A typology of supply chain resilience: Recognizing the multi-capability nature of proactive and reactive contexts

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ABSTRACT

Even though resilience has received ample attention in recent literature, there is still a dearth of research when it comes to theorization of supply chain resilience capabilities. Against this background, we aim to develop a framework for supply chain resilience capabilities based on proactive and reactive contexts. Apart from using ANOVA, we also perform a nuanced analysis using the response surface methodology. The analysis is done based on a survey dataset collected from 291 manufacturing firms. The results indicate that different combinations of proactive and reactive resilience capabilities can have a differential impact on the performance indicators. Although both proactive and reactive capabilities are essential for ultimate resilience strategies, supply chains might initially benefit more from reactive capabilities than proactive ones. The comprehensive framework proposed in our research addresses a vital gap in current supply chain resilience theorization and could pave the way for further well-informed research on the evolving research domain. Moreover, this framework could serve as a powerful tool for supply chain managers to design and plan the development/improvement of resilience capabilities in collaboration with supply chain partners. They will be able to easily evaluate the current condition as well as targets for resilience capabilities.

Keywords – Resilience, Typology, Framework, Polynomial Regression, Performance

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"If you cannot measure it, you cannot manage it."

– Peter F. Drucker; Management Philosopher and Author

1. INTRODUCTION

Disruptions in the supply chains are causing widespread alarm because the frequency, depth, and breadth of disruptions are all on the rise simultaneously. More importantly, events like Brexit, the Suez-Canal obstruction, energy price hike, geo-political instability, and the COVID-19 pandemic have all had lasting impacts on businesses worldwide (Gunessee and Subramanian 2020; Hendry et al. 2019; Zhao et al. 2022). This is one of the key reasons why the concept of resilience has been gaining more attention in the management literature (Azadegan et al. 2020; Ekanayake, Shen, and Kumaraswamy 2020; Faruquee, Paulraj, and Irawan 2021; Iftikhar, Purvis, and Giannoccaro 2021; Kahiluoto, Mäkinen, and Kaseva 2020; Ekanayake, Shen, and Kumaraswamy 2021; Drozdibob et al. 2022). As a part of investing in the strategic development of capabilities, managers are reconsidering and redesigning the resilience capabilities (Zhao et al. 2022; Senna et al. 2021; Ekanayake, Shen, and Kumaraswamy 2021). In the face of container blockage at the US ports, businesses like Amazon made proactive plans such as investing in producing their own cargo containers and also chartering private cargo vessels, and, subsequently directing it towards less popular ports in the US to ensure better resilience; whereas after the 2021 container crisis, Walmart and Home Deport are following in the footsteps of Amazon to recover from the disruption (Kay 2021; Schoolov 2021). Therefore, it is extremely important for supply chain managers to understand the multi-capability context of proactive and reactive resilience, and how to strategize around it.

Resilience is the ability of a firm or supply chain network to recover from a disruption to perform better than before, or, at least, regain the original state efficiently (Ponomarov and Holcomb 2009; Drozdibob et al. 2022; Christopher and Peck 2004; Pettit, Fiksel, and Croxton 2010). With rising complications in the nature of disruptions, the concept of resilience is also expanding beyond firms (Scholten and Schilder 2015; Stone and Rahimifard 2018; Wamba and Queiroz 2020). Specifically, supply chain resilience is a network-wide concept that reflects a holistic approach to protecting and recovering across the entire supply chain, and not just a firm (Ali, Nagalingam, and Gurd 2017; Scholten, Scott, and Fynes 2014; Scholten and Schilder 2015). The underlying capabilities and the key time phase of those capabilities are critical for designing, planning, and delivering supply chain resilience (Ali, Mahfouz, and Arisha 2017; Drozdibob et al. 2022).

There have been a considerable number of empirical studies focusing on resilience. Extant literature examines (1) the role of different antecedents to resilience capabilities (Brandon-Jones et al. 2014; Dubey et al. 2019; Faruquee, Paulraj, and Irawan 2021; Scholten, Scott, and Fynes 2014, 2019; Vanpoucke and Ellis 2019), and (2) the impact of resilience strategies and capabilities on different outcomes (Chowdhury, Quaddus, and Agarwal 2019; Li et al. 2017; Rauer and Kaufmann 2015; Um and Han 2021; Ekanayake, Shen, and Kumaraswamy 2021; Drozdibob et al. 2022). Moreover, resilience has been approached from many different perspectives, such as readiness, redundancy, or reaction quality (Ali, Nagalingam, and Gurd 2017; Pettit, Fiksel, and Croxton 2010; Scholten and Schilder 2015; Sá et al. 2020), and represented through many capabilities (Ali, Mahfouz, and Arisha 2017; Ponomarov and Holcomb 2009; Tukamuhabwa et al. 2015). Resilience has also been assessed based on the consideration of cost efficiency (Brandon-Jones et al. 2014). Technological advancement and digitalization efforts to improve risk mitigation have also been addressed in the literature (Wamba and Queiroz 2020; Faruquee, Paulraj, and Irawan 2021; Ivanov, Dolgui, and Sokolov 2019; Razak, Hendry, and Stevenson 2021). More importantly, lately, there have been several rigorous literature reviews on resilience (Ali, Mahfouz, and Arisha 2017; Conz and Magnani 2020; Iftikhar, Purvis, and Giannoccaro 2021; Ponomarov and Holcomb 2009; Razak, Hendry, and Stevenson 2021; Stone and Rahimifard 2018; Tukamuhabwa et al. 2015). Considering all the recent and diverse research efforts on resilience (Ali, Mahfouz, and Arisha 2017; Iftikhar, Purvis, and Giannoccaro 2021; Scholten and Schilder 2015; Drozdibob et al. 2022), it is clear that robust theorization on resilience capabilities is still at an early stage.

Although researchers have recently developed conceptual frameworks for supply chain resilience from various perspectives (Azadegan and Dooley 2021; Kahn et al. 2018; Negri, Cagno, and Colicchia 2022; Wieland 2021; Wamba and Queiroz 2020; Mishra et al. 2020), one aspect that is lacking is the incorporation of a multi-capability aspect of supply chain resilience. Literature broadly recognizes the multi-capability nature of resilience and that it is almost impossible for a firm to be resilient based on a single capability (Ali, Mahfouz, and Arisha 2017; Dubey et al. 2018; Tukamuhabwa et al. 2015; Ekanayake, Shen, and Kumaraswamy 2021). Nonetheless, there is no conceptual or empirical framework involving a multi-capability conceptualization of resilience (Ali, Mahfouz, and Arisha 2017; Stone and Rahimifard 2018; Tukamuhabwa et al. 2015). Apart from addressing this gap in literature, it is also essential to conceptualize resilience as a multi-capability system because such an operationalization of resilience is prevalent in recent research as well as in industry practices (Ali, Mahfouz, and Arisha 2017; Brandon-Jones et al. 2014; Dubey et al. 2019; Faruquee, Paulraj, and Irawan 2021; Gilbert, Eyring, and Foster 2012; Villena and Gioia 2020). With this in context, this study develops a typological framework of multi-capability supply chain resilience.

A typology is a way of building theory through developing theoretical constructs as well as the underlying relationships with the possibility of empirical verification (Doty and

Glick 1994; Melcher, Khouja, and Booth 2002). A strong theory investigates underlying processes with the intent to understand the systematic reasons for a particular occurrence or nonoccurrence (Sutton and Staw 1995). Given that we aim to theorize on supply chain resilience by addressing the ideal combinations of multiple capabilities, we believe that a typology is a better fitting approach for our research. Although sometimes ideal conditions/theorizations are not the reflection of the real world, it is not only vital for theory building, but also to explore where reality stands (Brusco et al. 2017; Doty and Glick 1994; Miller 1996). A typology has deep theoretical impacts; it covers a generalizable grand theory as well as multiple mid-range theoretical groundings for each individual configuration of the typology and makes the classification easier for theoretical integration (Doty and Glick 1994; Melcher, Khouja, and Booth 2002). Cluster-based typology development is a classic approach to theory building (Miller 1996); rightly so, these approaches are still considered highly effective in operations and supply chain management research (Ancarani et al. 2019; Azadegan and Dooley 2021; Carter, Kaufmann, and Ketchen 2020; Dabhilkar, Birkie, and Kaulio 2016; Gunessee and Subramanian 2020). We ground our framework partly on contingency theory to cover the proactive and reactive aspects of disruption management (Galbraith 1973; Haußmann et al. 2012). We also draw upon the relational view because our framework uses a buyer-supplier dyadic (interorganizational) context based on the understanding that close relationships could help exchange partners to develop better resilience capabilities through the sharing of resources and knowledge (Dyer and Singh 1998; Dyer, Singh, and Hesterly 2018).

Our research effort makes some novel contributions to the literature on supply chain resilience. First, recent literature highlights the importance of studying resilience and has covered many different perspectives, contexts, and methods (Kaufmann, Esslinger, and Carter 2018; Tukamuhabwa et al. 2015; Drozdibob et al. 2022). However, the uncertainty and instability inherent in supply chains needs to be studied in greater detail because not concentrating on a larger dynamic environmental context could often increase vulnerability (Azadegan and Dooley 2021; Wieland 2021). Moreover, future research on resilience can benefit immensely from the deeper theorization that is offered by typologies (Dabhilkar, Birkie, and Kaulio 2016; Iftikhar, Purvis, and Giannoccaro 2021). Second, major literature reviews recognize two essential facts about resilience capabilities: (i) the need for building resilience through multiple capabilities, and (ii) the need to differentiate between the primary proactive and reactive nature of resilience capabilities (Ali, Mahfouz, and Arisha 2017; Ponomarov and Holcomb 2009; Tukamuhabwa et al. 2015; Drozdibob et al. 2022). Although Dabhilkar, Birkie, and Kaulio (2016), conceptualize proactive and reactive resilience in empirical research, they do not adopt a multi-capability perspective. Similarly, Drozdibob (2022) extends the fundamentals of resilience by considering the "points-in-time" of the recovery phases, wherein they talk about different time phases related to the before and after contexts of the disruption. Interestingly, while this framework also indicates the fundamental relationship between resources, capabilities and resilience processes, it does not include capabilities in further theorization. Reflecting on all these research efforts (Dabhilkar, Birkie, and Kaulio 2016; Drozdibob et al. 2022), we have used a broader context of before and after to introduce a theoretical framework for supply chain resilience capabilities that covers both multi-capability as well as proactive/reactive resilience contexts.

Third, this is one of the few typological frameworks for supply chain resilience that is also empirically verified. Moreover, this is possibly the first framework to focus specifically on resilience capabilities. It is important not only to use a typological structure for theory building, but also to empirically explore its viability. We believe that this multi-methodological approach will be beneficial for encouraging future research within supply chain resilience. Fourth, we also explore the performance impacts of different resilience configurations. This exercise could generate interesting insights into how different levels of proactive and reactive resilience capabilities can impact different performance indicators. Finally, our research also has multiple implications for practicing supply chain managers. The proposed framework will be a great tool for them to understand the fundamental and ideal structure of multi-capability resilience. Managers can specifically use this tool to assess not only the current state of their resilience capabilities, but also their desired combination of resilience capabilities. To the best of our knowledge, such a tool does not exist in management practices. Additionally, by exploring the performance impact of the framework, this study will also help managers to understand how different combinations could stimulate different performance indicators; thus, managers can focus on the required performance indicators and develop resilience capabilities accordingly.

2. CONCEPTUALIZING RESILIENCE AND PERFORMANCE

2.1. Supply Chain Resilience Capabilities

Different resilience capabilities are synthesized under three dimensions: robustness/resistance, stability/recovery, and adapting/benefiting (Helfgott 2018). Resilience covers the full spectrum of proactive to reactive nature, as it is a disaster/disruption management process in many ways. Resilience capabilities must cover every step of the process, including preparedness and immediate response to maintain stability as well as recovery and mitigation to cope with unavoidable changes (Helfgott 2018; Scholten, Scott, and Fynes 2014, 2019; Drozdibob et al. 2022).

Few researchers have approached resilience as a capability in itself (Ambulkar, Blackhurst, and Grawe 2015; Brandon-Jones et al. 2014; Durach and Machuca 2018). However, if we take a closer look at the measurement items used in these studies, we can see that a set of multiple capabilities are used to underpin the notion of resilience capability. Alternatively, there is also a significant amount of research that has measured multiple separate capabilities of resilience (Bowen et al. 2001; Braunscheidel and Suresh 2009; Dubey et al.

2018; Gunessee, Subramanian, and Ning 2018; Kroes and Ghosh 2010; Scholten and Schilder 2015; Wamba and Akter 2019). All these studies that have focused on specific capabilities might be adequate for some specific research context, but they fall short when it comes to operationalizing supply chain resilience in the generic sense. Moreover, different types of risk mitigation require different resilience capabilities. Thus, multiple capabilities are essential to develop a resilient supply chain (Um and Han 2021). Additionally, a resilience capability has little or no value as an isolated tool; these capabilities work far better when applied collectively (Brusset 2016; Chiang, Kocabasoglu-Hillmer, and Suresh 2012). Therefore, directly measuring resilience in an empirical research is not the right approach as resilience has multiple critical interconnected capabilities (Ali, Mahfouz, and Arisha 2017; Tukamuhabwa et al. 2015). Unfortunately, this notion of resilience measurement is still underdeveloped in extant research (Ali, Mahfouz, and Arisha 2017; Sá et al. 2020). Furthermore, reviews of resilience literature present exhaustive lists of diverse capabilities that could be used to underpin the concept of resilience (Ali, Mahfouz, and Arisha 2017; Pettit, Fiksel, and Croxton 2010; Tukamuhabwa et al. 2015); yet none of the existing frameworks incorporate a multi-capability conceptualization of supply chain resilience.

Another fundamental issue in resilience research is the time context - under which disruption phase will a resilience capability have the highest impact? There is no one right way to classify resilience capability. Extant literature did not cover any uniform timeframe-based classification strategy for resilience; instead, the dominating common theme for classification is based on a disruption mitigation framework (Helfgott 2018; Ponomarov and Holcomb 2009; Scholten, Scott, and Fynes 2014; Drozdibob et al. 2022; Shishodia, Verma, and Jain 2020). According to the disruption mitigation framework, different resilience capabilities can be classified based on the prime impact time considering the pre and post context of disruption, which is proactive and reactive resilience (Ali, Mahfouz, and Arisha 2017; Dabhilkar, Birkie, and Kaulio 2016; Iftikhar, Purvis, and Giannoccaro 2021; Jia et al. 2020; Tukamuhabwa et al. 2015). Moreover, the fundamentals of preventive and adaptive, essentially proactive and reactive per se, is quite prevalent in disruption and contingency theorization (Galbraith 1973; Haußmann et al. 2012). The recent work of Drozdibob et al. (2022) points out that there are 17 existing frameworks that have unclear structures or segmentation. Based on these existing frameworks, Drozdibob et al. (2022) segment the complete resilience process into five stages, wherein stages 1 and 2 represent the before (proactive) impact grouping while stages 3 to 5 represent the after (reactive) impact grouping. Following these literature and theorization, we have embraced a broader scope and forwarded a multi-capability resilience framework that is grounded on the proactive and reactive contexts of resilience capabilities.

2.2. Proactive and Reactive Resilience Capabilities

Based on the literature reviews of resilience, we use four first-order constructs for measuring each second-order construct of proactive and reactive resilience (Ali, Mahfouz, and Arisha 2017; Pettit, Fiksel, and Croxton 2010; Ponomarov and Holcomb 2009; Tukamuhabwa et al. 2015). Proactive resilience is operationalized through warning capability, visibility, robustness, and supply management capability, whereas reactive resilience is operationalized using agility, recovery capability, flexibility, and adaptability. Our choice of first-order constructs are driven by two reasons: (1) the constructs are frequently used in literature to represent the respective proactive and reactive resilience contexts; and (2) each set of first-order constructs are sufficiently well-connected and interdependent so as to ensure the conceptual strength of the second-order constructs (Doll, Xia, and Torkzadeh 1994; Sarstedt et al. 2021).

Proactive resilience indicates the supply chain’s ability of readiness, anticipation, alertness, and to develop contingency planning against potential risk or disruptions (Ali, Mahfouz, and Arisha 2017; Dabhilkar, Birkie, and Kaulio 2016; Iftikhar, Purvis, and

Giannoccaro 2021). Proactive resilience is often explained as a defense system that is built up through connectivity, physical resources, and information sharing (Wang et al. 2018). There are four dimensions that encompass proactive resilience: awareness, self-assessment, preventive improvements, and planning preparedness (Jia et al. 2020). Extant literature on resilience uses many different constructs which essentially reflect these dimensions; e.g., supply management capability, traceability, warning capability, robustness, security, inventory planning, and visibility (Ali, Mahfouz, and Arisha 2017; Razak, Hendry, and Stevenson 2021; Tukamuhabwa et al. 2015). It is evident in extant literature that the four capabilities that we chose to construct the higher order resilience capability are not independent, but are often complementary in nature. For instance, supply management capability is the ability to ensure availability and access of material and information to minimize vulnerabilities (Bowen et al. 2001; Ponomarov and Holcomb 2009). Similarly, warning capability is the ability to anticipate potential threats and have a system/command center to ensure that the involved parties are duly warned (Pettit, Fiksel, and Croxton 2010; Riley et al. 2016). Visibility complements warning capability as it indicates the ability to see through the supply chain to spot any emerging disruption or risk (Tukamuhabwa et al. 2015). Robustness is the ability to resist change (Brandon-Jones et al. 2014); it means that the supply chain can function even under a disrupted environment (Ali, Mahfouz, and Arisha 2017). These capabilities collectively help the supply chain stay watchful and ready for possible/upcoming disruptions.

On the other hand, reactive resilience is the capability to respond to a disruption and to bounce back or regain stability (Ali, Mahfouz, and Arisha 2017; Brandon-Jones et al. 2014). Essentially it indicates the capability to recover the core functionality or achieve a new desirable state after a disruption occurs (Iftikhar, Purvis, and Giannoccaro 2021). Reactive resilience consists of during-disruption and post-disruption conditions. Therefore, all the constructs of reactive resilience are focused on the ability to respond, survive, return, and adjust (Conz and Magnani 2020; Iftikhar, Purvis, and Giannoccaro 2021).

As with proactive resilience, the reactive resilience dimensions are also explainable through multiple constructs, including safety buffer, redundancy, demand management, agility, recovery strategy, flexibility, velocity, and adaptability (Ali, Mahfouz, and Arisha 2017; Tukamuhabwa et al. 2015). Examples of the complementary nature for the four reactive resilience capabilities chosen are also vivid in literature. For example, flexibility can be defined as the ability to adjust to changing conditions due to disruption or interruption (Kroes and Ghosh 2010). Similarly, agility can help respond to unpredictable changes quickly (Dubey et al. 2018; Tukamuhabwa et al. 2015). Adaptability is the ability to quickly absorb the changes in the environment and adjust resources accordingly (Ali, Mahfouz, and Arisha 2017; Dubey et al. 2018). Lastly, recovery is the ability to minimize the impact of disruption and rebuild the operation from an after-shock (Ambulkar, Blackhurst, and Grawe 2015). Collectively these capabilities ensure the strength of a supply chain to face any known or unknown disruptions.

2.3. Constructing the Typology Framework

Typological matrix framework (ideal clustering approach) is one of the classic, yet essential, theory-building approaches (Brusco et al. 2017; Carter, Kaufmann, and Ketchen 2020; Doty and Glick 1994). This approach had been used to theorize many management/strategy concepts at the earlier stage (Law, Wong, and Mobley 1998; Leonard-Barton 1992). Even in emerging research areas, typology and taxonomy still make substantial contributions (Ancarani et al. 2019; Azadegan and Dooley 2021; Dabhilkar, Birkie, and Kaulio 2016; Gunessee and Subramanian 2020; Reed et al. 2021; Revilla and Saenz 2017). The typology approach has a specifically important role when it comes to the progress of supply chain management research concepts (Brusco et al. 2017).

Through typology, we investigate the different combinations based on the levels of proactive and reactive resilience capabilities, both as complementary and substitutional natures. Grounded on cluster-based theorization guidelines (Brusco et al. 2017; Carter, Kaufmann, and Ketchen 2020; Doty and Glick 1994; Miller 1996; Revilla and Saenz 2017), we propose the 2x2 "FEND" typology framework given in Figure 1. Here both proactive and reactive resilience are each categorized as low and high. The four resulting clusters are labeled as Fragile, Eagle-eye, Nimble, and Durable supply chains based on the level and combination of proactive and reactive resilience capabilities.

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2.3.1. Fragile Supply Chain: Figure 1 shows that the fragile supply chain configuration has a lower application of every resilience capability. Thus, these firms leave their supply chains exposed, unprepared and operating in a highly vulnerable environment. First, a lack of a proactive resilience capability creates blind spots even for disruptions that are predictable in other supply chains (Craighead et al. 2007). Therefore, the fragile supply chain can be significantly interrupted even by minor disruptions. Moreover, the subsequent lack of reactive resilience makes the recovery harder (Craighead et al. 2007; Pettit, Fiksel, and Croxton 2010). This happens because a Fragile supply chain lacks all three key aspects of contingency planning (preplan, adjust and adapt); therefore, its vulnerabilities pertaining to uncertainty and complexity are quite extreme (Galbraith 1973; Haußmann et al. 2012). Second, even when these Fragile supply chains try to mitigate or manage a disruption, they might often run into more trouble due to a higher power imbalance between the supply chain partners. For example, when the focal firm holds significant resources and the relational interdependency is low, the focal firm can focus on internal resilience (Sá et al. 2020). Under such circumstances, the supply chain partners could easily feel rebellious, leading to a relational conflict and more disruption (Twomey 1978). This is also conceptually aligned with the tenets of the relational view, in that it indicates that lower levels of complementarity will quickly damage or terminate relational collaborations (Dyer, Singh, and Hesterly 2018).

2.3.2. Eagle-Eye Supply Chain: This supply chain configuration reflects high proactive resilience capabilities and low reactive resilience capabilities (Figure 1). Such a supply chain always stays vigilant about any changes or signs of disruption because a higher concentration on proactive resilience indicates planning ahead and developing countermeasures accordingly (Dabhilkar, Birkie, and Kaulio 2016). These supply chains seem to believe that, by default, supply chains are risky and the most effective way to mitigate the negative impact is to have a clear understanding as well as an early warning about potential disruptions (Braunscheidel and Suresh 2009; Craighead et al. 2007; Riley et al. 2016). In other words, when it comes to handling instability and contingency, these supply chains are more focused on preparedness and preplanning rather than adjusting (Galbraith 1973; Haußmann et al. 2012). Considering these characteristics, we label this configuration as an Eagle-eye supply chain. The higher focus on warning capability or visibility across the supply chain requires strong connectivity and competency across the supply chain (Barratt and Oke 2007). Therefore, theoretically, the Eagle-eye supply chain will find it essential to focus on compatible and complementary resources and knowledge sharing (Dyer, Singh, and Hesterly 2018; Wamba and Akter 2019). Higher competency in the buyer-supplier relationship will bring more clarity to the supply chain, making spotting disruptions easier. Thus, it is plausible that the Eagle-eye supply chain will have more reason to focus on relationship development. However, rapid and unforeseen changes can still damage these supply chains, and recovery can be particularly challenging in such cases.

2.3.3. Nimble Supply Chain: This configuration considers reactive resilience as its core strength. These supply chains believe that uncertainties will remain in the supply chain and are unavoidable (Craighead et al. 2007). Thus, predicting is not always possible; even trying to predict may not make the eventual solution any more straightforward. Therefore, being flexible toward changes and uncertainties is considered a more practical approach (Gligor 2016). Changing with disruptions can help a supply chain recover quicker (Braunscheidel and Suresh 2009). Fundamentally, these are cost-sensitive supply chains that tend to believe that the cost of being proactively resilient supersedes the benefit (Brandon-Jones et al. 2014; Tukamuhabwa et al. 2015). Instead, the focus is on being inherently resilient and optimal in cost efficiency (Mandal 2012). In this configuration, supply chains focus on a spontaneous reaction while facing uncertainty and disruption; these are fluid yet sturdy supply chains. Thus, we label this cluster as a Nimble supply chain. In order to face a disruption head-on, to adapt and to recover, a supply chain requires agility, flexibility, and adaptability (Aslam et al. 2018; Prater, Biehl, and Smith 2001). Maintaining reactive capabilities in the supply chain requires collaboration and sharing across the supply chain (Aslam et al. 2018; Dubey et al. 2018; Jia et al. 2020). This is particularly important because in a post disruption context, facilitating resilience capabilities to be lithe will require a lot of resources, expertise, and information. Moreover, based on the contingency perspective, the focus here is on reactive strategic aspects such as adjusting and adapting (Galbraith 1973; Haußmann et al. 2012), which is a complete contrast to the Eagle-eye configuration. Collectively, being reactive could be helpful; sometimes, it might be the only alternative when interdependency is extraordinarily high and other alternatives are limited (Dyer, Singh, and Hesterly 2018).

2.3.4. Durable Supply Chain: This supply chain configuration has higher levels of proactive as well as reactive resilience capabilities (Figure 1). These supply chains prefer to stay watchful and prepared and try to be quick to adapt to the changing environment. These supply chains often have a lot to lose during disruptions, which justifies the high investment in every resilience aspect. The reason to apply both types of capabilities is to be consistently resilient. In other words, this segment believes that resilience is a strategic capability to manage all sorts of risks and disruptions (both expected or unforeseen) and not just some specific incidents (Azadegan and Dooley 2021; Tukamuhabwa, Stevenson, and Busby 2017). Therefore, these supply chains are careful and efficient in both types of resilience capabilities, making them the strongest against disruption and uncertainty (Jia et al. 2020). Moreover, this cluster covers all three strategic aspects of contingency (Galbraith 1973; Haußmann et al. 2012), thereby providing the best support within complex and uncertain contexts. Based on all these reasons, we label this cluster as a Durable supply chain. Often, steadiness is fundamental in a Durable supply chain; the realization that any disruption could cause long-term damage supports the practice of applying every resilience capability that is available. Another reason for being a Durable supply chain could be the narrow-expected margin of performance, which means that even a slight deviation from standard/expected performance can be fatal and ruin the business/brand altogether (Iftikhar, Purvis, and Giannoccaro 2021; Um and Han 2021).

2.3.5. Juxtaposing the Different Clusters: In contrast to the Fragile supply chain, the Eagle-eye and Nimble supply chains should have better resource sharing, knowledge sharing, and a proper governance structure to get successful resilience capabilities. Additionally, compared to the other three configurations, the Durable supply chain could have the highest level of sharing and collaboration with a strong relational governance. Therefore, the transition from Fragile to Durable supply chains echoes the fundamentals of the relational view by indicating that higher collaboration in buyer-supplier relationships could deliver higher competitive advantage at an interorganizational level through the collective development of resilience capabilities (Dyer and Singh 1998; Dyer, Singh, and Hesterly 2018).

2.4. Performance Measurements

Testing the theoretical framework or testing the impact of a capability using performance measures as outcome variables is a highly common and an acceptable approach (Flynn, Huo, and Zhao 2010; Gunasekaran, Patel, and McGaughey 2004). Besides, exploratory research often tends to study the primary impact on different types of performance measures (Altay et al. 2018; Ancarani et al. 2019; Flynn, Huo, and Zhao 2010; Kathuria 2000). Recent literature also seems to have a growing interest in testing supply chain resilience from the perspective of different performance measurements (Iftikhar, Purvis, and Giannoccaro 2021). Additionally, how resilience capability drives different types of performance is a popular question in literature (Chowdhury, Quaddus, and Agarwal 2019; Gunessee, Subramanian, and Ning 2018; Ralston and Blackhurst 2020); this could be driven by the rationale that resilience capabilities should have an immediate impact on supply chain performance and relational performance as opposed to financial performance. Though end of the line quantitative (like cost or financial) performance measures are prevalent in supply chain literature (Chen and Paulraj 2004; Li et al. 2017), literature is still evolving when it comes to measuring the immediate performance of a supply chain along the notions of uncertainty (Akın Ateş et al. 2021; Iftikhar, Purvis, and Giannoccaro 2021). In summary, we contend that testing the FEND framework against key performance metrics is of paramount importance in understanding its true potential.

In order to get a good sense of overall performance, operational performance indicators are important (Flynn, Huo, and Zhao 2010). Additionally, there are many non-financial supply chain performance measures that specifically try to address the uncertainty and dynamic aspects of supply chain networks (Qrunfleh and Tarafdar 2014). Therefore, resilience capabilities should be juxtaposed against these performance measures too. Another critical aspect of performance is relational performance. Relational performance is highly associated with maintaining stability in the operation as well as controlling uncertainties (Liu, Luo, and Liu 2009). It can also reflect the collective goal achievement and collaborative advantage through collaboration (Li et al. 2010). Moreover, there are many different types of resilience capabilities and these may have a differential impact on performance measures based on the combination of capabilities and the context of the application. Based on a synthesis of literature on operational performance, supply chain performance, and relational performance (Beamon 1999; Li et al. 2010; Liu, Luo, and Liu 2009; Qrunfleh and Tarafdar 2014; Swift, Guide Jr., and Muthulingam 2019), we explore how these three performance aspects are associated with the different classifications of the FEND framework.

3. METHODOLOGY

3.1. Data Collection and Measurement Instruments

Based on established survey research guidelines, a cross-sectional online survey instrument was used for data collection (Ketokivi 2019; Montabon, Daugherty, and Chen 2018; Podsakoff et al. 2003). Data was collected from different manufacturing firms located in the United States of America and the United Kingdom. Our sample contains eleven different industry categories ranging between the two-digit SIC codes of 20 and 75. All key constructs were measured with multi-items using a seven-point Likert scale. In total, we contacted 1136 potential respondents and received 395 qualified responses. All the respondents held high-level managerial roles related to operations/procurement/supply chain and were experienced in disruption management. After removing faulty responses (e.g., completed within one-third of the average response-time, providing consistently same answers, etc.), we had a sample of 291 responses, providing a 25.4% effective response rate. We collected data between late 2019 and early 2020. All measurement items were taken from extant literature and then pre-tested using experts and pilot data collection; this ensured the contextual validity of our measurement items. The measurement items and their literature sources are provided in Appendix A. As indicated earlier, we tested the relationship between the FEND framework and different performance dimensions. The measurement items for the three performance dimensions are also provided in Appendix A. Please refer to Figure 2 for the analytical steps used in this research.

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3.2. Reliability, Validity, and Biases

We ran multiple analyses to establish validity, reliability, and unidimensionality. We followed the confirmatory factor analysis (CFA) approach through an eleven-factor model (Chen & Paulraj, 2004). All CFA factor loadings ranged between 0.63 to 0.88. The CFA model showed good fit; Normed Chi-Square = 2.16 ($\leq$ 5.0); Non-Normed Fit Index = 0.98 ($\geq$ 0.90); Comparative Fit Index = 0.98 ($\geq$ 0.90); Standardized Root Mean Square Residual = 0.05 ($\leq$ 0.08); Root Mean Square Error of Approximation = 0.06 ($\leq$ 0.08). Thus, we can conclude that all goodness-of-fit index values are within the required range (Chen and Paulraj 2004; Hu and Bentler 1999). However, we deleted three items from the dataset to improve the overall model fit (please refer to Appendix A). Coefficient alpha along with coefficient omega (as well as robust alpha and omega) values were calculated for all the constructs (Cronbach 1971; McDonald 1999); these values are all above the minimum limit. Composite reliability (CR) and Average Variance Extracted (AVE) scores were also measured and found to be within range (Bagozzi and Yi 1988; Fawcett et al. 2014). All the measurement items, along with corresponding factor loading, items' primary source, and other reliability indicators, are given in Appendix A.

In order to assess discriminant validity, we applied the Fornell and Larcker test (Fornell and Larcker 1981). Appendix B shows all the correlation values; the correlation values are lower than the respective square root of AVE values (please refer to Appendix A), except for agility where the square root of AVE value is lower than its correlation with supply chain performance. Additionally, although within the limit, flexibility shows a very high correlation, and it is closer to the corresponding square root of AVE values for operational and supply chain performance indicators. However, the measurement of agility and flexibility are well connected and theoretically similar to the indicators of performance measurement (Agarwal, Shankar, and Tiwari 2006; Beamon 1999). Therefore, agility and flexibility show high correlations (close to the square root of AVE) with operational and supply chain performance indicators. We tested for heterotrait-monotrait (HTMT) to ensure rigor because HTMT is considered more stringent than other approaches (Henseler, Ringle, and Sarstedt 2015), and we found consistent results. All HTMT values are between 0.50 to 0.85, except for the corresponding value between agility to supply chain performance, which is 0.90. However, while the HTMT cutoff point is generally 0.85, literature suggests that theoretically-related constructs can go up to 0.90 (Henseler, Ringle, and Sarstedt 2015). Therefore, we can conclude that our data is reliable and valid.

Since a single respondent from each firm answered all the questions, we were careful about common method bias. As a design approach, we separated the variables into multiple sections with separate instructions for the respondents, thereby reducing the possibility of the respondents guessing the connections between variables or causality; we also ensured that the respondents held higher-level management roles (Montabon, Daugherty, and Chen 2018; Podsakoff et al. 2003). Second, we performed Harman's single factor test (Paulraj 2009; Podsakoff et al. 2003; Revilla and Saenz 2017). A single factor did not emerge from the test, and the first factor did not account for most of the variance, so common method bias is considered unlikely. We also applied the Widaman test for a better understanding of common method bias (Widaman 1985). While comparing the theoretical factor model with the second substitute model (theoretical factor and method factor), there is a minor improvement in the model fit, responsible for only 4% of the total variance. According to other researches that have applied this method, this is acceptable (Paulraj, Lado, and Chen 2008; Podsakoff et al. 2003; Williams, Cote, and Buckley 1989). Next, we checked for non-response bias. We divided the survey responses into early respondent and late respondent groups based on response date and applied group comparison tests (Chen and Paulraj 2004; Paulraj 2009). The results show little difference between the groups ($p<0.05$), suggesting that non-response bias might not be an issue.

3.3. Second-Order Constructs and Clustering Approach

Before applying this operationalization of proactive and reactive resilience to explore the FEND framework, we validate the second-order operationalization by using the target coefficient approach (Marsh and Hocevar 1988). This approach uses a chi-square ratio to show how much the second-order construct explains the variance within the first-order constructs. We ran two sets of CFA models for both proactive and reactive resilience. First, we calculated the average score for each multi-item first-order construct, and then we used the average score of the four first-order constructs to calculate the score for the second-order resilience capabilities. For reactive resilience, we ran the first model with items of four first-order capabilities. The second CFA model included all first-order constructs along with the second-order construct. The first model is considered as the target model, and the chi-square ratio is calculated as the first model to the second model's chi-square value. Then the same process was repeated for proactive resilience. The target coefficient values for proactive and reactive supply chain resilience are 0.96 and 0.98, respectively. In both cases, the values are very close to 1, suggesting that the second-order constructs capture a higher amount of variance (Doll, Xia, and Torkzadeh 1994; Marsh and Hocevar 1988).

In this typology conceptualization, we want to test how data fit in the ideal conditions, and not the other way around like in a taxonomy-based conceptualization (Doty and Glick 1994; Paulraj 2009). Thus, we used a high and low logic-based approach to decide upon the cluster membership from the level of response on the proactive and reactive resilience constructs (Paulraj, Chen, and Chung 2006). In order to achieve the high and low configurations of the FEND framework, we categorized each response based on the mean value of the second-order constructs; scores below the mean were considered as low while scores above the mean were considered as high. Therefore, we had high and low scores for both proactive and reactive resilience. In proactive resilience capabilities, 44.3% of the sample fell in the low resilience group; on the contrary, 46.4% of the sample fell in the low reactive resilience group. Based on this, we determined the cluster membership of each row of data. After this process, we ended up with 109 in the Fragile cluster, 26 in the Eagle-eye cluster, 20 in the Nimble cluster, and 136 in the Durable cluster. Although Eagle-eye and Nimble clusters have fewer samples than others, they were still considered to be sufficient to run meaningful analysis (Kathuria 2000).

4. EMPIRICAL EXPLORATIONS

We ran two separate sets of analyses using the cluster configurations that we had developed based on the FEND framework. First, we used one-way ANOVA to test all the first-order resilience capabilities and the performance measures. Second, we used the response surface methodology to explore the level of performance indicators across different configurations of proactive and reactive resilience capabilities as per the FEND framework. We contend that both of these analyses are necessary to conduct a robust exploration of the framework. We needed to know how capabilities are constructed for each configuration and how each configuration is different from others. Additionally, it is also important to see how different combinations of proactive and reactive capabilities impact performance. Since we are not testing any specific hypothesis, this approach provides more flexibility to explore the connections between resilience capabilities and their performance impacts.

4.1. ANOVA Analysis

We conducted our analysis in two stages following extant literature (Paulraj, Chen, and Chung 2006; Paulraj 2009; Revilla and Saenz 2017). Once we had manually developed the cluster membership for both proactive and reactive resilience, we used this to establish values of the configurations of the framework. Next, we conducted the one-way ANOVA along with the Scheffe post-hoc tests (Hair et al. 2019; Paulraj, Chen, and Chung 2006). The Scheffe method is used to determine the differences and distances between the group means of each pair of cluster (Slater and Olson 2001). This method is beneficial for unequal sample sizes in groups and helps estimate all possible contrasts between the factor level means (Kathuria 2000; Paulraj, Chen, and Chung 2006). Unlike data driven taxonomies, a typology is a theorization through an ideal clustering approach (Brusco et al. 2017; Doty and Glick 1994). Therefore, our data resulted in an unequal distribution of firms across the ideal typological clusters; accordingly, the Scheffe method is critical in our analysis.

= = = = Insert **Table 1** around here = = = =

Table 1 presents the ANOVA results; Panel-A presents the results for the first-order resilience capabilities and panel-B presents the results for performance. Table 1 also includes evidence that all the first-order constructs are significantly different across clusters at $p<0.001$ level (Kathuria 2000). In Panel-A, the Eagle-eye configuration shows no difference from the Durable configuration for the proactive resilience capabilities based on the 95% confidence level of Scheffe pairwise tests. Similarly, reactive resilience capabilities show no difference between Nimble and Durable configurations. Moreover, the alternative configurations (where proactive is high and reactive is low and vice versa) – Eagle-eye and Nimble clusters – show a clear difference for all resilience capabilities except the warning capability.

The performance indicators have a similar pattern in clustering association. The average value for performance dimensions is in ascending order for Fragile, Eagle-eye, Nimble and Durable configurations (Panel-B in Table 1). Moreover, the Scheffe pairwise tests indicate that the Durable configuration is different from the others for operational performance. Supply chain performance has no segregation between the Fragile and Eagle-eye configurations, but both are different from the Durable configuration. However, in the case of relational performance, only the Fragile configuration is different from the other three configurations, and there are no differences between the Eagle-eye, Nimble and Durable configurations.

Finally, we applied a robustness check to ensure the reliability of our results (Hair et al. 2019; Paulraj 2009). Specifically, instead of mean values, we used the median values to determine high and low for reactive and proactive resilience. Subsequently, we conducted the one-way ANOVA tests for all resilience capabilities and performance constructs. Median-based results were consistent with the results of mean-based clusters, and the results are presented in Appendix C.

4.2. Polynomial Regression

We adopted the polynomial regression method to further explore the benefits of the different typological configurations. This could be considered better than other linear regression approaches. First, it reflects a synergistic balance across multiple ideal types, and requires exploring the nonlinear relationship among constructs (Doty and Glick 1994). In other words, we can test both the slope and curvature of the surface at the same time. Especially, in an exploratory research effort like ours, it could provide much needed clarity. Second, this methodology can help us to explore the effects of the coexistence of the two exogenous variables on an endogenous variable. In effect, we can explore how different combinations of proactive and reactive resilience capabilities can impact performance. Moreover, through the response surface methodology, we can illustrate not just the highest and lowest points, but also all other intermediate performance levels. Therefore, we use the response surface methodology to further explore the combined impact of proactive and reactive resilience, which are essentially the four clusters of the FEND framework. To develop our tests, we used well-accepted guidelines (Edwards and Parry 1993; Myers 1999) and followed the recent examples of response surface methodology (Liu and Wei 2021; Liu et al. 2020; Wach et al. 2021). Details pertaining to this analysis is presented in Appendix D. The results of the polynomial regression models are illustrated in Figure 3. We also calculated the 95% bias-corrected confidence interval (CI) for slope and curvature along the symmetry and asymmetry lines (Edwards and Cable 2009; Liu and Wei 2021) using the bootstrapping approach involving 5000 replications. These results are presented in Appendix E.

= = = = Insert **Figure 3** around here = = = =

First, we ran the polynomial regression model with operational performance as the outcome variable (adjusted R^2 =0.51; model F=34.38). As for the symmetry line, we found the slope to be significant (0.659; CI=[0.305, 0.915]); moreover, the curvature of this line was also significant (0.134; CI=[0.052, 0.247]). This indicates that operational performance improves when both proactive and reactive resilience increase simultaneously. At the same time, since the curvature is significant, operational performance could dip slightly before going up. Alternatively, the slope along the asymmetry line was significant (-1.224; CI=[-2.047, -0.582]). Though the curvature along the asymmetry line was an inverted U shape (Plot-A of Figure 3), it was found to be insignificant (-0.845; CI=[-2.309, 0.322]). Second, we ran the polynomial regression model with supply chain performance as the outcome variable (adjusted R^2 =0.59; model F=47.72). As for the symmetry line, the slope (0.708; CI=[0.325, 1.005]) and the curvature (0.099; CI=[0.002, 0.233]) were both significant. Alternatively, along the asymmetry line, the slope was significant (-1.105; CI=[-1.886, -0.431]) while the curvature (-0.016; CI=[-1.397, 0.801]) was not. Therefore, low proactive combined with high reactive resilience results in higher supply chain performance than high proactive combined with low reactive resilience. Third, we ran the polynomial regression model with relational performance as the outcome variable (adjusted R^2 =0.51; model F=33.98). The slope along the symmetry line is significant (0.496; CI=[0.276, 0.806]), but the curvature is not (0.069; CI=[-0.028, 0.141]). Thus, relational performance improves when proactive and reactive resilience increase simultaneously. On the other hand, Plot-C of Figure 3 indicates a U-shaped curvature along the asymmetry line, indicating the possibility that both Eagle-eye and Nimble configurations will have higher relational performance than moderate levels of both proactive and reactive resilience. However, in this case, we found both the slope (-0.272; CI=[-0.985, 0.484]) and the curvature (0.515; CI=[-0.245, 1.206]) to be insignificant.

5. DISCUSSION

Recently there have been some highly thought-provoking studies on conceptualizing supply chain resilience (Azadegan and Dooley 2021; Iftikhar, Purvis, and Giannoccaro 2021; Pettit, Croxton, and Fiksel 2019; Stone and Rahimifard 2018; Drozdibob et al. 2022). We believe that our research adds to this emerging body of knowledge by providing a nuanced insight into conceptualizing supply chain resilience capabilities using the FEND framework. Extant literature suggests that resilience should be conceptualized using multiple capabilities and these capabilities could be categorized as either proactive or reactive (Dabhilkar, Birkie, and Kaulio 2016; Jia et al. 2020; Tukamuhabwa et al. 2015). Additionally, looking at the interorganizational perspective is also essential for resilience capabilities. Supply chain resilience capabilities can be a source of strategic advantage for a supply chain as long as the partners are invested in collaborative development through resource and knowledge sharing (Dyer, Singh, and Hesterly 2018). Thus, different resilience capabilities are connected and interdependent at an interorganizational level (Ali, Mahfouz, and Arisha 2017; Pettit, Fiksel, and Croxton 2010; Tukamuhabwa et al. 2015). To the best of our knowledge, this research is the very first endeavor to combine these two aspirations together by developing a typological framework on proactive and reactive resilience through a multi-capability perspective. Accordingly, the FEND framework has the potential to contribute critically to the theorization and application of supply chain resilience capabilities.

5.1. Theoretical Implications

Establishing the protocol for measuring and developing the higher-order constructs of resilience capabilities will enhance the strength of future resilience research. Of course, it is not conceptually wrong to focus on a single resilience capability in any research, more so when the research context is focused on a specific resilience capability (Gligor, Esmark, and Holcomb 2015; Roy, Gilbert, and Lai 2019). However, when the scope of future research is to examine the impact or antecedents of the level of supply chain resilience capability, we contend that our multi-capability operationalization will be more appropriate. Although extant literature on resilience collectively indicates that there is no single right way to build up resilience (Helfgott 2018; Kahn et al. 2018; Pettit, Fiksel, and Croxton 2010), focusing too much on a single capability and trying to be resilient can drive a supply chain into a more complicated position and lead to ineffective performance. Our FEND framework suggests that there are different choices when it comes to resilience capabilities and that supply chains can choose from these configurations to match their requirements and performance aspirations (Ponomarov and Holcomb 2009; Tukamuhabwa et al. 2015). Moreover, our findings also demonstrate the FEND framework's impact on non-financial performance indicators. Specifically, our results suggest that the effects of resilience capabilities could be highly diverse. Overall, our findings add interesting theoretical insights.

First, there is a clear improvement in all performance indicators when we move from the Fragile to the Durable supply chain configuration. At the same time, the existence of a significant curvature for operational and supply chain performance (Figure 3, Plot A & B) indicates that performance can go down slightly before improving. One possible reason could be the adverse impact of the sudden change in standard practices (Klein et al. 2019; Konig, Graf-Vlachy, and Schoberl 2020). The introduction of higher levels of resilience capabilities can bring about many changes in the operation and governance styles (Shin and Park 2021; Um and Han 2021). Therefore, both internal and interorganizational performances can be primarily hampered by the introduction of any resilience capability, which is the case when the supply chain tries to move out of the Fragile cluster. Second, in all three cases, the Nimble supply chain shows higher performance than the Eagle-eye supply chain (though not statistically significant for relational performance). Thus, if a supply chain has to choose between proactive and reactive capabilities, there is a higher chance that, generally, they will be better off by being reactively resilient. However, it does not imply that proactive resilience capabilities are ineffective. These capabilities are certainly helpful when a supply chain wants to move from the Nimble to the Durable cluster. In other words, we conjecture that to ensure better performance, a supply chain that wants to move out of the Fragile context should first develop reactive capabilities and subsequently explore proactive capabilities to become Durable. A key reason for this strategy is that the reactive capabilities could also help in building the required intensity in relationships which are considered a precursor to proactive resilience.

Third, relational performance is a unique context. Any existence of resilience capabilities at the interorganizational level could significantly improve relational performance (Chowdhury, Quaddus, and Agarwal 2019). This is supported by the tenets of the relational view (Dyer, Singh, and Hesterly 2018) because developing any level of resilience capability will require investments and sharing in relationships. Thus, it can quickly improve the standards of the relationship. Fourth, all three models have different shapes and levels of performance impacts. Thus, which performance is essential for a particular supply chain will determine which combination of resilience capabilities is more valuable. Although all performances eventually lead to the financial bottom line (Akın Ateş et al. 2021; Droge, Jayaram, and Vickery 2004), different industries or supply chains get more out of the different performance measures. Fifth, extant literature indicates that there is a serious cost associated with the resilience capabilities development (Brandon-Jones et al. 2014; Tukamuhabwa et al.

2015). Additionally, following our FEND framework and developing multi-capability resilience should require significant consideration of the costs and benefits of being resilient. Besides considering the impacts of the Nimble and Durable clusters (Figure 3) on the performance metrics, our findings also raise a concern that it is crucial to understand how a Durable supply chain could get around the cost implications of its resilience capabilities - does it really pay off to develop both reactive and proactive resilience capabilities?

5.2. Managerial Implications

The FEND framework would be a great tool for managers to improve their resilience strategy and capability. Our conceptualization of proactive and reactive supply chain resilience has three key direct benefits for managers when it comes to making insightful strategic decisions. First, there are a lot of supply chains that are still in the Fragile stage and have a limited understanding of resilience. In the current dynamic business environment, this is quite dangerous. Thus, the FEND framework will be a valuable initial tool for supply chain managers who want to learn and improve their resilience capabilities. Managers can begin by examining the current proactive and reactive capabilities that they have and assess the effectiveness of those capabilities to understand their position in the FEND framework. Specifically, knowing (1) the configuration that closely matches their current supply chain condition, and (2) the configuration that is more desirable for them, will subsequently enable firms to better plan the transition as this will answer the fundamental question of which capabilities they should focus on developing further. Second, the required resilience capabilities are not rigid and every supply chain may not benefit similarly from every capability. However, we cover the most used resilience capabilities and sufficiently explain the operationalization process. Thus, a similar approach can be adapted with other different combinations of resilience capabilities based on the specific context of the supply chain or industry characteristics (Faruquee, Paulraj, and Irawan 2021). For instance, for the healthcare industry to be reactively resilient, hospitals need flexibility and speed along with quick access to patient-related knowledge (Rubbio et al. 2019). Therefore, every supply chain should look into their relevant collective skills, strength, and industry nature to develop the required complementary resilience capabilities.

Third, in a multi-capability resilience conceptualization, supply chain managers can select the resilience capabilities based on the available resources, expertise, and tacit knowledge across the supply chain. Managers could also consider the vulnerability contexts associated explicitly with the supply chain. Subsequently, managers can also explore the potential impact on different performance metrics. Alternatively, they can work backwards by selecting the resilience configuration that matches their performance expectations. Therefore, managers should understand that there is no 'one size fits all' type of solution when it comes to resilience. Blindly following best industry practices from other superior supply chains might not help without sufficient contextual clarity on their own supply chain's available resources and strengths (Azadegan and Dooley 2021; Iftikhar, Purvis, and Giannoccaro 2021). So, by clearly indicating the current conditions of a supply chain and which ideal conditions it could aspire to be in, our framework can help managers to identify the resilience strategies to be developed. In other words, the FEND framework will improve managers' ability to measure and manage resilience capabilities for superior and stable performance.

5.3. Future Research Directions and Limitations

Our research is based on the conceptualization of ideal contexts of supply chain resilience capabilities. Against this backdrop, we have made some guiding assumptions such as (1) resilience will need to be built based on specific multiple capabilities, (2) resilience should be at a supply chain relationship level, not at a firm level, and (3) positive relationships and supply chain partners bring complementary resources. Though these assumptions have made the conceptualization of this framework possible, addressing these limitations in future research will be valuable for both researchers and managers. Most importantly, based on the

FEND framework, researchers will be able to ask research questions that might not have been plausible before.

First, future research could explore buyer-supplier relationships and other relational antecedents across the different types of resilience capability clusters. Since resilience is a concept that revolves around the mitigation of risks and disruptions, it is necessary to know more about the prerequisites for the different configurations of resilience capabilities. Moreover, relational conflicts and opportunistic behavior always bring hurdles in buyer-supplier relationships (Tangpong, Hung, and Ro 2010). Thus, knowing how different configurations of resilience capabilities can be affected by the dark sides of the buyer-supplier relationship will also be highly value-adding. Second, some resilience capabilities can be defined differently as "during" disruption rather than before (proactive) or after (reactive) (Ali, Mahfouz, and Arisha 2017). Additionally, few capabilities can be dynamic in that they could be considered as both proactive and reactive (Tukamuhabwa et al. 2015). Capabilities such as redundancy or velocity need to be built up over time and can impact both pre and post-disruption contexts (Ribeiro and Barbosa-Povoa 2018; Tukamuhabwa et al. 2015). While we have developed a typological framework to help in the preliminary understanding of resilience capabilities, it will be valuable for future research to study such dynamic resilience capabilities separately. Moreover, other industry-specific resilience capabilities can also be considered within the context of applying the FEND framework. We encourage the development of empirical and analytical models that are based on industry data to address this industry-specific consideration. Additionally, given that the elaborate framework of "point-in-time" phasing of resilience proposed by Drozdibobc et al. (2022), is closely connected to our multi-capability FEND framework, we recommend future empirical research to use both frameworks collectively to specifically see the role of different resilience capabilities on each stage of a resilience process. Apart from the possibility of developing different levels of capability combinations, this effort could also extend the clusters of the framework beyond the 2x2 structure.

Third, given the development of recent large-scale disruptions like Brexit or COVID-19, it will be enlightening to explore the meso-level or macro-level resilience strategies (Azadegan and Dooley 2021) along with the FEND framework. Specifically, how the Fragile and Durable supply chains would face large-scale disruptions and how the meso-level and macro-level strategic alliances would work in such supply chains, will be critical questions to answer. Finally, extant literature indicates a strong cost sensitivity when it comes to resilience (Tukamuhabwa et al. 2015). Scholars argue that extensive investment in resilience may not pay off in the long run (Brandon-Jones et al. 2014; Mandal 2012). Thus, specific research focusing on costs as well as the returns of investing in proactive and reactive resilience capabilities will benefit both researchers and managers. The FEND framework is an early stage theorization for resilience capabilities; thus, it will be valuable to explore this further based on data collected from emerging and underdeveloped economies in order to understand how the proactive and reactive resilience structure changes in different economic contexts. Moreover, by exploring an ideal framework, our research could have some unobserved heterogeneity. We believe that future research explorations and implementations of this framework should be better equipped to address this issue.

6. **Conclusion**

This research presented a typological framework for supply chain resilience capabilities. Based on the supply chain's level of proactive and reactive resilience capabilities, the FEND framework presented four strategic clusters, namely, Fragile, Eagle-eye, Nimble and Durable. We used survey data to test this framework. First, we used the one-way ANOVA to explore ideal clusters in the framework. Subsequently, we applied the polynomial regression analysis to see how the different combinations of resilience capabilities impact the operational, supply chain, and relational performances. Through our exploratory analysis, we conclude that in order to develop a resilience mechanism, the supply chain should start from reactive capabilities to proactive capabilities until it becomes Durable. Although it will require interorganizational collaboration and sharing, a multi-capability supply chain with Durable resilience capabilities will gain better stability in performance.

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Figure 1: FEND framework

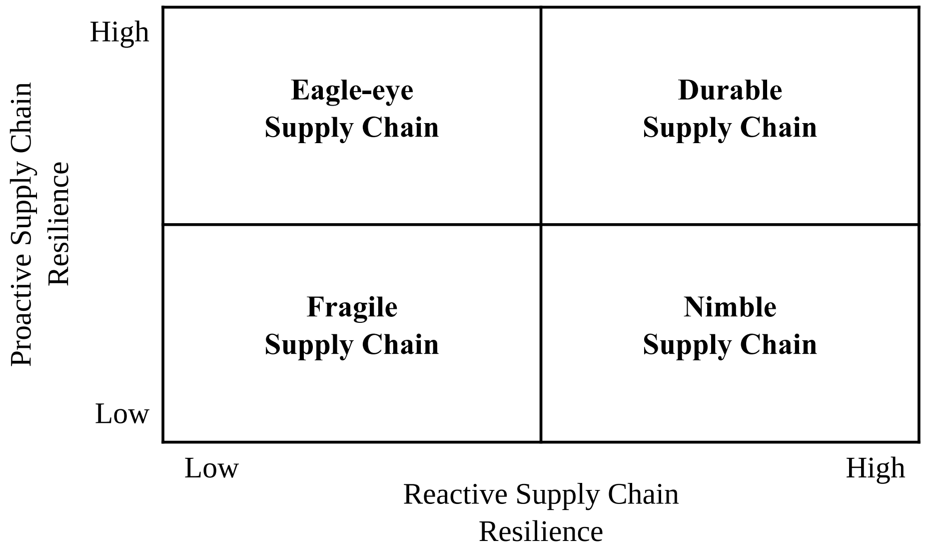

Figure 2: Methodological flowchart

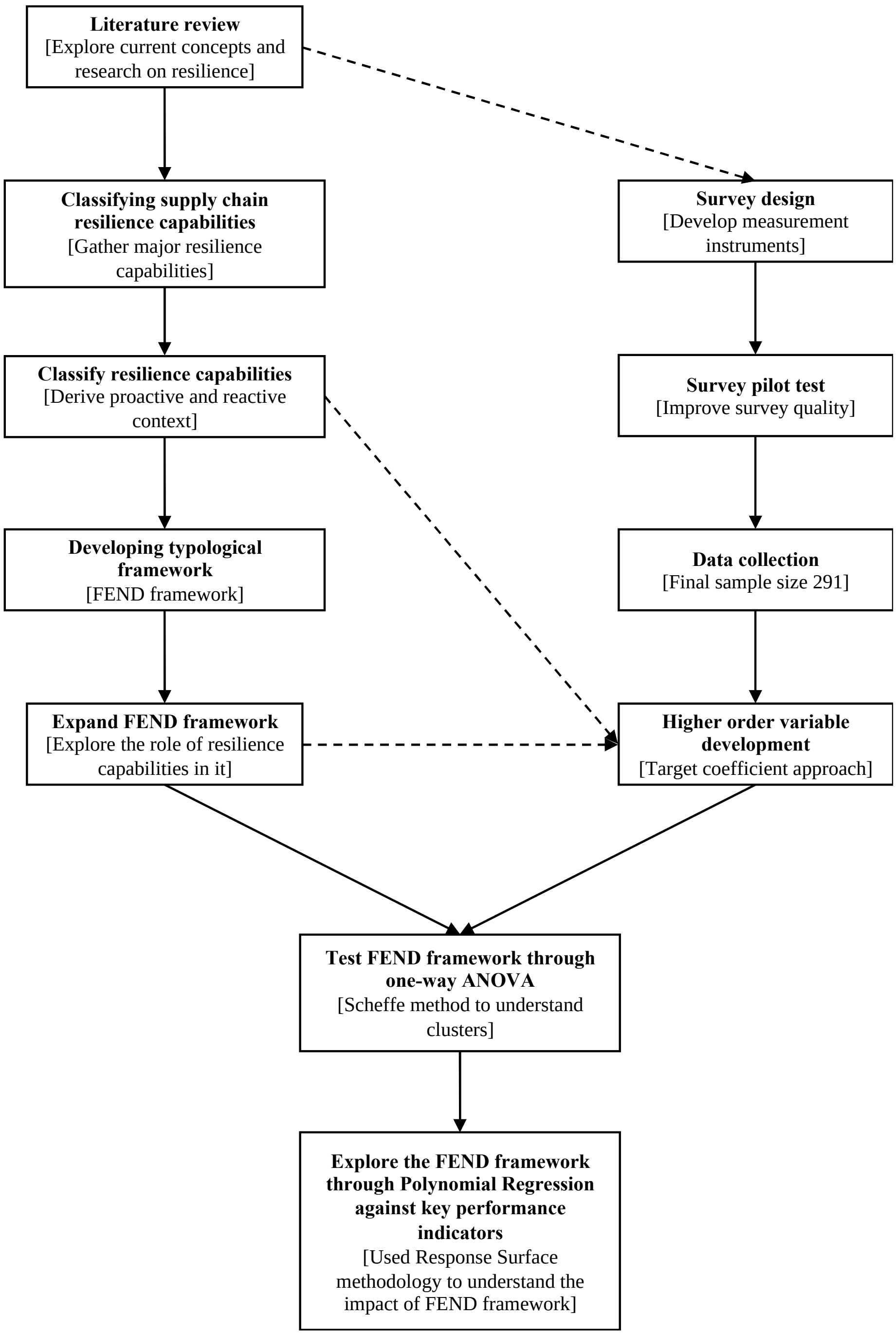

Figure 3: Effect of FEND framework on different performance indicators

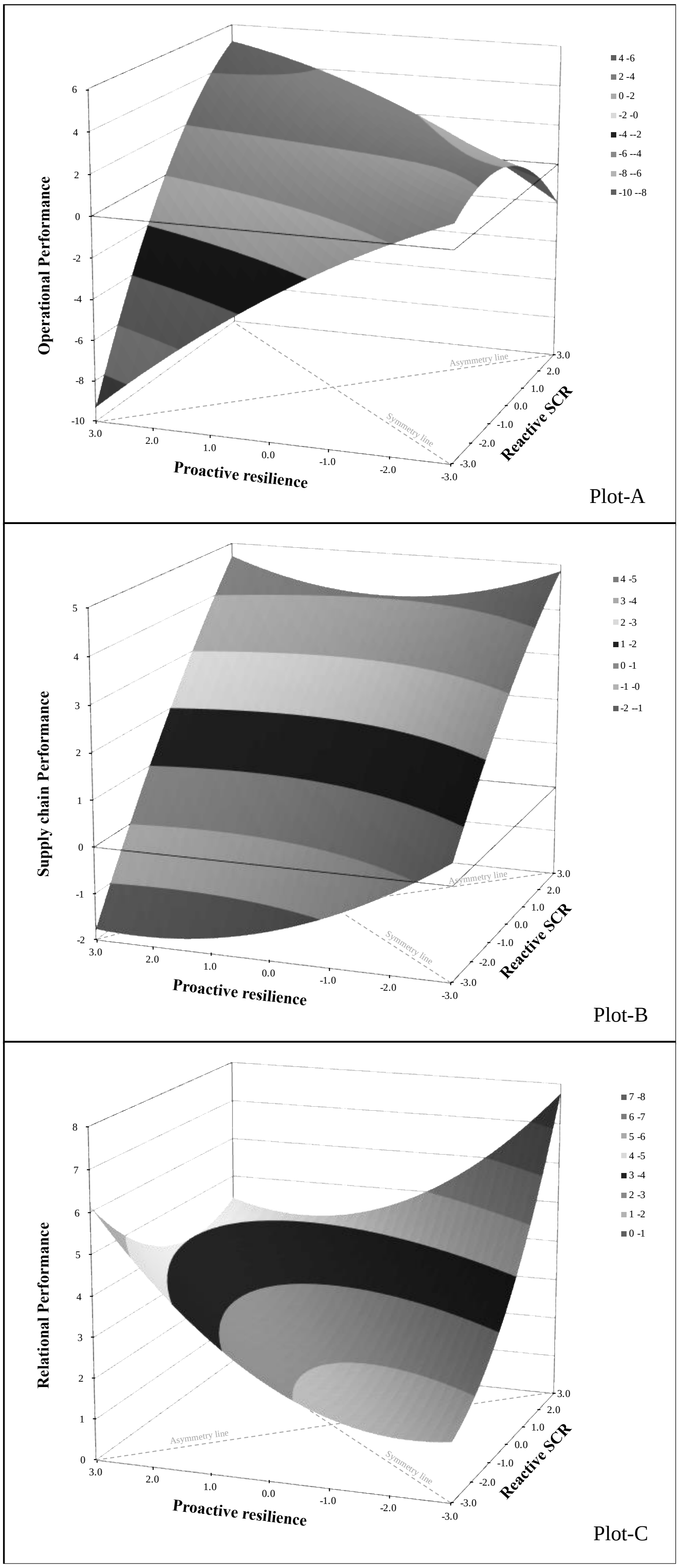

Table 1: Resilience capabilities by clusters

	Fragile SC n=109 (1)	Eagle-eye SC n=26 (2)	Nimble SC n=20 (3)	Durable SC n=136 (4)	F-value (probability)
Panel A					
CM Capability					
Cluster mean	4.73 (2,3,4)	5.86 (1,3)	5.33 (1,2,4)	6.21 (1,3)	78.9 (p< 0.001)
SE	0.09	0.11	0.21	0.05	
Warning					
Cluster mean	4.37 (2,3,4)	5.7 (1)	5.24 (1,4)	6.11 (1,3)	88.5 (p< 0.001)
SE	0.10	0.11	0.17	0.06	
Visibility					
Cluster mean	4.54 (2,4)	5.66 (1,3)	4.78 (2,4)	6.09 (1,3)	62.3 (p< 0.001)
SE	0.10	0.13	0.28	0.07	
Robustness					
Cluster mean	4.34 (2,4)	5.60 (1,3)	4.68 (2,4)	5.95 (1,3)	71.2 (p< 0.001)
SE	0.10	0.14	0.27	0.06	
Adaptability					
Cluster mean	4.58 (2,3,4)	5.35 (1,3,4)	6.07 (1,2)	6.28 (1,2)	95.3 (p< 0.001)
SE	0.10	0.11	0.15	0.04	
Agility					
Cluster mean	4.66 (2,3,4)	5.35 (1,3,4)	5.92 (1,2)	6.14 (1,2)	83.5 (p< 0.001)
SE	0.09	0.12	0.12	0.05	
Flexibility					
Cluster mean	4.65 (3,4)	4.97 (3,4)	5.76 (1,2)	6.16 (1,2)	80.2 (p< 0.001)
SE	0.09	0.13	0.17	0.05	
Recovery					
Cluster mean	4.75 (2,3,4)	5.33 (1,3,4)	6.12 (1,2)	6.21 (1,2)	79.5 (p< 0.001)
SE	0.09	0.15	0.11	0.05	
Panel B					
Operational performance					
Cluster mean	4.44 (3,4)	4.97 (4)	5.18 (1,4)	6.00 (1,2,3)	50.5 (p< 0.001)
SE	0.11	0.16	0.31	0.07	
Supply Chain performance					
Cluster mean	4.64 (3,4)	5.02 (4)	5.49 (1)	6.01 (1,2)	57.4 (p< 0.001)
SE	0.09	0.17	0.21	0.06	
Relational performance					
Cluster mean	5.06 (2,3,4)	5.80 (1)	6.18 (1)	6.17 (1)	52.2 (p< 0.001)
SE	0.09	0.10	0.13	0.05	

Note*: The numbers in parentheses show the group number(s) that are significantly different at the 0.05 level based on the Scheffe pairwise tests.*

Appendix A
Measurement Instrument

Supply management capability is measured with a five-item scale covering predictability and uncertainty in the buyer-supplier relationship (Bowen et al. 2001). Warning capability measurement has three items focused on predicting and flagging issues (Riley et al. 2016). Alternatively, the two-item measurement of visibility is about information and knowledge transfer across the supply chain, which is a well-used visibility measurement (Braunscheidel and Suresh 2009). Our four-item robustness measure is specific about explaining the readiness of an operation (Brandon-Jones et al. 2014). Adaptability is a reactive resilience capability, and the selected five measurement items indicate a supply chain’s ability to get along with changes and disruption (Dubey et al. 2018). Unlike adaptability, the four-item recovery measurement focuses on improving after disruption and downfall (Riley et al. 2016). On the other hand, the five-item agility measurement explores the changing ability of a supply chain according to the market change (Dubey et al. 2018). The last resilience capability for this study, flexibility, is measured with a six-item scale indicating how well a supply chain manages the dynamic nature of its business (Kroes and Ghosh 2010).

We measured three different dimensions of non-financial performance to understand the overall immediate performance contexts of the supply chain (Beamon 1999; Gunasekaran, Patel, and McGaughey 2004). In order to understand the performance of the focal firm, we used a three-item measurement of operational performance (Flynn, Huo, and Zhao 2010). We used a four-item supply chain performance measure focused on the market dynamism and disruption management context (Beamon 1999; Qrunfleh and Tarafdar 2014). The last performance construct that we have included is relational performance; specifically, we adapted a five-item scale focused on the strength and collective benefit of the relationship (Li et al. 2010; Liu, Luo, and Liu 2009).

Measurement Instrument

Indicators *(Coefficient Alpha, Coefficient Omega, Composite Reliability, Average Variance Extracted)*	**Std. Loading**
Supply management capabilities (Bowen et al., 2001) *(α = 0.80; Ω = 0.80; CR = 0.80; AVE = 0.50)*	
“We have liaison between purchasing and other functions”	Removed
“We have detailed purchasing policies and procedures”	0.65
“We follow partnership approach with suppliers”	0.63
“We have technical skills of purchasing professionals”	0.81
“We hold advanced understanding of environmental issues and how they affect supply”	0.72
Warning capability (Riley et al., 2016) *(α = 0.84; Ω = 0.84; CR = 0.84; AVE = 0.64)*	
“Our firm has procedures to identify threats”	0.80
“Within our network, there are systems to warn employees about potential threats”	0.85
“Within our network, the command centre identifies actual disruptions”	0.74
Visibility (Braunscheidel & Suresh, 2009) *(α = 0.86; Ω = 0.86; CR = 0.86; AVE = 0.76)*	
“Inventory levels are visible through the supply chain”	0.86
“Demand levels are visible throughout the supply chain”	0.88
Robustness (Brandon-Jones et al., 2014) *(α = 0.88; Ω = 0.88; CR = 0.88; AVE = 0.65)*	
“In case of a disruption, our operations would be able to continue”	0.82
“In case of a disruption, we would still be able to meet customer demand”	0.83
“In case of a disruption, our performance would not deviate significantly from targets”	0.76
“In case of a disruption, the supply chain would still be able to carry out its regular functions”	0.82
Adaptability (Dubey et al., 2018) *(α = 0.80; Ω = 0.80; CR = 0.80; AVE = 0.58)*	
“We monitor economies all over the world to spot new supply bases and markets”	Removed
“We use intermediaries to develop fresh suppliers and logistics infrastructure”	Removed
“We evaluate the needs of end-consumers and not just immediate customers”	0.74
“We create flexible product designs”	0.70
“We determine where our products stand in terms of technology cycles and product life cycles”	0.83
Agility (Dubey et al., 2018) *(α = 0.87; Ω = 0.87; CR = 0.87; AVE = 0.58)*	
“We work hard to promote the flow of information with our suppliers and customers”	0.75
“We work hard to develop collaborative relationships with suppliers”	0.76
“We design for postponement: Build inventory buffers by maintaining a stockpile of inexpensive but key components”	0.71
“We have a dependable logistics system or partner”	0.80
“We draw up contingency plans and develop crisis management teams”	0.77
Flexibility (Kroes & Ghosh, 2010) *(α = 0.89; Ω = 0.89; CR = 0.89; AVE = 0.57)*	
“We are flexible to adjust capacity and/or volume effectively within a short time period”	0.72
“We are flexible to adjust deliveries to meet customer requirements”	0.75
“We are flexible to customise products to meet customer specifications”	0.79
“We are flexible to make design changes in the product after production has started”	0.71
“We are flexible in offering a large number of product features or options”	0.77
“We have high production flexibility to allow the efficient new product introduction”	0.78
Recovery (Riley et al., 2016) *(α = 0.84; Ω = 0.85; CR = 0.84; AVE = 0.57)*	

“When a disruption occurs, our firm immediately starts recovery efforts”	0.75
“Once a threat is identified, our firm deploys resources to reduce the negative effects”	0.68
“Our firm's command centre deploys recovery resources to reduce the effects of a disruption”	0.83
“We restructure our resource base to react to the changing business environment”	0.75
Operational performance (Flynn et al., 2010)	
(α = 0.87; Ω = 0.87; CR = 0.86; AVE = 0.68)	
“Our firm can quickly modify products to meet our major customer's requirements”	0.79
“Our firm can quickly introduce new products into the market”	0.81
“Our firm can quickly respond to changes in market demand”	0.87
Supply chain (SC) performance (Qrunfleh & Tarafdar, 2014)	
(α = 0.86; Ω = 0.86; CR = 0.86; AVE = 0.60)	
“Our supply chain is able to handle nonstandard orders”	0.75
“Our supply chain is able to meet special customer specification requirements”	0.79
“Our supply chain is able to produce products characterised by numerous features, options, sizes, and colours”	0.77
“Our supply chain is able to rapidly adjust capacity so as to accelerate or decelerate production in response to changes in customer demand”	0.79
Relational performance (Li et al., 2010; Liu et al., 2009)	
(α = 0.89; Ω = 0.89; CR = 0.89; AVE = 0.62)	
“Overall, we are satisfied with the performance of this relationship”	0.77
“This relationship has realised the goals we set out to achieve”	0.80
“The relationship with this supplier has contributed to our core competencies and competitive advantage”	0.72
“Our relationship with this supplier is very attractive with respect to discounts”	0.81
“We are very pleased to do business with this supplier since it improves our customer base or satisfaction”	0.82

Model Fit Indices: Normed Chi-Square = 2.16 (≤ 5.0); Non-Normed Fit Index = 0.98 (≥ 0.90); Comparative Fit Index = 0.98 (≥ 0.90); Standardized Root Mean Square Residual = 0.05 (≤ 0.08); Root Mean Square Error of Approximation = 0.06 (≤ 0.08)

Appendix B
Correlation between Constructs

Factors	Mean	SD	CA	WC	VB	RB	AD	AG	FX	RV	OP	SP	RP
SM Capability (CA)	5.56	1.02	**0.71**										
Warning capability (WC)	5.36	1.16	0.68	**0.80**									
Visibility (VB)	5.38	1.16	0.51	0.47	**0.87**								
Robustness (RB)	5.23	1.16	0.53	0.62	0.45	**0.81**							
Adaptability (AD)	5.54	1.12	0.67	0.66	0.53	0.63	**0.76**						
Agility (AG)	5.50	1.01	0.61	0.64	0.63	0.58	0.69	**0.76**					
Flexibility (FX)	5.46	1.06	0.55	0.57	0.54	0.58	0.63	0.69	**0.76**				
Recovery (RV)	5.58	1.02	0.55	0.62	0.46	0.65	0.67	0.64	0.63	**0.75**			
Operational performance (OP)	5.26	1.22	0.51	0.47	0.48	0.52	0.54	0.56	0.75	0.54	**0.82**		
SC performance (SP)	5.37	1.04	0.50	0.50	0.58	0.53	0.59	0.78	0.71	0.56	0.65	**0.78**	
Relational performance (RP)	5.72	0.89	0.57	0.45	0.50	0.44	0.55	0.64	0.54	0.53	0.46	0.57	**0.78**
Buying Firm's size	6.22	2.14	0.33	0.33	0.22	0.22	0.22	0.22	0.06	0.16	0.05	0.11	0.06
Buying Firm's age	36.21	28.47	0.08	-0.03	-0.01	-0.02	-0.01	-0.04	-0.14	0.03	-0.15	-0.04	0.06
Relationship's age	14.17	12.78	-0.02	-0.03	-0.03	-0.03	-0.04	0.03	-0.04	0.01	-0.10	0.03	-0.03
Supplier's importance	5.35	1.12	0.28	0.29	0.19	0.27	0.33	0.33	0.29	0.32	0.25	0.26	0.44

[**] *All correlations are significant at the 0.01 level (2-tailed).*

[a] *The values along the diagonal are the square root of the AVE values.*

Appendix C
Resilience capabilities by clusters (alternative median-based clusters)

	Fragile SC n=124 (1)	Eagle-eye SC n=22 (2)	Nimble SC n=25 (3)	Durable SC n=120 (4)	F-value (probability)
Panel A					
CM Capability					
Cluster mean	4.83 (2,3,4)	5.86 (1)	5.47 (1,4)	6.28 (1,3)	73.4 (p< 0.001)
SE	0.08	0.13	0.18	0.05	
Warning					
Cluster mean	4.47 (2,3,4)	5.91 (1,3)	5.27 (1,2,4)	6.18 (1,3)	86.8 (p< 0.001)
SE	0.10	0.12	0.15	0.06	
Visibility					
Cluster mean	4.65 (2,4)	5.75 (1,3)	5.00 (2,4)	6.13 (1,3)	53.5 (p< 0.001)
SE	0.09	0.14	0.25	0.07	
Robustness					
Cluster mean	4.44 (2,4)	5.80 (1,3)	4.81 (2,4)	6.02 (1,3)	70.3 (p< 0.001)
SE	0.10	0.12	0.22	0.06	
Adaptability					
Cluster mean	4.68 (2,3,4)	5.48 (1,3,4)	6.05 (1,2)	6.33 (1,2)	86.6 (p< 0.001)
SE	0.10	0.15	0.12	0.04	
Agility					
Cluster mean	4.73 (2,3,4)	5.52 (1,3,4)	6.02 (1,2)	6.18 (1,2)	81.9 (p< 0.001)
SE	0.09	0.11	0.09	0.05	
Flexibility					
Cluster mean	4.70 (3,4)	5.05 (3,4)	5.85 (1,2)	6.22 (1,2)	82.1 (p< 0.001)
SE	0.09	0.15	0.15	0.05	
Recovery					
Cluster mean	4.82 (2,3,4)	5.41 (1,3,4)	6.10 (1,2)	6.28 (1,2)	81.4 (p< 0.001)
SE	0.08	0.16	0.09	0.05	
Panel B					
Operational performance					
Cluster mean	4.51 (3,4)	4.97 (4)	5.29 (1,4)	6.09 (1,2,3)	53.7 (p< 0.001)
SE	0.10	0.23	0.25	0.07	
Supply Chain performance					
Cluster mean	4.68 (3,4)	5.18 (4)	5.63 (1)	6.07 (1,2)	59.2 (p< 0.001)
SE	0.08	0.21	0.19	0.06	
Relational performance					
Cluster mean	5.16 (2,3,4)	5.83 (1)	6.16 (1)	6.20 (1)	44.1 (p< 0.001)
SE	0.08	0.08	0.13	0.05	

***Note**: The numbers in parentheses show the group number(s) that are significantly different at the 0.05 level based on the Scheffe pairwise tests.*

Appendix D
Polynomial Regression Analysis

Independent variables for these polynomial regression equations are proactive resilience [P] and reactive resilience [R]. We scale-centered the proactive and reactive resilience and subsequently tested both linear and curvilinear effects (Edwards and Cable 2009); since proactive and reactive resilience scores do not contain any zero value, scale centering could be considered appropriate (Dalal and Zickar 2012). Subsequently, we calculated the interaction and quadratic terms (P^2, R^2, and PR). The outcome variables (represented by Z in the below equation) are operational performance, supply chain performance, and relational performance. Specifically, we estimated the following polynomial regression equations:

$$Z = \beta_0 + \beta_1 P + \beta_2 R + \beta_3 P^2 + \beta_4 PR + \beta_5 R^2 + Controls + e \qquad (1)$$

We included four control variables in these models. First, older and larger firms are traditionally considered to have higher resources and stability. So, these firms could perform better (Bai, Sheng, and Li 2016; Wagner and Bode 2014). Thus, we control for both the focal firm's age (in years) and firm's size (number of employees) (Ambulkar, Blackhurst, and Grawe 2015; Wagner and Bode 2014). Second, given that the length as well as the importance of a relationship could both have a significant impact on performance, we also control for these. Relationship length was captured using the number of years the firms worked together. The importance of the supplier was captured using two 7-point Likert scale items (Azadegan and Dooley 2010; Poppo, Zhou, and Li 2016).

Appendix E
Response Surface Results

	Effect on Operational performance	Effect on Supply chain performance	Effect on Relational performance
Symmetry line			
Slope ($\beta_1 + \beta_2$)	0.659	0.708	0.496
95% bias-corrected CI	[0.305, 0.915]	[0.325, 1.005]	[0.276, 0.806]
Curvature ($\beta_3 + \beta_4 + \beta_5$)	0.134	0.099	0.069
95% bias-corrected CI	[0.052, 0.247]	[0.002, 0.233]	[-0.028, 0.141]
Asymmetry line			
Slope ($\beta_1 - \beta_2$)	-1.224	-1.105	-0.272
95% bias-corrected CI	[-2.047, -0.582]	[-1.886, -0.431]	[-0.985, 0.484]
Curvature ($\beta_3 - \beta_4 + \beta_5$)	-0.845	-0.016	0.515
95% bias-corrected CI	[-2.309, 0.322]	[-1.397, 0.801]	[-0.245, 1.206]