acceptable (Chan et al., 1997). We opted for a web-based survey approach (Grant et al., 2005) due to the target population size, the number of questions, and the cost involved in contacting respondents. Answers were anonymized to allay respondent identification problems.

The population of supply chain managers was approached through an electronic mailing campaign to the 8,000 French tested e-mail addresses of a Supply Chain newsletter. The subscribers are opt-in readers with an interest in general supply-chain management news. Even though 366 replies were recorded, only 171 were valid for statistical analysis, a response rate of 2.1% of the identified population and 47% of the sample usable (Yu and Cooper, 1983). This response rate is comparable to other research within the field of supply chain management (e.g., Van der Vaart and Van Donk, 2008; Wagner, 2010).

Several economic sectors are represented by the sample, thus increasing the results' generality.The usable subset included firms operating in the

13

following sectors: food and beverage (17.5%), retail (25.7%), and general manufacturing (24.0%). The sample reflects a dominant proportion of small to medium sized firms; 67.3% have less than 1,250 employees.

3.2. Common method bias

Since there was a single informant per organization, the potential for common method bias (CMB) was assessed. There is no single best method available to test CMB (Podsakoff et al., 2012). Furthermore, the choice of method is a subject of intense debate, as is the question of whether CMB can affect data (for a critical discussion see Richardson et al., 2009). We applied the Harman (1967) single-factor test of CMB (Podsakoff and Organ, 1986; Podsakoff et al., 2003), which revealed twelve distinct factors with eigenvalues above or near one that cumulatively explained 87.6% of total variance. According to this test, if common method bias exists, one of the following should be observed: (1) a single factor will emerge from a factor analysis of all survey items (Podsakoff and Organ, 1986); or (2) one general factor will emerge that accounts for most of the common variance existing in the data. The first factor explained 24.32% of the variance, which was not the majority of total variance and thus considered to be low enough.

3.3. Non-response bias

Because significant numbers of the targeted population failed to respond, we checked for possible non-response bias using a "time-trend extrapolation test" in which "late" versus "early" respondents are compared along key study variables (first suggested by Oppenheim, 1966). The assumption behind this test is that "late" respondents are very similar to non-respondents, since their responses would not have been recorded without follow-up efforts (Armstrong and Overton, 1977). The t-tests conducted showed no significant differences between "early" and "late" respondents along any of the key study variables.

3.4. Measurement

Capabilities and Resilience: The four theoretical constructs of our conceptual model—excluding the moderating and control variables—constitute latent variables requiring indirect measurement (see Table 3). We sifted through the nine references in literature that deal with resilience or one of the lower-order capabilities using empirical surveys (Lavastre et al., 2012; Mandal, 2012; Qrunfleh and Tarafdar, 2013, 2014; Richey et al., 2012; Kern et al., 2012; Moon et al., 2012; Hoffmann et al., 2013), and the survey presented in Wilden et al. (2013), which uses dynamic capabilities as second order constructs. The focus in each of these surveys is different from ours: often the supply chain manager is not considered to be the decision maker—given the questions or items, the respondent could be a production manager, a chief executive officer, or an IT chief information officer; or he or she responds to strategic or policy statements such as "we select the best quality supplier". Actual and practical usage of managerial tools and resources are not contemplated. In fact, there is a decided absence of scales based upon the set of physical, financial, human, technological, and organizational resources (Grant, 1991), coordinated by organizational routines (Nelson and Winter, 1982), and deployed in an organization and across organizations. Consequently, we determined that our study required a grounding in actual usage of such sets by supply chain managers in their daily work inside their organizations as well as in the relationships with suppliers and distributors or customers.

So, following Churchill (1979), we started with the domain specification of each construct and collected the relevant measurement items in the literature. However, rather than blindly applying previously utilized measurement items, we used them as a starting point, and revised them based on the feedback from five experts in the supply chain practice at CapGemini Consulting France. These practitioners were aware of the scope and purpose of our study and thus were able to provide precise feedback on the measurement

15

items. Using their feedback we were able to tailor each measurement item to most accurately measure the underlying construct. As such, we employed a grounded approach to make the items as accurate as possible, given our study context. This approach to develop the final items provides for a very high level of face and content validity, while increasing the practical relevance and applicability of the research. After receiving the feedback, we had to accommodate specific changes in the constructs, which the experts had criticized as being too complicated and having limited face validity. The measures for supply chain resilience were thus deductively and inductively developed with the help of practitioners.

A draft version of the survey questionnaire was pre-tested among experts and journalists from supplychainmagazine.fr. As a result of this pretest, some inconsistencies and unclear formulations were addressed. Given the numerous definitions of resilience available in the literature and the prevalent confusion in the minds of practitioners (Kidd, 2000), it was expected that a particularly wide cross-section would emerge. A broad consensus was achieved through a general discussion in which each participant described the effect of each practice on the overall supply chain and how this effect could be achieved and measured. In a subsequent pre-test, the questionnaire was presented to five supply chain managers, whose remarks were then incorporated. When questioned about capabilities, the respondents were asked to rate their agreement, with a response range from totally disagree (rated 1) to fully agree (rated 5). For each capability, managers were asked to specify if it was "not applicable to their particular case" (rated 1), "under consideration" (rated 2), partly deployed (3), fully deployed but still only partially used (4), to fully deployed and in use (rated 5). The result is a list of 9 affirmations about capabilities found in their supply chains. A final updated list was drawn up that captures both the comments about clarity and simplicity as well as system- or process-related remarks about their capabilities. The list of all measurement items underlying the constructs of our conceptual model

16

can be found in the appendix.

We consider all constructs in our model to be of a reflective nature. We base this decision on the notions of Jarvis et al. (2003): The direction of causality goes from the latent construct towards the indicators for all of our constructs. This is of particular importance for our dependent construct Resilience (η_1), given Lee and Cadogan (2013) critique on treating formative constructs as being dependent.

Supply Chain Risks: To measure the three supply chain risk variables we followed the notions of Walters (2006) and Heckman et al. (2015), who distinguish between risk that is external to the supply chain, including political, social, environmental and economic risks, and risk that is internal to the supply chain, which is related to suppliers and customers (see Table 3). Our questionnaire asks respondents to indicate the degree to which their supply chain is affected by the various dimensions of supply chain risk and thus treat these responses as manifest variables.

3.5. Control variables

We consider two control variable that potentially influence the proposed effects in our conceptual model: company size (c_1, operationalised by the number of employees) and industry affiliation (c_2). The inclusion of the first control is supported by discussion on the different roles and practices of SCM in large as opposed to small organisations, and thus the notion that the size of a company affects the advantages gained from SCM (Arend and Wisner, 2005).

In terms of the second control Harland (1996) identified that the position of a company in a supply chain (= industry affiliation) affects the management of supply chains. Given the distribution of industry affiliation in our samples we use a dichotomous scale to measure our control variable, that is, the companies –represented by our respondents– are either affiliated to the manufacturing, retail or any other industry.

17

4. Analyses

4.1. Variance-Based Structural Equation Modeling

This study uses variance-based structural equation modeling (VBSEM) (two main references are Wold, 1982, 1985), a technique for component-based structural estimation modeling. Variance-based SEM has distinctive features compared to covariance-based SEM (SEM-ML). VBSEM has less restrictive assumptions on characteristics such as measurement scales, sample size, and distributional assumptions (Chin, 1998b; Tenenhaus et al., 2005). Chin and Newsted (1999) observe that VBSEM is generally better suited to studies in which the objective is prediction, or the phenomenon under study is new or changing. Instead of relying on overall goodness-of-fit tests, variance-based SEM tests the strength and direction of individual paths by statistical significance (Calantone et al., 1998). The sample size requirement for VBSEM is ten times the larger value of the following: (a) the block with the largest number of indicators, or (b) the dependent latent variable with the largest number of independent variables impacting it (Chin, 1998b). Tenenhaus et al. (2005), in a more theory-oriented paper that complements the work of Chin (1998b), compares both SEM-ML and VBSEM. Even though it is recognized that these methods give different results, for our purpose, VBSEM is more suitable given that the theory is still in development. Maximum Likelihood modeling techniques are better suited once confirmatory studies have been made (Lee et al., 2006). VBSEM allows for more exploratory investigations into the links between certain enablers and the traits of supply chains due to its less rigorous requirement of restrictive assumptions.

4.2. Evaluation of the measurement and structural model

To systematically evaluate our VBSEM results, we first investigated the measurement model and subsequently the structural model (Hair et al., 2014). All t-values of the factor loadings are highly significant at $p < 0.001$

(see Table 3). Further, all loadings exceed the suggested size of 0.70 (Hulland, 1999). The internal consistency is also satisfactory for all factors (Cronbach's ($\alpha > 0.70$), and for all factors the composite reliability (ρ) meets the requirement of being above 0.70 (Fornell and Larcker, 1981). The degree of convergent validity proved to be acceptable, with the average variances extracted (AVE) higher than 0.50 (Bagozzi and Yi, 1988). With regard to the constructs' discriminant validity, the AVE is larger than the highest of the squared inter-correlations with the other factors in the measurement models (see Table 1). Additionally, all factor loadings on the assigned factor are higher than cross-loadings on the non-assigned factors Chin (1998a). To conclude, all constructs in the model show sufficient validity.

Table 1: Convergent validity, composite reliability and discriminant validity measures for capabilities

Constructs	ρ	α	ξ_1	ξ_2	ξ_3	η_1
External (ξ_1)	.855	.781	(.776)			
Integration (ξ_2)	.814	.701	.479	(.723)		
Flexibility (ξ_3)	.812	.752	.143	.265	(.730)	
Resilience (η_1)	.865	.792	.292	.372	.301	(.785)

Average variance extracted values (AVE) shown on the diagonal;

Squared correlation matrix for constructs below the diagonal;

α, Cronbach's alpha; ρ, composite reliability;

Structural model: Unlike covariance-based SEM, its variance-based counterpart does not offer comparable global fit measures (e.g., Henseler and Sarstedt, 2013; Hair et al., 2012). Rather than calculating goodness-of-fit measures as proposed by Tenenhaus et al. (2005); Hair et al. (2014) suggest investigating the coefficient of determination (r^2-value) and the significance of the structural path coefficient to use as primary evaluation criteria for the structural model. Our estimation shows an r^2-value of .221 which represents a satisfactory value. Furthermore, two out of three structural paths

19

are significant and as such, represent medium-size effects according to Cohen (1988).

4.3. Model robustness test

Next, we evaluate the impact of our two control variables (c_1, c_2) on the main associations in our model (see Figure 2), following the procedure applied by Robson et al. (2008). The direct impact of c_1 and c_2 operationalized by three dummy variables (for the manufacturing, retailing and other industries) on the dependent construct ξ_2 are all insignificant (*t*-values $\ll 1.965$) and very weak. When comparing the structural associations as proposed in our hypotheses by including or excluding the control variables in the model, we see that the coefficients change insignificantly on the third decimal place and the significance of the associations do not change.

These results suggest that the two control variables do not confound the proposed relationships in our conceptual model. Moreover, we can conclude that the structural associations are independent of the industry affiliation and company size. Since the two control variables lack explanatory power, we trimmed our model and excluded them from the following analysis.

5. Results

5.1. Structural effects

The estimation results in Table 2 show that the effect of external capabilities on resilience is insignificant on a 5% level ($\gamma_{11}, .144; p > .05$). We therefore cannot support the first hypothesis. Nevertheless, the other two capability constructs, that is, integration and flexibility, impact resilience significantly ($\gamma_{12}, .246; \gamma_{13}, .214; p, < .01$). Consequently, hypotheses H2 and H3 are supported.

5.2. Moderating effects

To test the proposed moderating effects we applied the product indicator approach, as suggested by, among others, Busemeyer and Jones (1983)

Table 2: Estimation results

Hypothesis (structural effects)	Coeff.
H1 (γ_{11}): External Capabilities (ξ_1)$\rightarrow$ Resilience (η_1)	$.144^{\text{ns}}$
H2 (γ_{12}): Integration Capabilities (ξ_2)$\rightarrow$ Resilience (η_1)	$.246^{***}$
H3 (γ_{13}): Flexibility Capabilities (ξ_3)$\rightarrow$ Resilience (η_1)	$.214^{**}$
Hypothesis (moderation effects)	
External to the supply chain: External Risks (μ_1)‡	
$H_{41}.\mu_1$: External capabilities (ξ_1) x External risks (μ_{11})$\rightarrow$ Resilience (η_1)	$-.213^{*}$
$H_{42}.\mu_1$: Integration capabilities (ξ_2) x External risks (μ_{11})$\rightarrow$ Resilience (η_1)	$.215^{\text{ns}}$
$H_{43}.\mu_1$: Flexibility capabilities (ξ_3) x External risks (μ_{11})$\rightarrow$ Resilience (η_1)	$.003^{\text{ns}}$
Internal to the supply chain: Supplier risks (μ_2)	
$H_{42}.\mu_2$: External capabilities (ξ_1) x Supplier risks (μ_{12}) $\rightarrow$ Resilience (η_1)	$-.176^{\text{ns}}$
$H_{42}.\mu_2$: Integration capabilities (ξ_2) x Supplier risks (μ_{12}) $\rightarrow$ Resilience (η_1)	$.214^{**}$
$H_{43}.\mu_2$: Flexibility capabilities (ξ_3) x Supplier risks (μ_{12})$\rightarrow$ Resilience (η_1)	$.011^{\text{ns}}$
Internal to the supply chain: Customer risks (μ_3)	
$H_{41}.\mu_3$: External capabilities (ξ_1) x Customer risks (μ_{13}) $\rightarrow$ Resilience (η_1)	$-.111^{\text{ns}}$
$H_{42}.\mu_3$: Integration capabilities (ξ_2) x Customer risks (μ_{13}) $\rightarrow$ Resilience (η_1)	$-.091^{\text{ns}}$
$H_{43}.\mu_3$: Flexibility capabilities (ξ_3) x Customer risks (μ_{13})$\rightarrow$ Resilience (η_1)	$-.128^{\text{ns}}$

Notes: t-values calculated by applying a bootstrapping procedure with 1,000 sub-samples (Chin, 1998b); ns, non-significant; *,$p < .05$; **,$p < .01$; ***, $p < .001$;‡, derived measurement that combines the rating results related to social, political, economic, and environmental risks, through the calculation of mean values; caefficients of determination, $r^2_{\eta_1}$, .221.

and Kenny and Judd (1984). This means that for each moderating effect a product term is calculated using the indicators of a predicting variable (in our case, one of the three capability constructs, ξ_1, ξ_2 or ξ_3) and the moderator variables (μ_1, μ_2 or μ_3) (Henseler and Chin, 2010). This term is then included as a (latent) interaction term and as such represents the moderating effects (see hypothesis H4) in the conceptual model. The impact of the interaction term on resilience (η_1) measures the significance and the size of

the moderating effects.

Henseler and Chin (2010) recommend the product indicator approach for models such as that proposed in this paper, specifically, models where the purpose of the estimation is to (1) explain impacts, (2) describe interaction effects, and (3) focus on the prediction of endogenous constructs. Furthermore, the product indicator approach is regarded as superior to the frequently used multi-group analysis when the moderating variable is of a continuous nature. Multi-group analysis, and thus the test for invariance between coefficients, is most appropriate in the case of dichotomous moderating variables and experimental designs (Bagozzi et al., 1991).

In terms of external risks (μ_1) the results show only a negative significant moderating effect ($-.213; p < .05$) on the association between External Capabilities on Resilience (γ_{11}). Thus, an increasing economic risk leads to a weaker impact of external capabilities on resilience. In terms of supplier risk (μ_2), we found a significant moderating effect ($.214, p < .01$) on the relationship between Integration Capabilities and Resilience. This means that the effect becomes stronger as the supplier risk increases. Customer Risk turned out to have no moderating impact ($p > .05$) on any of the structural effects. We can conclude that External and Supplier Risk represent significant moderators as they affect at least one structural path in the model. Consequently H_{41} and H_{42} can be supported.

6. Discussion and concluding remarks

In this paper we provide insights into the lower-order capabilities that help a supply chain to achieve resilience. We provide a research framework that builds upon earlier literature about resilience in supply chains. Within a dynamic capability setting grounded in the Resource-Based View, we describe how lower-order capabilities developed using cross-functional and inter-organizational routines can provide a supply chain with higher-order operational capabilities.

22

Through our research we substantiate the theory-driven conceptual model of supply chain resilience, which is regarded as a major source of competitive advantage (Chang and Grimm, 2006; Li et al., 2008; Wisner, 2003). Starting from theoretical definitions of resilience in supply chains, we have operationalized them with supply chain managers, trait by trait. A conceptual model, embedded in the dynamic capability approach, was developed and tested using data from French supply chain managers. In summarizing the contributions of this paper, we distinguish between implications for theory and for practice.

Implications for theory

First, we conclude that in the view of supply chain managers, resilience is not easily enhanced, even though it is a highly desirable trait (Bhamra et al., 2011). In answer to the first question we asked in the Introduction, only integration and flexibility capabilities positively affect the resilience level of a supply chain. These findings resonate with those revealed through the Blackhurst et al. (2011) case study research. There, three major categories of factors were deemed to enhance resilience: human capital resources, organizational and inter-organizational capital resources, and physical capital resources. Of these, organizational resources were said to include defined communication networks, contingency plans, and supplier relationship management.

Second, we found that our results deviate from findings in the literature. As regards the results reported from the empirical investigation in Mandal (2012), the link between external capabilities and resilience cannot be corroborated, while the link between the supply chain infrastructure and integration and resilience is only partially validated. This may be due to the fact that the sample selection in Mandal (2012) is composed of IT professionals and not supply chain managers. We are unable to confirm the notions of Klibi et al. (2010) and see that the Efficient Customer Response type of external collaboration practices —as exemplified by Vendor Managed Inventories and

Warehouse Management Systems— to streamline inventories across echelons have no impact on resilience.

Third, we selectively found moderating effects of supply chain risks on the relationships between capabilities and the resilience of a supply chain. More specifically, the question we asked in the Introduction was: How do environmental factors related to supply chains influence the effectiveness of these practices? The answer we provide here supports the notions developed in Walters (2006) in terms of risks external to the supply chain as well as risks internal to the supply chain related to suppliers. Interestingly, we find that customer risks do not play a significant role in affecting the proposed relationships in our model.

The size of the focal firm as a proxy for the extension of the supply chain has no influence on its resilience, even though it should be a facilitating factor in the implementation of lower-order capabilities. This seems surprising for, as recognized in Waters (2007) several times, larger firms have more sophisticated tools and should thus be better placed to address market as well as environmental risks.

By applying the dynamic capabilities approach as a theoretical underpinning of our research, we have highlighted the link between specific lower-order capabilities and a supply chain's operational capability, namely, resilience. Additional research is required along three directions: (a) how to enhance specific supply chain capabilities; (b) how to combine those operational capabilities and how best to add learning capabilities that can be made dynamic; and (c) how to link such operational capabilities for the competitive advantage of a supply chain.

Implications for practice

In this paper, contrary to most papers dealing with the subject of resilience, we have positioned ourselves from the point of view of supply chain managers to understand how the actions, decisions, and practices they apply, the routines they set up, the collaborative and coordination effort and resources

that they build upon contribute to the resilience of the supply chain to which their firm belongs.

Our results indicate that only some practices and asset and human deployments will provide an increased measure of this quality. Managers who combine and enhance both integration and flexibility capabilities will observe a level of resilience in their supply chain. This means that they must not only use information technology tools and routines to integrate their internal organization (through their ERP) but also use other supply chain management software to integrate their suppliers, customers, distributors, and logistics service providers. These efforts enhance collaboration by sharing forecasts and sales data and allowing continuous inventory adjustments. In conjunction with logistics service providers, using track and trace technologies for goods provides advanced tip-offs about events and glitches that affect service levels and quality. It is a notable result that the supply chains affected by high supplier risk concomitantly deploy these integration practices and resources.

Our results show that External Capabilities do not influence resilience. When we delve into the tools, practices, and routines involved, the following interpretation can be suggested: Supply chain managers do not have ample experience in applying efficient customer response policies, deploying both warehouse and transport management systems, streamlining inventories, as well as deploying vendor managed inventories. Hence the resilience effects have yet to be observed. The implementation of the routines and processes of Integration Capabilities, which involve the deployment of supply chain management software connected to the ERP—managing supplier performance, using business intelligence software to generate reports providing insights into the working of the supply chain as well as tracking goods—are all somewhat recent and require additional managerial capacities and training to be deployed effectively. Such practices may have not yet been mastered by all supply chains. This view is reinforced by the result that the influence of

integration capabilities on resilience is higher when supplier risk is higher. That is, when a supply chain is subject to significant internal risks, the best line of conduct is to foster increased integration of the chain links so as to enhance its overall resilience.

Flexibility capabilities enhance resilience: Resilience can be augmented through the combination of alternative production and site plans, as well as by making plans more flexible and versatile. The pertinence of the deployment of these resources and routines increases with the incidence of external risks faced by the supply chain, such as raw material price hikes, political upheavals, or regulatory changes. Flexibility functions in several dimensions. The first dimension is the ability to meet new demands in terms of product type or quantities. The second is the ability to reconfigure the supply chain (upstream and downstream) by flexibly deciding whether to make or buy, to change locations, or to implement site specialization, while keeping tabs on a pool of suppliers. Unavoidably, such abilities in a supply chain go hand in hand with the supply chain manager's increased ability to detect and measure risks. A supply chain manager should deploy processes to identify and monitor risks and potential areas of trouble as a complement to the practices discussed above.

When controlling for the impact of the size of the firm, we found that the size of the focal firm is not an impediment to resilience, as even small businesses with limited resources can achieve the same level of resilience as larger firms. Neither could we distinguish an effect due to the economic sector. By extension, the focal firm can occupy any position in the supply chain (from manufacturer to retailer) without this position affecting its ability to enhance resilience.

7. Limitations and future research agenda

As with all research, this study has some limitations. The respondents to our survey were French managers, which results in a bias towards a West-

ern European supply chain context. Future studies could be conducted in other country settings. Furthermore, we do not differentiate between different industries and supply chain stages (except as control variables), the study of which might yield additional insights. We applied a single-informant approach and thus rely exclusively on the perspective of supply chain managers. Using experts from other parts of the organization, such as marketing or finance, could complement our findings.

Our conceptual model only considers one moderator: supply chain risks. Further analyses of our data should include other moderators, such as firm or supply chain characteristics, to identify particular capability-resilience relationships.

Our approach is quantitative in nature. Qualitative interviews or focus group discussions with managers would help to understand better why external capabilities do not affect resilience whereas the other capabilities do.

Finally, further research is needed about the role of managerial expertise in building upon information technology as the means to embed managerial processes both within and across organizations so enhancing resilience. Information technology would need to be separated into more nuanced categories involving lower-order practices and routines (such as ERP, MRP II, collaborative platforms, tracking & tracing) or higher-order structures, such as information aggregation systems for business intelligence. In this way, researchers could better evaluate the potential impact of each set of practices on supply chain resilience.

8. Appendix

Table 3: External indicators and loading factors

Latent construct Indicator	λ	t-value	p-value
ξ_1: External Capabilities			
x11: deploying an Efficient Customer Response policy	.950	23.944	<.001
x12: deploying WMS and TMS	.804	13.132	<.001
x13: streamlining and resizing inventory in the distribution network	.644	7.089	<.001
x14: deploying a Vendor Managed Inventory policy	.666	6.836	<.001
ξ_2: Integration Capabilities			
x21:managing the performance of your suppliers in a collaborative way	.740	11.135	<.001
x22: integrating ERP with other SCM tools	.648	6.532	<.001
x23: deploying IT-based reporting tools	.784	16.870	<.001
x24: deploying tracking & tracing tools	.715	10.482	<.001
ξ_3: Flexibility Capabilities			
x31: setting up alternative production contingency plans	.903	23.989	<.001
x32: developing the versatility and flexibility of your sites	.791	11.888	<.001
x33:making production sites specialize per technology or product	.690	6.645	<.001
η_1: Resilience			
y11: Your supply chain system enables you to evaluate your process vulnerabilities constantly	.722	11.266	<.001
y12: You deploy alternative plans associated with identified risks	.829	21.426	<.001
y13: Your firm is able to evaluate the levels of risk facing your supply chain	.851	25.749	<.001
y14: Your supply chain organization allows you to increase visibility over all your chain	.730	10.081	<.001
Supplier Risks			
m11: Your supply chain is affected by external political risks			
m12: Your supply chain is affected by external social risks			
m13: Your supply chain is affected by external environmental risks	N/A	N/A	N/A
m14: Your supply chain is affected by external economic risks			
m2 : Your supply chain is affected by risks related to your suppliers			
m3 : Your supply chain is affected by risks related to your customers			

Notions : All statements based on a five-point Likert scale (1, completely disagree, 5, completely agree)