Necessary Antecedents of Supply Chain Resilience: The Nonnegotiable Influence of Supply Chain Responsiveness and Collaboration

Abstract

According to the social-ecological systems view, a resilient supply chain possesses the ability to persist, adapt, and transform in the face of disruptions. Extant research has identified a range of antecedents that foster supply chain resilience but without distinguishing between those that are sufficient and those that are necessary. While altering sufficient antecedents might affect resilience, their absence does not preclude it because of the potential compensatory effects of other factors. Conversely, necessary antecedents are indispensable, as their absence prevents the realization of resilience, a scenario that cannot be rectified by modifying other antecedents. Grounded in dynamic capabilities theory, this research hypothesized that supply chain visibility, responsiveness, flexibility, and collaboration are necessary antecedents of supply chain resilience. To empirically test this, the research applied Necessary Condition Analysis (NCA) to survey data from 479 manufacturing firms in Australia. The results indicate that only supply chain responsiveness and collaboration are necessary antecedents. A bottleneck analysis was also undertaken to determine how much supply chain collaboration and responsiveness is needed to achieve different levels of supply chain resilience. The research proposes a two-tiered maturity model—Tier 1 (necessary) capabilities versus Tier 2 (contributory) capabilities—for building supply chain resilience and extends dynamic capabilities theory by demonstrating that specific capabilities may be nonnegotiable for enhancing sensing, seizing, and resource reconfiguration capacities. The research provides managerial guidance for determining how limited organizational resources can be most efficiently deployed to handle disruptions.

Keywords: Supply chain resilience; necessary condition analysis; dynamic capabilities; supply chain disruption; supply chain collaboration; supply chain responsiveness

1. Introduction

In today's rapidly evolving business landscape, securing a sustained competitive advantage is paramount for firms. The supply chain can be a key source of this advantage (Prajogo et al., 2021), but disruptions can destabilize supply chains and undermine their contribution to firms' competitive edge (Bode et al., 2011). Over the past two decades, a significant body of research has investigated how the detrimental effects of disruptions can be mitigated. As a result, supply chain resilience has evolved to represent a capability that enables the supply chain to be alert to potential disruptions and to persist or adapt in response to disruptions that materialize (Ambulkar et al., 2015; Tukamuhabwa et al., 2015; Wieland, 2021; Wieland et al., 2023). Despite substantial growth in research on supply chain resilience (Agrawal & Jain, 2021; Han et al., 2020; Stadtfeld & Gruchmann, 2024), recent events have highlighted the shortcomings of academic insights for equipping supply chain managers with the necessary tools to handle disruption (Rahman et al., 2021). For example, the COVID-19 pandemic led to over 94% of Fortune 1000 companies reporting significant disruptions to their global supply chains (Sherman, 2020). Moreover, the Russia–Ukraine conflict exacerbated disruptions induced by the pandemic, hindering global economic recovery (Stackpole, 2022).

Prior research has identified a wide range of antecedents to supply chain resilience whilst making the implicit assumption that each one is independently sufficient for producing resilience (Bokrantz & Dul, 2023; Dul 2025). For example, Nikookar and Yanadori (2022a) suggested that supply chain visibility, responsiveness, and flexibility are antecedents of supply resilience, where each independently contributes to building supply chain resilience. Although altering a so-called sufficient antecedent could affect the level of resilience, its absence does not necessarily lead to a failure to achieve resilience altogether due to the potential compensatory effects of other antecedents (Hauff et al., 2021).

While the insights provided by prior research into sufficient antecedents are immensely valuable, the presence of some antecedents might be absolutely essential for achieving supply chain resilience (Bokrantz & Dul, 2023). Yet, extant research has remained mostly silent about the essential antecedents of supply chain resilience. In contrast to sufficient antecedents, essential antecedents are necessary conditions for achieving an outcome. While the presence of essential antecedents does not guarantee an outcome, their absence does ensure the outcome will not materialize (Bokrantz & Dul, 2023; Goertz, 2003; Hauff et al., 2021). In other words, all essential antecedents must be in place to avoid guaranteed failure in achieving supply chain resilience. For example, if a level of responsiveness is deemed necessary for supply chain resilience, then the supply chain will fail to handle a disruption when responsiveness is absent. Any effort to improve resilience without responsiveness would be wasteful. Therefore, this research advocates a paradigm shift when investigating how to build supply chain resilience – from a sole focus on sufficiency to a broader perspective that includes necessity (Dul, 2016a).

Dynamic capabilities theory (Teece, 2007) is a widely adopted theoretical framework for investigating supply chain resilience (Hendry et al., 2019; Gölgeci & Ponomarov, 2013; Kähkönen et al., 2023; Nikookar & Yanadori, 2022a; Stadtfeld & Gruchmann, 2024; Tukamuhabwa et al., 2015). It is most commonly used to identify capabilities that act as sufficient contributors to higher-order dynamic capabilities, enabling firms to achieve competitive advantage under conditions of uncertainty (Teece, 2007). This, however, does not preclude it from being used to understand why some capabilities may also act as necessary contributors to the development of dynamic capabilities. Prescribed by dynamic capabilities theory, this study argues that supply chain resilience is a higher-order dynamic capability for addressing uncertainties triggered by disruptions. The research hypothesizes that four organizational capabilities—supply chain visibility, responsiveness, flexibility, and collaboration—act as necessary elements of supply chain resilience and uses empirical data to substantiate this claim. The following research question is posed:

RQ: Which antecedents are necessary for building supply chain resilience?

A novel theorization mandates a suitable methodological framework (i.e., theory–method fit; Dul et al., 2023; Linder et al., 2022). Thus, this research deploys the Necessary Condition Analysis (NCA) method (Dul, 2016a) to empirically test the hypotheses using survey data from 479 manufacturing firms in Australia. NCA is uniquely suited to uncovering conditions that act as critical bottlenecks—those that must be present at a certain level for the outcome to materialize at a certain level. In the context of this study, NCA enables the determination of antecedents that function as necessary conditions for achieving supply chain resilience. The absence of these antecedents means resilience cannot occur regardless of the presence or strength of other contributing factors (Dul, 2016a).

Developing theory that elaborates on the necessary conditions for achieving supply chain resilience has the potential to offer substantial contributions. Without addressing necessity, theoretical models fall short of explaining why supply chain resilience is attainable in some instances but elusive in others (Bokrantz & Dul, 2023). While extant research has created an enormous amount of knowledge on how various antecedents probabilistically contribute to resilience outcomes in a supply chain context, there has been only limited investigation into which of these antecedents are necessary conditions. Recent studies have begun to explore the use of NCA in this domain (e.g., Jain et al., 2024; Sun et al., 2025), often in response to calls to identify necessary conditions (e.g., Yin et al., 2024). However, these contributions have typically been exploratory or inductive in nature or been performed as an "ad-hoc" analysis. This research builds on this foundation by theorizing necessity condition relationships based on dynamic capabilities theory and by empirically testing four hypothesized necessary antecedents.

Of the four hypothesized antecedents, only supply chain responsiveness and collaboration are found to be necessary for supply chain resilience. By contrast, visibility and flexibility, though widely emphasized in the literature, do not emerge as necessary antecedents. Although visibility enhances awareness and facilitates the identification of disruptions (Somapa et al., 2018; Tiwari et al., 2024), resilience is fundamentally about persistence, adaptation, and transformation in response to disruption (Wieland et al., 2023). This emphasis on how firms respond (over merely what they are aware of) might explain why visibility is not deemed to be an absolute necessity for resilience. Similarly, while flexibility facilitates adjustments (Sheffi & Rice, 2005), this might be insufficient for responding to the frequent and severe events that characterize today's competitive environment. In other words, more transformative or network-level change (Zinn & Goldsby, 2019) beyond the scope of flexibility is often required, rendering it non-essential for building resilience.

A two-tiered maturity model—Tier 1 (necessary) capabilities versus Tier 2 (contributory) capabilities—is proposed for building supply chain resilience. Valuable insights are also provided into the level of resource mobilization required for these necessary capabilities to achieve different resilience levels. This nuances the novel findings of the research by recognizing that while supply chain responsiveness and collaboration are vital for bolstering supply chain resilience, their necessity depends on the specific resilience thresholds a firm aims to achieve. More generally, the research extends dynamic capabilities theory by demonstrating that specific capabilities may be nonnegotiable for enhancing sensing, seizing, and resource reconfiguration capacities. In a practical sense, this has implications for the strategic allocation of scarce organizational resources.

The remainder of this paper is organized as follows. The next section discusses the theoretical underpinnings of the research, beginning with a thorough discussion of the necessity approach to causality. This is followed by a deep dive into the concept of supply chain resilience and its necessary antecedents through the lens of dynamic capabilities theory. The research method is then outlined, explaining how empirical data were collected and how the NCA approach was applied to the dataset. The results are discussed, followed by the implications for research, practice, and society. Finally, the limitations are acknowledged and future research opportunities are outlined.

2. Theoretical underpinnings

2.1 Necessity approach to causality

This section discusses the concept of necessity causality, a critical complement to the widely adopted sufficiency-based perspective, to establish a robust foundation for the current study. This includes unpacking how necessary conditions differ from probabilistically sufficient conditions and explaining why understanding this distinction is vital to advancing supply chain resilience theory and practice. This discussion foregrounds the subsequent conceptualization of supply chain resilience and its necessary antecedents.

Hume's definition of causality forms the basis of contemporary research on causal relationships within the social sciences (Dul, 2024). That is, "… we may define a cause to be an object, followed by another, and where all the objects, similar to the first, are followed by objects, similar to the second: Or in other words, where, if the first object had not been, the second never had existed" (Hume, 1756, as cited in Dul, 2024). Causality can be conceptualized through three perspectives: deterministic, probabilistic, and typicality-based causality (Dul, 2024). The deterministic perspective asserts that the causal relationship always holds true, whereas the probabilistic perspective implies that the relationship is likely to hold true. Meanwhile, the typicality perspective implies that a causal relationship generally holds but also allows for exceptions. Unlike the probabilistic view, which is grounded in probability distributions, typicality is based on observed patterns and deviations from what is commonly expected (Dul, 2024). Exceptions are characterized by the number of instances that deviate from what is considered typical.

The first part of Hume's definition reflects the notion of *sufficiency* in causality. In its deterministic form, sufficiency causality means that the presence of independent variables leads to the occurrence of the outcome. In contrast, probabilistic sufficiency causality posits that independent variables alter the likelihood of the outcome occurring (Dul, 2024). Even if one of these variables remains unchanged, the outcome may still be altered because of the compensatory influence of other variables (Hauff et al., 2021). Typical sufficiency, by contrast, holds that a combination of factors generally leads to the outcome, but exceptions may occur. Within supply chain research, most empirical studies implicitly rely on probabilistic sufficiency. Brandon-Jones et al. (2014), for example, showed that information sharing and connectivity raise the probability that a firm can absorb and recover from disruption because these capabilities heighten supply chain visibility.

While sufficiency helps explain how a combination of antecedents can cause an outcome—whether consistently (deterministic), generally (typical), or likely (probabilistic)—the second part of Hume's definition draws attention to a complementary, albeit less explored viewpoint on causality: the idea of necessary causality. A necessary condition can be represented as "$\neg X \rightarrow \neg Y$" (if *X* is absent, *Y* cannot occur). Deterministic necessary causality implies that the outcome cannot happen unless the condition is present—its absence always prevents the outcome. Probabilistic necessary causality suggests that the absence of the condition lowers the likelihood of the outcome, although it may still occur in some cases. Typical necessary causality refers to conditions that are generally required for the outcome, with occasional exceptions where the outcome arises even in their absence. Drawing on the resource-based view, Brandon-Jones et al. (2014) noted that visibility-enhancing resources are "necessary but not sufficient" for competitive advantage. This means that higher levels of information sharing, or connectivity, are associated with greater resilience, yet the absence of complementary resources can still preclude superior performance. This underscores the distinction between probabilistic sufficiency and deterministic necessity.

Table 1 provides a comparison of the three perspectives on causality (deterministic, probabilistic, and typicality-based perspective) in relation to both sufficiency and necessity. This research embraces the typicality perspective and treats exceptions as part of the phenomenon (Dul, 2024), thus retaining them for further analysis.

---------------------------------Insert Table 1 Approximately Here-------------------------

Both sufficiency and necessity causality are important to enhancing the discourse on supply chain management. Sufficiency theories can effectively predict outcomes or identify certain variables that might pave the way for an outcome. However, this does not determine whether the presence of the variable is essential for that outcome to occur. This shortcoming is addressed by the necessity causality approach. While necessary variables might not always lead to the expected outcome, their absence can prevent it (Hauff et al., 2021). A combination of the two approaches, discerning both sufficient and necessary variables, is pivotal for holistic theory building in supply chain management (Bokrantz & Dul, 2023). In fact, amalgamating these perspectives is key to a profound grasp of the complexities that exist in developing various outcomes related to supply chains (Bokrantz & Dul, 2023). Although the sufficiency-based perspective, particularly in its probabilistic form, is well established in the supply chain resilience literature, the necessity-based perspective is currently lacking.

Both probabilistic sufficiency and necessity logic enrich theorizing in supply chain management. Probabilistic sufficiency pinpoints variables that raise the likelihood of an outcome, but it cannot show whether those variables are indispensable. Necessity logic closes that gap: a necessary condition may not produce the outcome by itself, but its absence categorically blocks it (Hauff et al., 2021). Integrating the two perspectives—mapping what is sufficient and what is necessary—supports more complete theory building (Bokrantz & Dul, 2023). Empirical work has already used fuzzy-set qualitative comparative analysis (fsQCA) to uncover necessity-in-kind relationships, where a condition simply must be present or absent (Vis & Dul, 2018). By contrast, the literature is almost silent on necessity-in-degree, a perspective advanced by NCA, which specifies *how much* of a condition is required for *how much* of an outcome (Dul, 2016b). Recent research outside the supply chain domain—for example, on digital entrepreneurial ecosystems—has demonstrated the extra insight that degree-type analyses can yield (Torres & Godinho, 2022). Addressing this shortcoming, this research applies NCA to identify degree-type necessary conditions for supply chain resilience.

From a practical perspective, the implications of necessity causality for the supply chain management domain are potentially very significant, offering detailed and impactful insights for managerial decision making. For example, although studies have emphasized that suppliers may be sources of innovation and novel ideas (Roy et al., 2004; Van Echtelt et al., 2008), interorganizational trust is known to be a necessary antecedent for fostering supplier-driven innovation (van der Valk et al., 2016). This idea suggests that while supply chain managers should leverage their suppliers to boost innovation (Van Echtelt et al., 2008), a lack of mutual trust with those suppliers—even in the presence of other contractual governance mechanisms—could hinder the generation of innovative ideas (van der Valk et al., 2016). Consequently, managers should strategically allocate resources and prioritize the nurturing of trust as a foundational requirement for fostering supplier-led innovation.

Understanding the necessary antecedents of supply chain resilience is paramount, although the evidence base remains limited (e.g., Jain et al., 2024; Sun et al., 2025). The following section elaborates on the conceptualization of supply chain resilience as a firm's dynamic capability. Leveraging dynamic capabilities theory, the research hypothesizes four necessary organizational capabilities—supply chain visibility, responsiveness, flexibility, and collaboration—for building supply chain resilience.

2.2 Supply chain resilience

Supply chain resilience has garnered significant attention in recent years following disruptions such as the COVID-19 pandemic, geopolitical conflicts, and natural disasters. The COVID-19 pandemic, for example, caused unprecedented disruptions to global supply chains, affecting production, transportation, and distribution networks. The effects of the pandemic on supply chains were exacerbated by other events, such as trade wars and regional instabilities (Ali et al., 2024), which triggered sudden changes in trade policies, tariffs, and regulations (Roscoe et al., 2022). Although companies that had invested in resilient supply chain practices still experienced disruptions, they were better able to manage them, maintaining operations and fulfilling customer demands more effectively than those that had not (Ivanov & Dolgui, 2021; Queiroz et al., 2022).

Definitions of supply chain resilience have gradually evolved since the inception of this concept. Initially, supply chain resilience was concerned with the ability of a supply chain to return to its original state after a disruption. For example, Jüttner and Maklan (2011) defined it as the ability to return to a state of dynamic equilibrium after being disturbed. Similarly, Wieland and Wallenburg (2013) stressed that supply chain resilience is a supply chain's capability to overcome disruptions and maintain operational continuity. Other definitions have highlighted the potential to transition to a desirable state after being disrupted (Christopher & Peck, 2004). For example, Tang (2006) described supply chain resilience as the capability to cope with unexpected disturbances and recover to an original or improved state. Ponomarov and Holcomb (2009) built on this idea by emphasizing the adaptive capability of a supply chain to prepare for unexpected events, respond to disruptions, and recover while maintaining the continuity of operations. Similarly, Kamalahmadi and Parast (2016) defined the concept as anticipating, resisting, absorbing, responding to, adapting to, and recovering from disruptions in a timely and cost-effective manner.

In recent years, a new understanding of supply chain resilience that builds upon the social-ecological systems perspective has emerged (Adobor & McMullen, 2018; Wieland, 2021; Wieland & Durach, 2021). This interpretation emphasizes adaptation and transformation in response to disruptions. Wieland and Durach (2021) defined social-ecological supply chain resilience as “the capacity of a supply chain to persist, adapt, or transform in the face of change” (p. 316). While persistence is characterized by continued efforts to achieve goals despite obstacles, failures, or opposition, adaptation and transformation signify a more radical change in response to disruptions (Wieland et al., 2023). Adaptation in this context refers to the strategic adjustment of operations and practices to maintain functionality under changing conditions. Transformation involves fundamentally rethinking and redesigning the supply chain’s structure and processes to make them withstand future disruptions.

Collectively, prior definitions involve managing disruptions effectively as they occur and restoring normal operations to pre-disruption or better levels while learning and transforming (Ali et al., 2022; Razak et al., 2024). The breadth of the concept is captured in the work of Ambulkar et al. (2015), who highlighted the importance of alertness to supply chain disruptions and the role of adaptation and rapid transformation in navigating the changes induced by disruption. This definition is widely accepted in the supply chain resilience research community, as evidenced by its high citations, supporting its validity and applicability. The dimensions within Ambulkar et al.'s (2015) definition have also been rigorously validated through empirical research.

Supply chain resilience has increasingly been recognized as a key dynamic capability (Gölgeci & Ponomarov, 2013; Hendry et al., 2019), enabling firms to retain alignment with a changing environment by (i) sensing, or actively remaining alert to emerging opportunities and challenges; (ii) seizing, or developing plans to adapt to these changes; and (iii) reconfiguring, or adjusting the resource base and capabilities to implement plans (Holmqvist, 2004; Teece, 2007). These three capacities of dynamic capabilities align closely with the dimensions of supply chain resilience from Ambulkar et al. (2015), which are alertness, adaptation, and response to disruptions. Therefore, this research draws on Ambulkar et al.'s (2015) definition of supply chain resilience and on dynamic capabilities theory (Teece, 2007).

2.3 Necessary antecedents of supply chain resilience

Dynamic capabilities provide firms with the capacity for alertness and adaptation to environmental changes (Wang & Ahmed, 2007), enabling them to remain competitive when the external environment moves from stability toward dynamism (Teece, 2007). This theory is commonly used to identify sufficient capabilities that contribute to building higher-order dynamic capabilities. However, at its core, the theory also provides a blueprint for identifying capabilities that are necessary for the development of dynamic capabilities themselves. This perspective has received only limited attention in the literature—just like necessity causality itself has been underexplored.

A dynamic capability is developed through three capacities within a firm, i.e., sensing, seizing, and reconfiguring resources (Teece, 2007). These capacities represent foundational qualities that enable a firm to remain aligned with the ever-changing environment. If any of the three capacities is absent, then dynamic capabilities cannot be built. This is because: (i) without sensing, firms fail to detect relevant environmental shifts; (ii) without seizing, they cannot act on these shifts in a timely manner, even if they are identified; and, (iii) without reconfiguration, they cannot adapt their resource base effectively to implement actions and respond to shifts. Thus, these capacities are indispensable foundations for dynamic capabilities. If supply chain resilience is a dynamic capability, then building these three capacities—sensing, seizing, and reconfiguring resources—is necessary for fostering resilience (Kähkönen et al., 2023).

Capacity and capability may appear similar at first glance; however, they are inherently distinctive. Capacity signifies a quality within a firm that can be further honed (Jurie, 2000), whereas capabilities are derived through the strategic bundling of organizational resources (Wang & Ahmed, 2007) aimed at enhancing firm capacities. In other words, capabilities are the mechanisms through which capacities are built and operationalized. This implies that a set of organizational capabilities, which are necessary antecedents for building supply chain resilience, must exist that firms can carefully cultivate to build the sensing, seizing, and reconfiguring resources required for fostering resilience. That is, although their presence does not guarantee it will be achieved, supply chain resilience will not materialize if these capabilities are absent. The next section elaborates on the theoretical justifications for positing that supply chain visibility, responsiveness, flexibility, and collaboration are four necessary capabilities for building the sensing, seizing, and resource reconfiguration capacities required to cultivate supply chain resilience.

It is important to note that several other antecedents of supply chain resilience, such as integration, inventory and capacity buffering, capacity redundancy, structural alterations to supply networks, and lead-time compression have also been suggested in the literature (Jiang et al., 2024; Kim et al., 2015; Nikookar & Yanadori, 2022b; Spiegler et al., 2012). While this study does not dispute the potential necessity role of these antecedents in building supply chain resilience, it does not explore them in detail. Instead, the focus is on four key antecedents—supply chain visibility, responsiveness, flexibility, and collaboration—as these are aligned directly with the principles of the theoretical lens adopted in this research: dynamic capabilities theory. Further investigation into the necessity of other potential antecedents is certainly warranted in the future, but this study is specifically oriented around those that best fit within the chosen theoretical framework.

2.3.1 Supply chain visibility (X) as a necessary antecedent of supply chain resilience (Y)

Supply chain visibility (X) is defined as the degree to which easy access is provided to accurate, timely, complete, and usefully formatted data from internal systems, supply chain partners, and market sources (Somapa et al., 2018). Within globally-dispersed supply chains that face moderate-to-high demand and supply uncertainty—the empirical context and theoretical domain of this research—visibility represents the primary sensing mechanism through which disruptions can be detected. It enhances situational awareness and decision making by providing firms with the critical information needed to identify disruptions, monitor performance, and respond proactively to changing conditions.

Supply chain visibility (X) is posited to be a necessary antecedent of supply chain resilience (Y) because it is necessary for sensing, a core element of dynamic capabilities (Helfat & Peteraf, 2009; Teece, 2007). Sensing involves scanning and monitoring the environment for potential disruptions and opportunities (O'Reilly & Tushman, 2008), thereby enhancing a firm's ability to handle disruptions. Visibility within the supply chain enables the timely collection of accurate data regarding environmental changes (Barratt & Oke, 2007), which is crucial for effective sensing (Helfat & Peteraf, 2015). In highly visible supply chains, actors provide critical information about their operations, allowing firms to detect shifts and anticipate disruptions (Barratt & Oke, 2007). This capacity directly enhances a firm's preparedness for significant disruptions, which is a key aspect of resilience (Wieland & Wallenburg, 2013).

The importance of visibility is further underscored by the role it plays in navigating disruptions. End-to-end supply chain visibility is essential for sensing and staying alert to potential disruptions as it provides the necessary information to respond effectively (Kleindorfer & Saad, 2005). Without enhanced visibility, firms lack the critical tools needed to collect data about their operational status, particularly in relation to potential disruptions (Williams et al., 2013). Firms are often caught off guard when disruptions occur in less visible parts of the supply chain, leading to a loss of resilience (Kurniawan et al., 2017).

A lack of visibility within supply chains, therefore, emerges as a significant impediment to a firm's ability to stay alert and identify disruptions. Guided by Dul's (2025) thought experiment, the question was asked whether a genuinely resilient supply chain (Y) could plausibly exist without visibility (¬X). Rare counter-examples—such as fully vertically integrated chains that substitute hierarchical control for information sharing—might limit the theoretical domain to multi-tier supply chains in which legally independent actors rely on information exchange. Consequently, this study posits that supply chain visibility is a necessary antecedent for constructing supply chain resilience within that domain. Information sharing and data streams must be in place before a disruption unfolds to ensure resilience, hence visibility must pre-exist the shock; installing it *ex-post* cannot retroactively improve resilience.

H1: *Supply chain visibility is a necessary condition for building supply chain resilience in multi-tier and independently structured supply chains*.

2.3.2 Supply chain responsiveness (X) as a necessary antecedent of supply-chain resilience (Y)

Supply chain responsiveness (X) refers to the capability to quickly adapt and take appropriate action in response to changes or disruptions in the supply chain (Randall et al., 2023; Sheffi & Rice, 2005). The necessity claim is bound to firm-level operations in time-sensitive, make-to-order supply networks—the domain sampled here—where delayed response almost invariably magnifies losses. In such a context, supply chain responsiveness is used as an umbrella term that encompasses concepts such as supply chain agility or adaptability (Wieland & Wallenburg, 2012). Supply chain responsiveness enables firms to maintain operational continuity by swiftly addressing challenges, minimizing the impact of disruptions, and ensuring timely recovery in dynamic environments. Supply chain responsiveness is posited to be critical to the development of resilience, as it is a necessary antecedent that cannot be substituted for by other factors. In the framework of dynamic capabilities, seizing represents a firm's ability to act swiftly and effectively upon recognizing opportunities or threats in a volatile environment (Teece, 2007). Without this capacity, a firm may sense opportunities and threats but fail to act quickly enough, thereby losing its ability to maintain or achieve a competitive advantage in a volatile environment. Similarly, by its very nature and as a firm's dynamic capability, supply chain resilience depends on this seizing capacity for responding quickly and navigating the repercussions of disruptions to restore stability (Ambulkar et al., 2015).

In the supply chain context, responsiveness manifests as the ability to adapt rapidly to fluctuations, whether these arise from consumer behavior, competitor actions, or any other environmental changes (Kim & Lee, 2010). Responsiveness involves rapid and efficient decision making in response to emerging threats. Only a responsive supply chain can make nimble reactions to changes, ensuring that favorable outcomes are achieved despite volatile conditions (Gunasekaran et al., 2008). Without responsiveness, a firm may detect disruptions but fail to act in time, thereby undermining its capacity to maintain or regain a competitive edge.

The intertwined, network-like structure of supply chains means disruptions can quickly escalate, exacerbating risks for all parties (Blackhurst et al., 2011). The absence of responsiveness impairs a firm's ability to make quick decisions during a disruption (Gligor et al., 2019), which weakens the seizing capacity that is essential for resilience. Evidence from previous research has demonstrated that a lack of responsiveness cannot be substituted for by other factors. For instance, in a simulation study, responsive supply chains were found to outperform nonresponsive supply chains during disruptive events (Azadeh et al., 2014). Responsiveness to disruption-induced changes can also lead to a sustained competitive advantage under challenging conditions (Carvalho et al., 2012). However, responsive routines, by definition, must be embedded *ex-ante*; once a disruption has occurred, a firm cannot "bolt on" responsiveness and still expect to contain the damage.

As recommended by Dul (2025), a thought experiment was conducted to explore whether genuinely resilient supply chains (Y) can plausibly exist without supply chain responsiveness (¬X). The thought experiment revealed that one rare counterexample would be a highly capital-intensive, fully integrated chain that relies on large strategic inventory buffers rather than rapid decision-making. Another possibility is a monopolistic environment in which customers accept long recovery times. These exceptions indicate that the theoretical domain of supply chain responsiveness as a necessary condition for resilience should be limited to multi-tier and independently structured supply chains that compete in time-sensitive markets and that cannot rely on excessive slack or monopoly power. Within this domain, the absence of responsiveness creates an insurmountable bottleneck for resilience as the supply chain's seizing capacity cannot be realized without it.

Given the fundamental role of supply chain responsiveness in shaping a supply chain's ability to swiftly mitigate risks, this study posits that it is a necessary antecedent for fostering supply chain resilience.

***H2**: Supply chain responsiveness is a necessary condition for building supply chain resilience in multi-tier and independently structured supply chains that compete in time-sensitive markets and cannot rely on excessive slack or monopoly power.*

2.3.3 Supply chain flexibility (X) as a necessary antecedent of supply chain resilience (Y)

Supply chain flexibility represents the capacity to dynamically adjust supply chain processes, structures, or resources to counter disruptions and adapt to shifting conditions (Nikookar & Yanadori, 2022b). It provides firms with the swiftness to reconfigure operations in response to unexpected changes, ensuring continued functionality and competitiveness in volatile environments. As posited by Teece (2007), past successes often compel organizations to amalgamate their resources, fostering a belief in their enduring effectiveness. This can aid firms in sustaining competitive advantages if environmental conditions remain steady (Kraaijenbrink et al., 2010). Previous research has highlighted that supply chain flexibility offers a hedge against the harmful repercussions of disruptions, facilitating supply chain resilience (Fiksel & Croxton, 2010; Pettit et al., 2003; Tang, 2006). In this research, it is argued that supply chain flexibility facilitates resilience by building resource reconfiguration capacity. Therefore, it is further posited that supply chain resilience cannot exist without supply chain flexibility. It is a necessary antecedent that directly affects a supply chain's ability to adapt to and recover from disruptions.

While the ability to reconfigure resources as a disruption unfolds is essential (O'Reilly & Tushman, 2008), the disruption itself can hinder access to the resources required to implement the reconfiguration. Only supply chain flexibility can provide a repertoire of resources that can be reconfigured to offset resource deficits in areas affected by a disruption (Rice & Caniato, 2003). Flexibility ensures that a firm or supply chain can reconfigure its resources by switching suppliers, modifying production processes, or employing alternative distribution methods, which maintain operational continuity in the face of adversity (Brusset & Teller, 2017). For instance, when a transportation network is disrupted, only a flexible supply chain can adapt by reconfiguring its transportation operations, such as by using alternative shipping routes or multimodal transportation systems to minimize the impact of the disruption (Ishfaq, 2012; Kurniawan et al., 2017).

A lack of flexibility can lead to firms having access to a set of resources that can only be used for a single purpose. This diminishes the resource reconfiguration capacity required for supply chain resilience. One could argue that the absence of flexibility may be compensated for by redundancies. Despite differences in terminology, past research has viewed redundancy as a route to creating forms of flexibility (Kristianto et al., 2014; Jüttner & Maklan, 2011). Redundancy involves duplicating resources that firms can reconfigure with other resources to keep the supply chain functioning during a disruption (Nikookar & Yanadori, 2022b). Therefore, redundancy can be seen as a special case of flexibility. It makes the resources needed for flexibility available and accessible to firms (Tukamuhabwa et al., 2015).

In summary, a lack of flexibility can leave a supply chain with a set of rigid resources that cannot be reconfigured. This situation inhibits the ability of the supply chain to adapt to or recover from disruptions effectively, thereby undermining its resilience. Therefore, it is argued that flexibility is not merely sufficient but necessary for resilience. Without it, a supply chain's capacity to withstand and recover from disruption is significantly compromised, making flexibility a critical antecedent that cannot be substituted for by other factors. However, flexibility must already reside in resources like physical assets, IT architecture, or contract terms prior to a disruption; creating flexibility after the fact does not avert immediate service failures.

Following Dul's (2025) thought experiment procedure, it was asked whether genuinely resilient supply chains (Y) can plausibly exist without flexibility (¬X). Two rare counter-scenarios emerged. First, a vertically integrated supply chain operating in a stable, monopoly market may rely on large, permanent redundancy buffers rather than dynamic reconfiguration. Second, highly standardized humanitarian pipelines with pre-positioned inventory and guaranteed donor funding can sometimes weather disruptions through sheer redundancy. These two exceptions suggest the theoretical domain of this research should be limited to *multi-tier and independently structured supply chains* that face disruption and cannot depend solely on excessive slack or monopoly power. Within this domain, the absence of flexibility creates an insurmountable bottleneck to resilience.

***H3**: Supply chain flexibility is a necessary condition for building supply chain resilience in multi-tier and independently structured supply chains that do not have access to excessive slack or monopoly power.*

2.3.4 Supply chain collaboration (X) as a necessary antecedent of supply-chain resilience (Y)

Supply chain collaboration is the final hypothesized necessary antecedent for building supply chain resilience. The theoretical domain is inter-firm networks characterized by high interdependence and low vertical integration, where no single actor can recover alone. In the supply chain management literature, terms such as cooperation, coordination, collaboration, and integration are often used interchangeably and positioned along a continuum (Power, 2005; Wankmüller & Reiner, 2020). However, these concepts represent qualitatively distinct activities. Cooperation refers to the act of supply chain stakeholders working alongside one another to meet individual or mutual objectives (Nolte et al., 2012). Coordination builds on cooperation by formalizing interactions, aligning processes, and synchronizing decisions across organizational boundaries (Wankmüller & Reiner, 2020).

Collaboration, in this context, represents a more advanced and integrative capability. It is defined as the coordinated execution of tasks and joint decision-making among supply chain partners with shared resources, aligned goals and incentives, knowledge exchange, and the implementation of joint governance mechanisms to achieve mutual outcomes (Cao & Zhang, 2011; Dubey et al., 2022; Feizabadi et al., 2019). As such, both cooperation and coordination form the foundations of collaboration, which in turn reflects a higher level of trust, commitment, and strategic alignment (Soosay & Hyland, 2015). Integration, by contrast, is often viewed as an outcome of cooperation, coordination, and collaboration involving the systemic management of information, material, financial, and relational flows across the supply chain (Power, 2005).

In this study, collaboration is posited as a distinct organizational capability that plays a critical role in enhancing the supply chain's ability to absorb and recover from disruptions and thus it contributes to resilience. By fostering trust and synergy, collaboration allows firms to leverage combined strengths and resources, enhancing their ability to navigate disruptions and achieve resilience. While some organizations may independently gather information and make decisions that mobilize resources to build resilience, such self-sufficiency is not a universal trait (Sarkis et al., 2011). The inherently networked structure of supply chains means a certain level of collaboration among supply chain partners is always needed to pool the critical resources and information necessary for responding to disruption (Azadegan & Dooley, 2021; Scholten

& Schilder, 2015). In general, firms must be interconnected with and mutually reliant on one another if they are to adapt to environmental shifts and secure competitive advantages (Pfeffer & Salancik, 1978). This interdependence becomes even more crucial within supply chain contexts; a supply chain embodies a "nexus of interconnected businesses" synchronized to deliver products or services to the final consumer (Lambert et al., 1998, p. 305). In a supply chain context, the information and resources needed to build the sensing, seizing, and resource reconfiguration capacities required to survive disruptions often reside within other members, referred to as *network resources* (Gulati, 1999). Therefore, this study argues that supply chain collaboration is a necessary antecedent of resilience, as it facilitates building sensing, seizing, and resource reconfiguration capacities.

Collaboration in a supply chain context refers to cooperative processes, whereby autonomous businesses work closely together to strategize and implement supply chain operations and achieve shared objectives and mutual benefits (Cao & Zhang, 2011). Collaboration is vital for several reasons. It promotes the exchange of information, which enhances the ability to anticipate and identify disruptions (Nikookar & Yanadori, 2022b). It allows for the sharing of insights and lessons from past disruptions, which improves strategic responses to future challenges (Jüttner & Maklan, 2011; Sheffi, 2001). It also provides access to essential resources during disruptions, which is crucial to a rapid response and recovery (Tukamuhabwa et al., 2015).

Without collaboration, firms may lack the necessary resources or insights needed to respond effectively to disruptions, thereby compromising their resilience. The ability to anticipate, strategize, and swiftly respond to disruptions is significantly enhanced by collaboration, which makes it indispensable for maintaining resilience (Chowdhury &

Quaddus, 2017). Therefore, alongside visibility, responsiveness, and flexibility, collaboration emerges as a critical antecedent of supply chain resilience. However, benefits brought about by collaboration are contingent upon factors like trust or information and resource sharing, which in turn require long-term relationship building; thus, collaboration must be established before a disruption strikes, otherwise partners will lack the relational capital needed to mount a coordinated response.

Following Dul's (2023) thought experiment procedure, it was asked whether genuinely resilient supply chains (Y) can plausibly exist without collaboration (¬X). Two rare counterexamples emerged. First, a vertically integrated firm that owns all upstream and downstream stages may rely on hierarchical control instead of partner collaboration. Second, monopolistic utilities operating under a government mandate may draw on state resources in lieu of network partners. These exceptions signal that the theoretical domain of this research should be limited to supply chains where resources, information and decision rights are distributed across legally independent actors. Within this domain, the absence of collaboration creates an insurmountable bottleneck to resilience because the sensing, seizing, and resource-reconfiguration capacities needed to withstand disruptions are dispersed across partners.

H4*: Supply chain collaboration is a necessary condition for building supply chain resilience in multi-tier and independently structured supply chains.*

Table 2 presents a summary of the hypotheses investigated in this research.

---------------------------------Insert Table 2 Approximately Here-------------------------

3. Research method

3.1 Construct operationalization

The variables included in this study are latent in nature. The authors followed Wieland et al.'s (2017) guidance by using scales established in prior research to operationalize each variable. The adopted scales focus on the focal firm, with each following a seven-point range from 1 (denoting strong disagreement) to 7 (denoting strong agreement), unless specified differently.

The four hypotheses stipulate that the necessary conditions for achieving supply chain resilience encompass supply chain visibility, responsiveness, flexibility, and collaboration. For supply chain resilience, Ambulkar et al.'s (2015) scale was adopted, as it aligns with the definition of resilience used in this research. For supply chain visibility, Williams et al.'s (2013) scale was selected. For supply chain responsiveness, Hallavo's (2015) scale was employed, although its three-item scale is below the minimum number recommended by Hair et al. (2010, p. 598). In line with common discipline practice (e.g., Bühler et al., 2016; Liu et al., 2017), the latter scale was augmented with an item from a closely related scale. Specifically, Bernardes's (2010) six-item supply chain responsiveness scale includes one item emphasizing swiftness of response ("Our supply chain responds quickly to our special requests"). This item was borrowed and added to Hallavo's (2015) items to measure supply chain responsiveness. Kurniawan et al.'s (2017) scale served as the measure of supply chain flexibility.

For supply chain collaboration, two salient scales were identified: the scale from Cai et al. (2016) and that from Richey and Autry (2009). A preliminary assessment revealed potential validity concerns regarding the use of either scale in isolation. The authors identified Cai et al.'s (2016) scale as overly verbose, potentially complicating comprehension for participants (Wieland et al., 2017). Furthermore, Richey and Autry's (2009) scale does not incorporate joint planning and decision making, a facet underscored in subsequent discourse on supply chain resilience (Scholten & Schilder, 2015). To rectify these gaps, the authors adapted Richey and Autry's (2009) scale by infusing an item from Cai et al. (2016): "We have joint decision-making activities with our supplier." A complete list of the scales used in this research is provided in Appendix 1.

3.2 Development of the survey instrument

The scale items were consolidated to construct the primary research instrument. Prior to data collection, the survey instrument was reviewed by a group of subject matter experts to ascertain item comprehensibility and precision. The review panel consisted of six academic researchers and three industry practitioners based in Australia, all with backgrounds in supply chain management. Feedback from this group was collected in 2019 and then integrated into the survey design. For example, one recommendation was that the survey should include a brief definition of terms such as "supply chain," "supplier," and "disruption." The survey instrument was improved in terms of its clarity and relevance to potential respondents by incorporating the subject matter experts' recommendations.

3.3 Research context

This research focuses on the manufacturing sector as its empirical context. This sector significantly influences the global economic landscape; however, increasing pressure on profit margins has driven manufacturing sector firms to adopt lean and agile strategies that reduce costs through process enhancements and waste minimization (Christopher & Towill, 2001). Although these strategies help manufacturers improve profitability, they may also increase the vulnerability of supply chains to disruptions.

According to the National Association of Manufacturers (2020), COVID-19 had a severe impact on 78% of manufacturing firms, which is a much higher effect than on many other industries. Additionally, prolonged border closures and heavy reliance on imported materials led to significant disruptions for 65% of Australian manufacturing firms during the 2020–2021 period (Parliament of Australia, 2022). Given the frequent nature of disruption and the associated high costs, manufacturing firms need to prioritize their ability to manage threats to supply chain performance (Carvalho et al., 2012). Strengthening supply chain resilience is especially critical as a manufacturer's success relies on the uninterrupted flow of materials through its supply chain (Sheffi & Rice, 2005).

3.4 Data collection

Australian manufacturing firms were targeted for data collection because of the importance of supply chain resilience within manufacturing. A commercial database was used to identify these firms and ensure that their operations corresponded with one of the 12 sectors in the manufacturing division, as defined by the Australian and New Zealand Standard Industrial Classification. Table 3 summarizes the profiles of the participating firms.

---------------------------------Insert Table 3 Approximately Here-------------------------

Supply chain executives from these firms were invited to participate in the survey, and Dillman et al.'s (2014) methods were employed to improve the response rate. Each potential participant received a unique survey link through an introductory email highlighting the study's objectives, its potential benefits to the manufacturing sector, the survey deadline, confidentiality assurances, and the option to decline participation. Incentives were also provided. Participants who completed the survey could opt to enter a draw for one of five AUD200 gift cards. Supply chain managers from 5,400 manufacturing firms received the primary invitation email, followed by two reminder emails dispatched in two-week intervals in 2019. This process yielded 595 valid responses (11.07 % response rate), a figure comparable with Ambulkar et al. (2015), Braunscheidel and Suresh (2009), and Bode and Macdonald (2017), who reported response rates of 11.04 %, 7.4 %, and 11.71 %, respectively. Although a formal *a-priori* power analysis was not undertaken, Dul's (2023) NCA guidelines were followed, which indicate that samples exceeding roughly 200 cases are usually sufficient to detect medium-sized necessity effects. By maximizing participation, the study secured 595 observations—comfortably above this threshold—providing adequate sensitivity for the intended tests.

Previous studies have raised concerns about the limitations of a single-respondent survey approach, as employed in this research, advocating for the inclusion of multiple respondents (Craighead et al., 2011). However, attempting to secure additional respondents in this context could be counterproductive. First, surveys involving multiple respondents often yield lower response rates than single-respondent surveys (Krause et al., 2018), which increases the risk of nonresponse bias and may compromise sample representativeness. Second, if the use of multiple respondents is suggested as a strategy for data triangulation, this approach is only effective when multiple data collection methods are employed to counterbalance the weaknesses of each individual method with the strengths of another (Jick, 1979). Third, even if data from additional respondents were successfully collected, the challenge of aggregating it could still raise concerns about the validity of the findings. There is no established method for aggregating perceptual data in the context of this research.

In addition, Krause et al. (2018) emphasized that “having multiple respondents is less important than selecting the right respondent—that is, the key informant” (p. 45). In survey research, a key informant is an individual who possesses in-depth knowledge of the phenomenon under study, has recent firsthand experience in the relevant area, and is both willing and able to provide the relevant information. Moreover, the choice between using a single key informant and using multiple informants should be guided by the research design. According to Krause et al. (2018), if the research question requires a single cognitive perspective and the required data can be provided accurately and without bias by one knowledgeable source, then relying on a single key informant is adequate. Within the context of the present study, supply chain executives fit the criteria, as they are the primary decision makers concerning their firms’ strategies for managing supply chain disruptions (Nikookar & Yanadori, 2022a). They are well positioned to provide objective insights that directly address the research question. Consequently, the potential risk associated with relying on a single key informant in this study is considered minimal.

3.5 Preliminary scale verification

Given the integration and modification of certain items in this study, it was important to ensure that the scales still measured the intended constructs. Related to this, Conway and Huffcutt (2003) and Heggestad et al. (2019) advised conducting an exploratory factor analysis (EFA). Therefore, EFA was performed on a random sample of 100 responses. These responses were later discarded from the analysis, resulting in a final sample of 495 responses.

Preliminary measures should be taken before conducting an EFA (Churchill, 1979; Hair et al., 2010). Specifically, Churchill (1979) endorsed a pre-EFA *scale purification* step. As detailed by Wieland et al. (2017), this process involves omitting items exhibiting weak correlations within multi-item scales. The purpose is to prevent EFA from generating any theoretically inconsistent dimensions (Churchill, 1979). For the purification process, the corrected item–total correlation (CITC) was calculated for each scale before items with low CICT values were removed (Dunn et al., 1994). A retention criterion of 0.50, as proposed by Koufteros et al. (1998), was employed. Consequently, two of the 23 items (across the five scales) were discarded, leaving 21 items for further evaluation.

Subsequently, EFA, using principal component factoring with Varimax (Kaiser Normalization) rotation to enable correlated factors (Reio & Shuck, 2015), was conducted on the 21 items. Consistent with the theoretical presumption, the EFA recommended five inherent factors. Further examination of the factor loadings using an item loading benchmark of 0.55 (Hair et al., 2010) did not result in the exclusion of any further items. Appendix 1 reports the factor loadings.

3.6 Reliability and validity

Although preliminary scale verification assisted in scale validation, further investigation into construct scale reliability was required to improve the rigor of the research. The reliability of the scales was evaluated using composite reliability (CR) and average variance extracted (AVE) measures. Taken together, the results indicate that the scales are reliable (see Appendix 1). All congeneric reliability scores ranged from 0.76 to 0.86, supporting acceptable reliability (CR score ≥ 0.70; Garver & Mentzer, 1999). Finally, all but one AVE values (*Supply Chain Visibility* = 0.49) fell within the acceptable bounds (AVE ≥ 0.50) recommended by Bagozzi et al. (1991). Although the AVE score for *Supply Chain Visibility* was marginally below the threshold, when the results of the other reliability test (i.e., CR) were considered, it was concluded that this scale was also sufficiently reliable.

Further investigations of construct validity were conducted by assessing unidimensionality, convergent validity, and discriminant validity (O'Leary-Kelly & Vokurka, 1998). Confirmatory factor analysis (CFA) is widely recognized as a robust tool for establishing clear conclusions on these aspects of validity. In this study, CFA was performed on the items that were finalized by the scale verification phase. The item-to-factor loadings in the CFA were all well above the threshold of 0.50, as recommended by Dunn et al. (1994). Additionally, the model demonstrated an adequate fit, with $\chi 2$ = 355.102 (df = 170), CFI = 0.95, TLI = 0.94, SRMR = 0.052, and RMSEA = 0.045. These item loadings—all exceeding 0.50, along with acceptable model fit indices—provide strong evidence supporting the assumption of unidimensionality. The unidimensionality of constructs, along with their statistically significant factor loadings, provides support for convergent validity (Anderson et al., 1991; Dunn et al., 1994). Lastly, the CFA results were carefully examined for potential cross-loadings as per Bollen (1989) and Hair et al. (2010). The absence of noticeable cross-loadings suggests that discriminant validity is well supported.

3.7 Testing for nonresponse bias and common method variance bias

The potential impact of nonresponse bias was investigated to ensure the validity of the results by comparing early and late respondents. According to Lambert and Harrington (1990), nonresponse bias is unlikely if no significant differences exist between early and late responses. An independent samples t-test was performed to compare the mean values of the first 30 and last 30 responses across all variables. The absence of statistically significant differences between these groups suggests that nonresponse bias is not a concern, supporting the validity of the research findings (Malhotra & Grover, 1998).

Given that both dependent and independent variables were measured simultaneously through a single method and collected from a single respondent, there is a risk of common method variance (CMV). Several *a-priori* strategies were implemented to mitigate this risk. A panel of subject matter experts from academia and industry reviewed the survey items before data collection. This process ensured clarity in item formulation, the avoidance of double-barreled questions, and the omission of potentially ambiguous terms. The survey was also administered anonymously, further reducing the likelihood of CMV.

Despite these precautions, perceptual scales may still be vulnerable to respondent biases, such as mood, social desirability, or the liking of the target (Spector et al., 2019). As recommended by Lindell and Whitney (2001), the correlational ideal marker technique was employed to assess the impact of potential CMV. This technique helps rule out CMV if partialling out the smallest positive correlation corresponding to the ideal marker variable does not render previously significant correlations nonsignificant (Richardson et al., 2009). An appropriate ideal marker variable should be subject to the same causes of CMV but theoretically unrelated to the variables of interest (Simmering et al., 2015; Spector et al., 2019). On the basis of Williams and McGonagle's (2016) recommendation, community satisfaction was selected as the ideal marker variable for the research. Community satisfaction was measured using a single-item scale from Theodori (2001). The correlation between community satisfaction and resilience had the smallest positive value (r = 0.002). Notably, none of the significant correlations became nonsignificant after partialling out this value, indicating that CMV does not pose a serious threat to the validity of this research (Lindell & Whitney, 2001).

3.8 Hypothesis testing

The four hypotheses posit that supply chain visibility, responsiveness, flexibility, and collaboration are necessary—in degree—for achieving supply chain resilience. The NCA framework was adopted to test necessity-in-degree relations as it is specifically designed for this purpose (Vis & Dul, 2018). One of the distinctive features of NCA is that it is not reliant on overarching causal structures, enabling it to operate even when a causal model is not fully specified (Dul, 2019). By contrast, misspecifications in causal models, such as omitting important variables or including irrelevant ones, can introduce errors or biases into regression-based methods (Rönkkö & Evermann, 2013). The independence of NCA from the underlying causal structure permits the evaluation of individual variables; this facilitates the creation of necessity theories, even with less complete models (Dul, 2016b). Its adaptability extends further by accommodating various types of variables, from dichotomous to multilevel or even continuous variables (Dul, 2016b), making it a suitable method for empirically testing the four hypotheses.

Necessary condition analysis begins by visually examining bivariate scatterplots and comparing each theorized necessary predictor against the desired outcome (Dul, 2025). Often, these scatterplots exhibit patterns that suggest a necessary relationship between predictors and outcomes; these patterns are highlighted by a distinct triangular no-data area known as the *ceiling zone* on the bivariate scatterplot (Goertz et al., 2013). A preliminary visual inspection of scatterplots that map supply chain visibility, responsiveness, flexibility, and collaboration against supply chain resilience revealed a potential necessary relationship between each predictor and supply chain resilience (see Figure 1).

--------------------------------Insert Figure 1 Approximately Here-------------------------

While the presence of empty space in the scatterplot indicates that a necessary relationship may exist, Dul (2023) suggested that a nuanced examination is needed. This involves establishing the ceiling line—a boundary on scatterplots that distinguishes populated areas from the ceiling zone—and subsequently computing the effect size to quantify the size of the no-data zone relative to the scope (Dul, 2016a). Here, the scope represents the potential data region determined by the predictor and the outcome's minimum and maximum values.

In NCA, the delineation of precise ceiling lines is paramount. Two primary methods are used to establish these lines. The first involves the envelopment of upper-left observations using a piecewise linear convex line (abbreviated as CE-FDH). The second method employs a regression trend line that cuts through the upper-left data points (known as the CR-FDH; Dul, 2025). Dul (2016a) advised using the CE-FDH line for discrete datasets and the CR-FDH line for continuous datasets. In this research, CR-FDH lines were used, as the data were sourced from average responses on seven-point Likert scales evaluated on a continuous scale. The CR-FDH lines are shown as orange lines in Figure 1.

The goal of NCA is to identify the necessary relationships quantified through the effect size. The larger the effect size, the stronger the necessary relationship (Dul et al., 2023). Dul et al. (2020) suggested using the approximate permutation test to calculate *p* values and confirm the statistical significance of effect sizes. For this research, the "nca_analysis" estimator from the NCA package (Version 4.0.1) in R was used to compute effect sizes, corresponding *p* values, and the accuracy levels of ceiling parameters (Table 4). In accordance with Meyer et al.'s (2017) guidance, exact *p*-values are reported. Parameter accuracy, in this context, pertains to how well the estimated parameters (e.g., the ceiling line) match or fit the observed data points in the scatterplot. High accuracy percentages signify that the estimated effect size closely aligns with the observed data (Dul, 2025).

4. Results

The analysis initially revealed that both supply chain responsiveness and collaboration have significant effect sizes, with values of 0.184 and 0.174, respectively. A robustness check was conducted following Dul's (2023) recommendations by repeating the analysis using CE-FDH ceiling lines and excluding identified outliers. No change was observed in the significance of the two previously non-significant necessary conditions—supply chain visibility and flexibility—when the ceiling line specification was changed from CR-FDH to CE-FDH. The effect size for supply chain responsiveness remained significant, whereas the effect size for supply chain collaboration dropped below the threshold for significance under the CE-FDH configuration. The latter result for collaboration can be attributed to a misalignment between the nature of the data and the alternative ceiling line (Dul, 2016a). Nevertheless, the result for collaboration is cautiously interpreted and, in line with Dul (2024), the research embraces the typicality approach to necessary causality between supply chain collaboration and supply chain resilience. That is, supply chain collaboration generally acts as a necessary antecedent of supply chain resilience, with certain exceptions.

The procedure recommended by Dul (2025) was followed to address outliers, resulting in the removal of 16 outliers. An examination of the sampling procedures confirmed all of these cases were within the study’s theoretical domain, and reliability checks on the item scores revealed no measurement error; hence they were classified as *outliers for unknown reasons*. These cases were excluded to maintain consistency with the typicality perspective on causal necessity (Dul, 2024). There was a notable inflation in the effect sizes when the analysis was rerun without these outliers. Specifically, the effect size for responsiveness increased from an initial value of 0.184 to 0.297, while the effect size for supply chain collaboration improved from 0.174 to 0.190. These stronger effect sizes further underscore the roles of responsiveness and collaboration as necessary antecedents of supply chain resilience.

Dul’s (2016a) guidelines for effect size interpretation suggest that values in the range of $0<d<0.1$ are “small”, $0.1<d<0.3$ are “medium”, $0.3<d<0.5$ are “large”, and $d>0.5$ are “very large”. Consistent with Dul (2025), $d \geq 0.10$ was adopted as the minimum practically relevant threshold, and $p < 0.05$ from NCA’s 10,000-replicate permutation test was treated as the criterion for statistical significance. The effect sizes for supply-chain responsiveness ($d = 0.297$, $p = 0.000$) and collaboration ($d = 0.174$, $p = 0.000$) met both thresholds and are therefore interpreted as *medium* and substantively necessary, supporting H2 and H4. In contrast, the effect sizes for supply chain visibility and flexibility fell below the threshold, thus, H1 and H3 are deemed not supported.

---------------------------------Insert Table 4 Approximately Here-------------------------

4.1 Bottleneck analysis

A bottleneck analysis is recommended as part of NCA (Bokhorst et al., 2022; van der Valk et al., 2016) to identify the precise thresholds required for necessary conditions to achieve the desired level of an outcome. However, such an analysis should only be conducted after confirming that a condition qualifies as necessary-in-kind (Dul, 2025).

This judgment is based on three criteria: (1) theoretical support, (2) a practically relevant effect size (d > 0.1), and (3) a statistically significant result ($p < 0.05$) (Dul, 2025). In this study, both supply chain responsiveness and collaboration met these requirements. Strong theoretical justification was provided in Section 2, the recalculated effect sizes—computed using the CR-FDH ceiling line on the dataset with outliers omitted—exceeded the practical threshold, and the associated *p*-values were statistically significant. Visual inspections of the scatterplots also revealed triangular ceiling zones, further suggesting a necessary relationship. Based on this convergence of evidence, supply chain responsiveness and collaboration were judged to be necessary in kind, and a bottleneck analysis was subsequently conducted to explore their necessity in degree.

The bottleneck analysis identifies the precise thresholds necessary for both supply chain responsiveness and collaboration to attain the projected degree of supply chain resilience. Bottleneck analysis is particularly insightful when multiple conditions are being considered simultaneously, offering a concise overview of the requisite levels of each condition (Bokrantz & Dul, 2023). By applying this method, previous studies have, for instance, highlighted the required levels of factors such as communication and leadership support in fostering lean practices (Knol et al., 2018), as well as the criticality of contracts and trust in supplier relationships (van der Valk et al., 2016).

Table 5, the *bottleneck table* (Dul, 2016a), specifies the threshold levels of the two necessary conditions (supply chain responsiveness and supply chain collaboration) that are independently required to achieve a specific desired level of supply chain resilience. The table maps the presence of supply chain responsiveness and supply chain collaboration against the presence of supply chain resilience, as inferred from the CR-FDH ceiling line functions depicted in Figure 1. For each level of supply chain resilience, ceiling line functions yield a threshold level at which supply chain responsiveness and collaboration become crucial.

The first column of Table 5 indicates the *percentage-of-range* level of supply chain resilience, and the subsequent columns each measure supply chain responsiveness and collaboration, also expressed as percentages of their respective ranges. Using the percentage-of-range normalizes each construct to its empirically observed span (max – min), ensuring comparability across variables that share a 1–7 Likert scale origin but that may exhibit different variances or distribution shapes. Note that the actual values of all three variables were measured on a 1–7 scale, as discussed in the Method section. For the bottleneck analysis, the items employed to operationalize the three constructs were used to interpret the percentage values. From a practical standpoint, this normalized format allows managers to set clear performance targets (e.g., “achieve at least 60% of the full capability range”) and facilitates benchmarking across different organizations or contexts.

Capabilities do not develop fully at once; rather, they accumulate progressively over time (Arikan & McGahan, 2010; Winter, 2003). For example, consider a hypothetical fashion firm that maintains stable operations by producing and selling the same product at a constant scale to the same customer segment. The capabilities sustaining this equilibrium are what Winter (2003) termed zero-level capabilities, i.e., those used to “earn a living now”. In contrast, firms like Zara have systematically advanced their supply chain responsiveness, enabling them to explore new market opportunities, adapt to shifting demand, and reduce lead times. Variation in capability development stems from differences in experience, resources, technology adoption, and management expertise. To provide practical insight, this research defines three capability-maturity zones—“low”

(0–30%), “moderate” (31–60%), and “high” (61–100%)—to illustrate the progression of supply chain resilience and its necessary antecedents. This three-tiered segmentation helps managers benchmark progress and set tangible goals (e.g., “elevate resilience into the advanced phase by reaching ≥60% of the range”). It also acknowledges that not all firms require the same capability level: those in stable environments may operate effectively within lower bands, while firms in volatile contexts must push towards higher capability levels to ensure continuity.

For resilience, scores from 0% to 30% indicate low resilience, where supply chains encounter substantial operational challenges in coping with disruptions, adapting flexibly, responding promptly, and maintaining awareness. Scores from 31% to 60% suggest moderate resilience, where supply chains handle disruptions with some effectiveness but exhibit areas needing further improvement in adaptability and responsiveness. Finally, scores from 61% to 100% denote high resilience, where supply chains effectively manage disruption-triggered changes and maintain optimal functionality.

Second, responsiveness levels are defined as follows. Scores from 0% to 30% indicate almost no responsiveness, with supply chains being typically slow in addressing needs and unable to reduce lead times, respond to stockouts, or accommodate special requests. Scores from 31% to 60% reflect moderate responsiveness, where supply chains manage fluctuations somewhat effectively but display notable deficiencies in managing stockouts and optimizing lead times. These levels suggest potential enhancements to improve responsiveness to market changes and special requests. Finally, supply chains scoring from 61% to 100% exhibit high responsiveness, characterized by their efficiency in addressing supply and demand shifts, managing lead times, and responding promptly to special requests, thus reducing stockouts and markdowns.

Third, collaboration levels are defined as follows. Scores from 0% to 30% represent minimal collaboration, where supply chains struggle with exercising joint decision making, sharing proprietary information, and working toward common goals, resulting in disjointed operations and missed synergy opportunities. This indicates a substantial need for strategies to strengthen partnerships and cooperative practices. Scores from 31% to 60% indicate moderate collaboration, where supply chains engage in some joint planning and information sharing, but the effectiveness of these efforts is inconsistent. Despite some established practices, gaps in mutual trust and shared strategic goals hinder the full potential of collaboration. This suggests that improvements are needed, particularly in enhancing communication and integrating collaborative practices across the supply chain. Finally, scores from 61% to 100% demonstrate high collaboration, where supply chains excel in maintaining robust partnerships, characterized by frequent joint decision making, proprietary information sharing, and the collective pursuit of new opportunities. “NN” in Table 5 denotes that a condition is “not necessary” at that resilience level.

---------------------------------Insert Table 5 Approximately Here-------------------------

Table 5 reveals that neither condition (i.e., neither supply chain responsiveness nor supply chain collaboration) is necessary to achieve a low level of supply chain resilience (up to 30%). However, when firms target moderate resilience (above 30%), a baseline level of responsiveness becomes necessary. Interestingly, the highest resilience levels are achievable with only a moderate level of responsiveness, indicating diminishing returns beyond the 60% threshold. If the required level indicated in Table 5 remains unattained, the condition may serve as a bottleneck to achieving supply chain resilience.

For collaboration, the requirement levels follow an interesting pattern that differs from that of responsiveness. Unlike the case of responsiveness, firms seeking a moderate level of resilience need only achieve a small level of supply chain collaboration; however, this changes if a high level of resilience is required. For low resilience, there is no need for collaboration, but this reverses for high resilience. In fact, a firm may need high collaboration to achieve high resilience. If the required level of collaboration is not achieved, this condition may serve as another bottleneck for achieving supply chain resilience. Although the level of collaboration required is lower than the level of responsiveness needed to exceed 50% resilience, the analysis demonstrates that some collaboration with supply chain partners is still necessary to achieve high resilience. It is noteworthy that while prescribed levels of supply chain responsiveness and collaboration are deemed necessary for achieving certain levels of resilience, their presence does not guarantee the realization of resilience.

5. Discussion and contributions

Extant research has acknowledged various capabilities as being antecedents of supply chain resilience (e.g., Ali & Gölgeci, 2019; Kamalahmadi & Parast, 2016). This research has delved deeper into this topic by empirically affirming that supply chain responsiveness and collaboration are necessary conditions for achieving supply chain resilience. While the mere presence of these capabilities does not guarantee supply chain resilience, their absence unequivocally prevents supply chain resilience, even when other antecedents suggested in the literature are present. This novel contribution expands understanding of resilience-building in supply chains and highlights the indispensable nature of these two capabilities in the face of disruption.

Supply chain disruptions vary in terms of severity and the pace at which they spread through the supply chain, requiring different levels of resilience (Lu et al., 2024; Nikookar & Yanadori, 2022a). This research has identified the levels of collaboration and responsiveness needed to achieve different degrees of supply chain resilience. For firms operating in stable environments, where disruptions are infrequent or minor, targeting a low level of resilience may suffice. This will enable resources to be allocated to other priorities unless collaboration and responsiveness provide additional benefits. However, where the environment shifts towards being more volatile (i.e., with more frequent and severe disruptions), a stronger commitment to these capabilities becomes essential. Interestingly, the findings revealed a critical distinction. While responsiveness is consistently necessary across all unstable environments, significant investments in collaborative relationships are only warranted when extreme volatility requires a very high level of resilience.

Responsiveness is essential for rapidly reacting to sudden disruption, but the importance of collaboration becomes especially pronounced in severe disruption scenarios that demand access to external resources beyond the affected firm's boundaries. These resources, often unavailable internally, can only be secured through collaborative partnerships. For instance, during the COVID-19 pandemic, many resilient supply chains relied on collaboration to mitigate disruptions; they sourced resources and aligned their operations across networks to manage the impact of widespread lockdowns. By fostering resource- and information-sharing, joint planning, and alignment, collaboration addresses informational blind spots and resource scarcity challenges that would otherwise undermine resilience.

In contrast to supply chain responsiveness and collaboration, supply chain visibility and flexibility did not emerge as necessary antecedents of resilience, challenging prevailing assumptions in extant literature. Before interpreting this null result substantively, two methodological explanations suggested by Necessity Theory (Dul, 2025) should be considered. First, the survey used to collect data for this research likely admitted a small number of *out-of-domain* cases—for instance, fully vertically-integrated or monopoly firms for which hierarchical control or large redundancy buffers substitute for inter-organizational visibility and flexibility. Such cases occupy the "empty space", yielding observations with high resilience despite low scores on the focal antecedent and thereby diluting the necessity signal. Second, both constructs were measured with single-informant, perceptual items that are susceptible to random and common-method error; even a handful of misclassified responses can obscure deterministic necessity relationships. Future research can mitigate these risks by restricting the sampling frame to multi-tier networks and triangulating survey data with archival indicators (e.g., enterprise resource planning (ERP) system trace logs for visibility or supplier-switch lead times for flexibility).

On a theoretical note, visibility is often lauded for providing timely, accurate, and structured information, enabling the proactive identification of disruptions (Somapa et al., 2018; Tiwari et al., 2024). However, the findings of this research suggest that visibility serves more as an enabler than a necessary condition. While visibility helps identify disruptions, resilience is fundamentally about the actions taken in response to their consequences through persistence, adaptation, and transformation (Wieland et al., 2023). For example, while widespread lockdowns during the COVID-19 pandemic to confine the spread of the virus caused massive disruptions, resilient supply chains focused less on understanding the origins of the lockdowns and more on mitigating their operational impact and on adjusting to lockdown-induced challenges. It is likely that their strategies for responding would have been the same regardless of what had caused the lockdowns. This finding highlights that although visibility aids situational awareness and helps to understand the root causes of a disruption, it is not essential for achieving resilience. Rather, remaining resilient depends on the practical actions taken to persist, adapt, or transform in the face of the disruption.

Similarly, flexibility falls short of being a necessary antecedent. Flexibility is often associated with the ability to adjust processes or resources in response to disruptions (Sheffi & Rice, 2005) as it allows firms to reconfigure resources and offset the loss of resources triggered by a disruption (Jüttner & Maklan, 2011). Firms possessing flexible supply chains can produce in-house or outsource, switch to other suppliers, change distribution modes, or relocate facilities to adapt to and recover from disruptions (Brusset & Teller, 2017). However, as the disruption landscape evolves to include more frequent and severe events such as extreme weather events, geopolitical tensions, and cyberattacks (Pournader et al., 2020), simple adjustments enabled by flexibility may no longer suffice. Extreme disruptions often render existing strategies obsolete (Nikookar et al., 2024), requiring transformative changes, such as network redesigns or the creation of new operational models (Zinn & Goldsby, 2019). While flexibility can facilitate these adjustments, achieving resilience in such scenarios often demands going beyond the scope of existing flexible resources. Therefore, flexibility becomes a facilitator rather than an absolute necessity.

5.1 Research implications

This research has contributed to the evolving theory of dynamic capabilities and to understanding how resilience can be built against supply chain disruptions (Stadtfeld & Gruchmann, 2024). It sheds light on two critical capabilities for sensing, seizing, and reconfiguring within a supply chain, thereby improving its resilience.

After decades of relative stability, firms have now entered an era marked by heightened turbulence (Ali et al., 2017). This increase in both volatility and associated levels of uncertainty threatens firms' competitive advantages (Pu et al., 2023). According to dynamic capabilities theory, firms can mitigate the impact of environmental uncertainty by developing capabilities that enhance their ability to sense, seize, and reconfigure resources (Teece, 2007). These capabilities enable them to adapt their operations in response to environmental shifts, thus preserving their competitive edge. While dynamic capabilities theory has the potential to shed light on the necessary building blocks of higher-order dynamic capabilities, prior research has largely applied dynamic capabilities theory as a sufficiency lens to identify capabilities that act as sufficient contributors to these dynamic capabilities (e.g., Nikookar & Yanadori, 2022). This research extends dynamic capabilities theory by demonstrating its predictive power for specifying capabilities that may be nonnegotiable for enhancing sensing, seizing, and reconfiguring capacities. Identifying these capabilities in a supply chain context provides new insights into how firms can leverage dynamic capabilities to thrive in increasingly volatile environments.

Previous scholarship has identified a long list of organizational capabilities, among which supply chain visibility, responsiveness, flexibility, and collaboration have been widely discussed as antecedents of supply chain resilience (e.g., Nikookar &

Yanadori, 2022a; Scholten & Schilder, 2015). This literature, however, has remained fragmented, with studies testing these antecedents simultaneously and confirming that they might be probabilistically sufficient for building resilience. The present research extends theory and research on supply chain resilience management by distinguishing which of the four antecedents are truly essential for supply chain resilience versus those that are contributory but substitutable. This systematic comparison reveals that supply chain responsiveness and collaboration are not only probabilistically sufficient, but also typically necessary antecedents for building supply chain resilience—without them, resilience cannot emerge regardless of investments in other capabilities. Additionally, the current research provides evidence in support of the assertion that visibility and flexibility, though sufficient, are not necessary in kind—firms can achieve resilience without them. Identifying the necessary antecedents addresses one of the main shortcomings of extant theoretical and empirical research on supply chain resilience – the lack of insight into nonnegotiable factors for achieving resilience. The message is clear: a lack of collaboration or responsiveness significantly impedes firms' ability to cultivate supply chain resilience, even if there are significant resource investments in some of the other antecedents of supply chain resilience (e.g., Ali & Gölgeci, 2019; Kamalahmadi & Parast, 2016).

The research further contributes to the supply chain resilience literature by systematically scrutinizing the necessary antecedents of supply chain resilience and providing valuable insights into the exact level of resource mobilization required for these capabilities to achieve different resilience levels. These findings challenge the one-size-fits-all recommendations prevalent in the literature, offering a tailored approach to building resilience in supply chains. A two-tiered maturity model—Tier 1 (necessary) capabilities versus Tier 2 (contributory) capabilities— is therefore proposed, offering a revolutionary view for building resilience that is tailored to specific objectives.

From a methodological standpoint, this research accentuates the pivotal role of the necessity perspective in establishing causality and highlights the utility of NCA (Dul, 2019) for advancing the supply chain management domain. While Bokrantz and Dul (2023) pioneered the initial framework for deploying NCA, this research offers an in-depth exposition of how this approach can be tailored to a distinct research topic. The study expands on Bokrantz and Dul's (2023) approach by integrating it with insights from other seminal contributions (Dul, 2019; Goertz et al., 2013). Consequently, this research enriches the existing discourse on necessity causality by demonstrating how the approach can be used to develop novel theoretical contributions to the supply chain management literature, particularly in the field of supply chain resilience.

5.2 Managerial implications

The findings of this research can guide managers in making strategic decisions about how limited organizational resources can be efficiently deployed to enhance supply chain resilience. While augmenting visibility and flexibility within the supply chain is important, this study suggests that if managers find themselves in a situation in which choices need to be made regarding which capabilities to prioritize, then building collaborative relationships with supply chain partners and elevating the responsiveness of the supply chain are good courses of action. Regarding collaboration, extant research underscores the pivotal role of blockchain technology and smart contracts for fostering collaboration within supply chains (Agrawal et al., 2023). Research also suggests the pivotal role of strategic supply chain partnerships and postponement strategies in building supply chain responsiveness (Qrunfleh & Tarafdar, 2013). Firms concerned about the substantial costs involved in adopting new technologies, enhancing supply chain partnerships, or implementing a postponement strategy may now be convinced to invest, knowing that these could enhance their supply chain resilience.

The findings of this research can also be used to calibrate the magnitude of each antecedent to foster the desired level of supply chain resilience. Supply chain disruptions manifest with varying frequencies across different industries and regions because of the influence of a multitude of factors, such as industry characteristics, environmental dynamism, or the geopolitical profile of a region. Consequently, firms nestled in environments characterized by sporadic disruptions may not require the same level of resilience as firms embedded in highly volatile and dynamic environments. The analysis presented in this research culminated in a bottleneck table that can be used as a guide to nuance firms' levels of collaboration and responsiveness to attain different plateaus of supply chain resilience. This could enable firms to develop a strategy tailored to their environmental contexts, resilience objectives, and resource endowments. For instance, firms that require only a modest level of resilience might focus on amplifying supply chain responsiveness. By contrast, firms requiring a high level of resilience should also allocate resources to activities that enhance supply chain collaboration.

5.3 Societal implications

By enhancing supply chain resilience, businesses can mitigate the effects of otherwise costly disruptions, ensuring the reliable supply of essential goods and services to society at reasonable prices. This improves consumer welfare and is particularly important given growing uncertainties in the current business landscape. This study also contributes to industry stability by safeguarding the continuity of operations. As a result, more job opportunities within local communities can be created, driving economic growth and fostering prosperity. Resilient supply chain capabilities also align with sustainability practices, advancing environmental goals and reducing ecological footprints. This, in turn, positively affects society by preserving natural resources and promoting environmental stewardship for future generations.

Furthermore, the insights gained from this research can aid in preparedness and response to natural disasters, reducing their adverse societal impact and expediting recovery efforts. Pointing businesses towards the most important tools and strategies to maintain their operations during crises helps communities recover swiftly and minimize economic and social disruptions. This research also serves as a valuable resource for policymakers, informing the development of regulations and incentives aimed at fortifying supply chain resilience. Policymakers can leverage the insights provided to craft policies that support resilient infrastructure, encourage sustainable practices, and foster a robust economy capable of withstanding future challenges.

5.4 Limitations and future research directions

This study has investigated supply chain resilience as a firm's dynamic capability, identifying essential antecedents at the organizational level. Prior research has investigated supply chain resilience using alternative frameworks and at other levels of analysis. For example, Han et al. (2020) considered supply chain resilience as a performance outcome, Nikookar and Yanadori (2022b) studied the managerial antecedents underpinning supply chain resilience, and Soni et al. (2014) explored how different supply network configurations affect resilience. These alternative approaches might result in the identification of other antecedents of supply chain resilience. Unlike a regression-focused approach, which is prone to potential pitfalls arising from omitted variables and inaccuracies in causal modelling (Rönkkö & Evermann, 2013), NCA derives empirical outcomes that are robust against the exclusion of other variables (Dul, 2019). Although this safeguards the validity of the findings, further research is encouraged to investigate the potential necessity of other antecedents. This could be conducted at the individual, team, and/or broader supply network level of analysis.

Meanwhile, the generalizability of the findings in this study is limited in two ways. First, by the inherent constraints of the applied data analysis technique. Similar to other quantitative data analysis techniques, NCA is limited when it comes to making inferences from a sample to the wider population (Bokrantz & Dul, 2023). Second, by the characteristics of the sample. In line with recent calls (e.g., Pagell, 2021), researchers are encouraged to replicate the approach adopted in other countries, such as at different stages of economic development, and in non-manufacturing industries, such as in the service or nonprofit sector, to corroborate and potentially augment the conclusions drawn in this study.

Finally, this research relied on a single-respondent survey for data collection. Although securing multiple respondents per firm in this context can sometimes increase the risk of nonresponse bias (Krause et al., 2018) and introduce challenges related to data aggregation, this is still acknowledged as a methodological limitation (Craighead et al., 2011). The potential bias introduced by single-respondent surveys, such as common method bias, may be less pronounced in the context of NCA because it identifies non-compensatory thresholds rather than relying on correlations or explained variance (R^2) (Dul, 2016). Nonetheless, future studies are encouraged to replicate this research using data collected from multiple key informants to strengthen the validity of the findings.

REFERENCES

Adobor, H., & McMullen, R. S. (2018). Supply chain resilience: A dynamic and multidimensional approach. *The International Journal of Logistics Management*, *29*(4), 1451–1471.

Agrawal, N., & Jain, R. K. (2021). Insights from systematic literature review of supply chain resilience and disruption. *Benchmarking: An International Journal*, *29*(8), 2495–2526.

Agrawal, T. K., Angelis, J., Khilji, W. A., Kalaiarasan, R., & Wiktorsson, M. (2023). Demonstration of a blockchain-based framework using smart contracts for supply chain collaboration. *International Journal of Production Research*, *61*(5), 1497–1516.

Ali, A., Mahfouz, A., & Arisha, A. (2017). Analyzing supply chain resilience: Integrating the constructs in a concept mapping framework via a systematic literature review. *Supply Chain Management: An International Journal*, *22*(1), 16–39.

Ali, I., & Gölgeci, I. (2019). Where is supply chain resilience research heading? A systematic and co-occurrence analysis. *International Journal of Physical Distribution & Logistics Management*, *49*(8), 793–815.

Ali, I., Arslan, A., Chowdhury, M., Khan, Z., & Tarba, S. Y. (2022). Reimagining global food value chains through effective resilience to COVID-19 shocks and similar future events: A dynamic capability perspective. *Journal of Business Research*, *141*, 1-12.

Ali, I., Gligor, D., Balta, M., Bozkurt, S., & Papadopoulos, T. (2024). From disruption to innovation: The importance of the supply chain leadership style for driving logistics innovation in the face of geopolitical disruptions. *Transportation Research Part E: Logistics and Transportation Review*, *187*, 103583.

Ambulkar, S., Blackhurst, J., & Grawe, S. (2015). Firm's resilience to supply chain disruptions: Scale development and empirical examination. *Journal of Operations Management*, *33–34*, 111–122.

Anderson, J. C., Gerbing, D. W., & Schmitt, N. (1991). Predicting the performance of measures in a confirmatory factor analysis with a pre-test assessment of their substantive validities. *Journal of Applied Psychology*, *76*(5), 732–740.

Arikan, A. M., & McGahan, A. M. (2010). The development of capabilities in new firms. *Strategic Management Journal*, 31(1), 1-18.

Azadegan, A., & Dooley, K. (2021). A typology of supply network resilience strategies: Complex collaborations in a complex world. *Journal of Supply Chain Management*, *57*(1), 17–26.

Azadeh, A., Atrchin, N., Salehi, V., & Shojaei, H. (2014). Modelling and improvement of supply chain with imprecise transportation delays and resilience factors. *International Journal of Logistics Research and Applications*, *17*(4), 269–282.

Bagozzi, R. P., Yi, Y., & Phillips, L. W. (1991). Assessing construct validity in organizational research. *Administrative Science Quarterly*, 421–458.

Barratt, M., & Oke, A. (2007). Antecedents of supply chain visibility in retail supply chains: A resource-based theory perspective. *Journal of Operations Management*, *25*(6), 1217–1233.

Bernardes, E. S. (2010). The effect of supply management on aspects of social capital and the impact on performance: A social network perspective. *Journal of Supply Chain Management*, *46*(1), 45–55.

Blackhurst, J., Dunn, K. S., & Craighead, C. W. (2011). An empirically derived framework of global supply resiliency. *Journal of Business Logistics*, *32*(4), 374–391.

Bode, C., & Macdonald, J. R. (2017). Stages of supply chain disruption response: Direct, constraining, and mediating factors for impact mitigation. *Decision Sciences*, *48*(5), 836–874.

Bode, C., Wagner, S. M., Petersen, K. J., & Ellram, L. M. (2011). Understanding responses to supply chain disruptions: Insights from information processing and resource dependence perspectives. *Academy of Management Journal*, *54*(4), 833–856.

Bokhorst, J. A., Knol, W., Slomp, J., & Bortolotti, T. (2022). Assessing to what extent smart manufacturing builds on lean principles. *International Journal of Production Economics*, *253*, 108599.

Bokrantz, J., & Dul, J. (2023). Building and testing necessity theories in supply chain management. *Journal of Supply Chain Management*, *59*(1), 48–65.

Bollen, K 1989, *Structural equations with latent variables*, Wiley, New York, NY.

Brandon-Jones, E., Squire, B., Autry, C. W., & Petersen, K. J. (2014). A contingent resource-based perspective of supply chain resilience and robustness. *Journal of Supply Chain Management*, *50*(3), 55–73.

Braunscheidel, M. J., & Suresh, N. C. (2009). The organizational antecedents of a firm's supply chain agility for risk mitigation and response. *Journal of Operations Management*, *27*(2), 119–140.

Brusset, X., & Teller, C. (2017). Supply chain capabilities, risks, and resilience. *International Journal of Production Economics*, *184*, 59–68.

Bühler, A., Wallenburg, C. M., Wieland, A., & Wagner, B. (2016). Accounting for external turbulence of logistics organizations via performance measurement systems. *Supply Chain Management: An International Journal*, *21*(6), 694–708.

Cai, Z., Huang, Q., Liu, H., & Liang, L. (2016). The moderating role of information technology capability in the relationship between supply chain collaboration and organizational responsiveness: Evidence from China. *International Journal of Operations & Production Management*, *36*(10), 1247–1271.

Cao, M., & Zhang, Q. (2011). Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of Operations Management*, *29*(3), 163–180.

Carvalho, H., Barroso, A. P., Machado, V. H., Azevedo, S., & Cruz-Machado, V. (2012). Supply chain redesign for resilience using simulation. *Computers & Industrial Engineering*, *62*(1), 329–341.

Chowdhury, M. M. H., & Quaddus, M. (2017). Supply chain resilience: Conceptualization and scale development using dynamic capability theory. *International Journal of Production Economics*, *188*, 185–204.

Christopher, M., & Peck, H. (2004). Building the resilient supply chain. *The International Journal of Logistics Management*, *15*(2), 1–14.

Christopher, M., & Towill, D. (2001). An integrated model for the design of agile supply chains. *International Journal of Physical Distribution & Logistics Management*, *31*(4), 235-246.

Churchill, G. A. Jr. (1979). A paradigm for developing better measures of marketing constructs. *Journal of Marketing Research*, *16*(1), 64–73.

Conway, J. M., & Huffcutt, A. I. (2003). A review and evaluation of exploratory factor analysis practices in organizational research. *Organizational Research Methods*, *6*(2), 147–168.

Craighead, C. W., Ketchen, D. J., Dunn, K. S., & Hult, G. T. M. (2011). Addressing common method variance: Guidelines for survey research on information technology, operations, and supply chain management. *IEEE Transactions on Engineering Management*, *58*(3), 578–588.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed-mode surveys: The tailored design method*. John Wiley & Sons.

Dubey, R., Bryde, D. J., Foropon, C., Graham, G., Giannakis, M., & Mishra, D. B. (2022). Agility in humanitarian supply chain: An organizational information processing perspective and relational view. *Annals of Operations Research*, *319*, 559–579.

Dul, J. (2016a). Necessary condition analysis (NCA) logic and methodology of "necessary but not sufficient" causality. *Organizational Research Methods*, *19*(1), 10–52.

Dul, J. (2016b). Identifying single necessary conditions with NCA and fsQCA. *Journal of Business Research*, *69*(4), 1516–1523.

Dul, J. (2019). *Conducting necessary condition analysis*. Sage Publications.

Dul, J. (2025). *Advances in necessary condition analysis: Version 1.5*. https://bookdown.org/ncabook/advanced_nca2/

Dul, J. (2024). A different causal perspective with necessary condition analysis. *Journal of Business Research*, *177*, 114618.

Dul, J., Hauff, S., & Bouncken, R. B. (2023). Necessary condition analysis (NCA): Review of research topics and guidelines for good practice. *Review of Managerial Science*, *17*(2), 683–714.

Dul, J., Van der Laan, E., & Kuik, R. (2020). A statistical significance test for necessary condition analysis. *Organizational Research Methods*, *23*(2), 385–395.

Dunn, S. C., Seaker, R. F., & Waller, M. A. (1994). Latent variables in business logistics research: Scale development and validation. *Journal of Business Logistics*, *15*(2), 145.

Feizabadi, J., Maloni, M., & Gligor, D. (2019). Benchmarking the triple-A supply chain: Orchestrating agility, adaptability, and alignment. *Benchmarking: An International Journal*, *26*(1), 271–295.

Garver, M. S., & Mentzer, J. T. (1999). Logistics research methods: Employing structural equation modeling to test for construct validity. *Journal of Business Logistics*, *20*(1), 33.

Gligor, D., Gligor, N., Holcomb, M., & Bozkurt, S. (2019). Distinguishing between the concepts of supply chain agility and resilience: A multidisciplinary literature review. *The International Journal of Logistics Management*, *30*(2), 467–487.

Goertz, G. (2003). *The substantive importance of necessary condition hypotheses*. In G. Goertz & H. Starr (Eds.), *Necessary conditions: Theory, methodology and applications*. Rowman and Littlefield.

Goertz, G., Hak, T., & Dul, J. (2013). Ceilings and floors: Where are there no observations? *Sociological Methods & Research*, *42*(1), 3–40.

Gölgeci, I., & Ponomarov, S. (2013). Does firm innovativeness enable effective responses to supply chain disruptions? An empirical study. *Supply Chain Management: An International Journal*, *18*(6), 604–617.

Gulati, R. (1999). Network location and learning: The influence of network resources and firm capabilities on alliance formation. *Strategic Management Journal*, *20*(5), 397–420.

Gunasekaran, A., Lai, K. H., & Cheng, T. E. (2008). Responsive supply chain: A competitive strategy in a networked economy. *Omega*, *36*(4), 549–564.

Hair, J. F., Anderson, R. E., Tatham, R. L., & William, B. C. (2010). *Multivariate data analysis: A global perspective* (5th ed.). Prentice-Hall International.

Hallavo, V. (2015). Superior performance through supply chain fit: A synthesis. *Supply Chain Management: An International Journal*, *20*(1), 71–82.

Han, Y., Chong, W. K., & Li, D. (2020). A systematic literature review of the capabilities and performance metrics of supply chain resilience. *International Journal of Production Research*, *58*(15), 4541–4566.

Hauff, S., Guerci, M., Dul, J., & van Rhee, H. (2021). Exploring necessary conditions in HRM research: Fundamental issues and methodological implications. *Human Resource Management Journal*, *31*(1), 18–36.

Heggestad, E. D., Scheaf, D. J., Banks, G. C., Monroe Hausfeld, M., Tonidandel, S., & Williams, E. B. (2019). Scale adaptation in organizational science research: A review and best-practice recommendations. *Journal of Management*, *45*(6), 2596–2627.

Helfat, C., & Peteraf, M. (2009). Understanding dynamic capabilities: Progress along a developmental path. *Strategic Organization*, *7*(1), 91–102.

Helfat, C., & Peteraf, M. (2015). Managerial cognitive capabilities and the micro foundations of dynamic capabilities. *Strategic Management Journal*, *36*(6), 831–850.

Hendry, L. C., Stevenson, M., MacBryde, J., Ball, P., Sayed, M., & Liu, L. (2019). Local food supply chain resilience to constitutional change: The Brexit effect. *International Journal of Operations & Production Management*, *39*(3), 429–453.

Holmqvist, M. (2004). Experiential learning processes of exploitation and exploration within and between organizations: An empirical study of product development. *Organization Science*, *15*(1), 70–81.

Ishfaq, R. (2012). Resilience through flexibility in transportation operations. *International Journal of Logistics Research and Applications*, *15*(4), 215–229.

Ivanov, D., & Dolgui, A. (2021). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Production Planning & Control*, *32*(9), 775-788.

Jain, N. K., Chakraborty, K., & Choudhary, P. (2024). Building supply chain resilience through industry 4.0 base technologies: role of supply chain visibility and environmental dynamism. *Journal of Business & Industrial Marketing*, *39*(8), 1750-1763.

Jiang, Y., Feng, T., & Huang, Y. (2024). Antecedent configurations toward supply chain resilience: The joint impact of supply chain integration and big data analytics capability. *Journal of Operations Management*, *70*(2), 257–284.

Jick, T. D. (1979). Mixing qualitative and quantitative methods: Triangulation in action. *Administrative Science Quarterly*, *24*, 602–611.

Jurie, J. (2000). Building capacity: Organizational competence and critical theory. *Journal of Organizational Change Management*, *13*(3), 264–274.

Jüttner, U., & Maklan, S. (2011). Supply chain resilience in the global financial crisis: An empirical study. *Supply Chain Management: An International Journal*, *16*(4), 246–259.

Kähkönen, A.-K., Evangelista, P., Hallikas, J., Immonen, M., & Lintukangas, K. (2023). COVID-19 as a trigger for dynamic capability development and supply chain resilience improvement. *International Journal of Production Research*, *61*(8), 2696–2715. https://doi.org/10.1080/00207543.2021.2009588

Kamalahmadi, M., & Parast, M. M. (2016). A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research. *International Journal of Production Economics*, *171*, 116–133.

Kim, D., & Lee, R. P. (2010). Systems collaboration and strategic collaboration: Their impacts on supply chain responsiveness and market performance. *Decision Sciences*, *41*(4), 955–981.

Kim, Y., Chen, Y. S., & Linderman, K. (2015). Supply network disruption and resilience: A network structural perspective. *Journal of Operations Management*, *33–34*, 43–59.

Kleindorfer, P. R., & Saad, G. H. (2005). Managing disruption risks in supply chains. *Production and Operations Management*, *14*(1), 53–68.

Knol, W. H., Slomp, J., Schouteten, R. L., & Lauche, K. (2018). Implementing lean practices in manufacturing SMEs: Testing 'critical success factors' using necessary condition analysis. *International Journal of Production Research*, *56*(11), 3955–3973.

Koufteros, X. A., Vonderembse, M. A., & Doll, W. J. (1998). Developing measures of time-based manufacturing. *Journal of Operations Management*, *16*(1), 21–41.

Kraaijenbrink, J., Spender, J. C., & Groen, A. J. (2010). The resource-based view: A review and assessment of its critiques. *Journal of Management*, *36*(1), 349–372.

Krause, D., Luzzini, D., & Lawson, B (2018). Building the case for a single key informant in supply chain management survey research. *Journal of Supply Chain Management*, *54*(1), 42–50.

Kristianto, Y. A., Gunasekaran, P., Helo and Hao, Y. (2014). A model of resilient supply chain network design: A two-stage programming with fuzzy shortest path. *Expert Systems with Applications*, *41*(10), 39–49.

Kurniawan, R., Zailani, S. H., Iranmanesh, M., & Rajagopal, P. (2017). The effects of vulnerability mitigation strategies on supply chain effectiveness: Risk culture as moderator. *Supply Chain Management*, *22*(1), 1–15.

Lambert, D., Stock, J. R., & Ellram, L. M. (1998). *Fundamentals of logistics management*. McGraw-Hill.

Lambert, D. M., & Harrington, T. C. (1990). Measuring nonresponse bias in customer service mail surveys, *Journal of Business Logistics*, *11*(2), 5–25.

Linder, C., Moulick, A. G., & Lechner, C. (2022). Necessary conditions and theory-method compatibility in quantitative entrepreneurship research. *Entrepreneurship Theory and Practice*, 10422587221102103.

Liu, C. L., Shang, K. C., Lirn, T. C., Lai, K. H., & Lun, Y. H. V. (2017). Supply chain resilience, firm performance, and management policies in the liner shipping industry. *Transportation Research Part A*, *110*, 202–219.

Lu, J., Yan, T., & Browning, T. R. (2024). Into the unknown? Explaining management nonresponse after a supply-base disruption. *Journal of Operations Management*, *70*(8), 1213–1233.

Malhotra, M. K., & Grover, V. (1998). An assessment of survey research in POM: From constructs to theory. *Journal of Operations Management*, *16*(4), 407–425.

Meyer, K. E., Van Witteloostuijn, A., & Beugelsdijk, S. (2017). What's in ap? Reassessing best practices for conducting and reporting hypothesis-testing research. *Research Methods in International Business*, *48*, 535–551.

National Association of Manufacturers (2020), "Economic and operational impacts of COVID-19 to manufacturers", available at: https://www.nam.org/coronasurvey (accessed 17 January 2024).

Nikookar, E., & Yanadori, Y. (2022a). Preparing supply chain for the next disruption beyond COVID-19: Managerial antecedents of supply chain resilience. *International Journal of Operations & Production Management*, *42*(1), 59–90.

Nikookar, E., & Yanadori, Y. (2022b). Forming post-COVID supply chains: Does supply chain managers' social network affect resilience? *International Journal of Physical Distribution & Logistics Management*, *52*(7), 538–566.

Nikookar, E., Stevenson, M., & Varsei, M. (2024). Building an antifragile supply chain: A capability blueprint for resilience and post-disruption growth. *Journal of Supply Chain Management*, *60*(1), 13-31.

Nolte, I. M., Martin, E. C., & Boenigk, S. (2012). Cross-sectoral coordination of disaster relief. *Public Management Review*, *14*(6), 707-730.

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). McGraw-Hill.

O'Leary-Kelly, S. W., & Vokurka, R. J. (1998). The empirical assessment of construct validity. *Journal of Operations Manage*ment, *16*(4), 387–405.

O'Reilly, C., & Tushman, M. (2008). Ambidexterity as a dynamic capability: Resolving the innovator's dilemma. *Research in Organizational Behavior*, *28*, 185–206.

Pagell, M. (2021). Replication without repeating ourselves: Addressing the replication crisis in operations and supply chain management research. *Journal of Operations Management*, *67*(1), 105–115.

Parliament of Australia (2020), "Effects of COVID-19 on Australia", available at: https://www.aph.gov.au/Parliamentary_Business/Committees/Joint/Foreign_Affairs_Defence_and_Trade/FADTandglobalpandemic/Report/section?id5committees%2Freportjnt%2F024552%2F73973 (accessed 15 January 2024).

Pettit, T. J., Croxton, K. L., & Fiksel, J. (2013). Ensuring supply chain resilience: development and implementation of an assessment tool. *Journal of Business Logistics*, *34*(1), 46-76.

Pettit, T. J., Fiksel, J., & Croxton, K. L. (2010). Ensuring supply chain resilience: development of a conceptual framework. *Journal of Business Logistics*, *31*(1), 1-21.

Pfeffer, J., & Salancik, G. R. (1978). *The external of organizations: A resource–dependence perspective*. New York.

Ponomarov, S. Y., & Holcomb, M. C. (2009). Understanding the concept of supply chain resilience. *The International Journal of Logistics Management*, *20*(1), 124-143.

Pournader, M., Kach, A., & Talluri, S. (2020). A review of the existing and emerging topics in the supply chain risk management literature. *Decision Sciences*, *51*(4), 867-919.

Power, D. (2005). Supply chain management integration and implementation: a literature review. *Supply chain management: an international journal*, *10*(4), 252-263.

Prajogo, D., Mena, C., & Chowdhury, M. (2021). The role of strategic collaborations and relational capital in enhancing product performance–a moderated-mediated model. *International Journal of Operations & Production Management*, *41*(3), 206–226.

Pu, G., Li, S., & Bai, J. (2023). Effect of supply chain resilience on firm's sustainable competitive advantage: A dynamic capability perspective. *Environmental Science and Pollution Research*, *30*(2), 4881–4898.

Qrunfleh, S., & Tarafdar, M. (2013). Lean and agile supply chain strategies and supply chain responsiveness: The role of strategic supplier partnership and postponement. *Supply Chain Management: An International Journal*, *18*(6), 571–582.

Queiroz, M. M., Wamba, S. F., Jabbour, C. J. C., & Machado, M. C. (2022). Supply chain resilience in the UK during the coronavirus pandemic: A resource orchestration perspective. *International Journal of Production Economics*, *245*, 108405.

Rahman, S., Ahsan, K., Sohal, A., Wieland, A., & Oloruntoba, A. (2021). New normal: Rethinking supply chains during and after COVID-19 global business environment. *International Journal of Physical Distribution and Logistics Management*. https://www.emeraldgrouppublishing.com/journal/ijpdlm/new-normal-rethinking-supply-chains-during-andafter-covid-19-global-business

Randall, T. R., Morgan, R. M., & Morton, A. R. (2003). Efficient versus responsive supply chain choice: an empirical examination of influential factors. *Journal of Product Innovation Management*, *20*(6), 430-443.

Razak, G. M., Stevenson, M., & Hendry, L. C. (2024). "I am because we are": The role of Sub-Saharan Africa's collectivist culture in achieving traceability and global supply chain resilience. *Journal of Supply Chain Management*. https://doi.org/10.1111/jscm.12330

Reio, T. G. Jr., & Shuck, B. (2015). Exploratory factor analysis: Implications for theory, research, and practice. *Advances in Developing Human Resources*, *17*(1), 12–25.

Rice, J., & Caniato, F. (2003). Building a secure and resilient supply network. *Supply Chain Management Review, 7*(5), 22–30.

Richardson, H. A., Simmering, M. J., & Sturman, M. C. (2009). A tale of three perspectives: Examining post hoc statistical techniques for detection and correction of common method variance. *Organizational Research Methods*, *12*(4), 762-800.

Richey, G. Jr., & Autry, C. W. (2009). Assessing interfirm collaboration/technology investment tradeoffs: The effects of technological readiness and organizational learning. *The International Journal of Logistics Management*, *20*(1), 30–56.

Rönkkö, M., & Evermann, J. (2013). A critical examination of common beliefs about partial least squares path modeling. *Organizational Research Methods*, *16*(3), 425–448.

Roscoe, S., Aktas, E., Petersen, K. J., Skipworth, H. D., Handfield, R. B., & Habib, F. (2022). Redesigning global supply chains during compounding geopolitical disruptions: the role of supply chain logics. *International Journal of Operations & Production Management*, *42*(9), 1407-1434.

Roy, S., Sivakumar, K., & Wilkinson, I. F. (2004). Innovation generation in supply chain relationships: A conceptual model and research propositions. *Journal of the Academy of Marketing Science*, *32*(1), 61–79.

Sarkis, J., Zhu, Q., & Lai, K.-h. (2011). An organizational theoretic review of green supply chain management literature. *International Journal of Production Economics*, *130*(1), 1–15.

Scholten, K., & Schilder, S. (2015). The role of collaboration in supply chain resilience. *Supply Chain Management: An International Journal*, *20*(4), 471–484.

Sheffi, Y. (2001). Supply chain management under the threat of international terrorism. *The International Journal of Logistics Management*, *12*(2), 1–11.

Sheffi, Y., & Rice, J. (2005). A supply chain view of the resilient enterprise. *MIT Sloan Management Review*, *47*(1), 41–48.

Sherman, E. (2020). *94% Of the fortune 1000 are seeing coronavirus supply chain disruptions: Report*. Fortune. https://fortune.com/2020/02/21/fortune-1000-coronavirus-china-supply-chain-impact/

Simmering, M. J., Fuller, C. M., Richardson, H. A., Ocal, Y., & Atinc, G. M. (2015). Marker variable choice, reporting, and interpretation in the detection of common method variance: A review and demonstration. *Organizational Research Methods*, *18*(3), 473-511.

Somapa, S., Cools, M., & Dullaert, W. (2018). Characterizing supply chain visibility–a literature review. *The International Journal of Logistics Management*, *29*(1), 308-339.

Soni, U., Jain, V., & Kumar, S. (2014). Measuring supply chain resilience using a deterministic modeling approach. *Computers & Industrial Engineering*, *74*, 11-25.

Soosay, C. A., & Hyland, P. (2015). A decade of supply chain collaboration and directions for future research. *Supply Chain Management: An International Journal*, *20*(6), 613-630.

Spector, P. E., Rosen, C. C., Richardson, H. A., Williams, L. J., & Johnson, R. E. (2019). A new perspective on method variance: A measure-centric approach. *Journal of Management*, *45*(3), 855-880.

Spiegler, V. L., Naim, M. M., & Wikner, J. (2012). A control engineering approach to the assessment of supply chain resilience. *International Journal of Production Research*, *50*(21), 6162–6187.

Stackpole, B. (2022). *Ripple effects from Russia-Ukraine war test global economies*. https://mitsloan.mit.edu/ideas-made-to-matter/ripple-effects-russia-ukraine-war-test-global-economies

Stadtfeld, G. M., & Gruchmann, T. (2024). Dynamic capabilities for supply chain resilience: A meta-review. *The International Journal of Logistics Management*, *35*(2), 623–648.

Sun, K., Ooi, K. B., Wei-Han Tan, G., & Lee, V. H. (2025). Small and medium-sized enterprises' path to sustainable supply chains: exploring the role of supply chain finance and risk management. *Supply Chain Management: An International Journal*, *30*(1), 1-18.

Tang, C. S. (2006). Robust strategies for mitigating supply chain disruptions. *International Journal of Logistics: Research and Applications*, *9*(1), 33-45.

Teece, D. J. (2007). Explicating dynamic capabilities: The nature and micro foundations of (sustainable) enterprise performance. *Strategic Management Journal*, *28*(13), 1319–1350.

Theodori, G. L. (2001). Examining the effects of community satisfaction and attachment on individual well-being. *Rural Sociology*, *66*(4), 618-628.

Tiwari, M., Bryde, D. J., Stavropolou, F., Dubey, R., Kumari, S., & Foropon, C. (2024). Modelling supply chain visibility, digital technologies, environmental dynamism and healthcare supply chain resilience: An organisation information processing theory perspective. *Transportation Research Part E: Logistics and Transportation Review*, *188*, 103613.

Torres, P., & Godinho, P. (2022). Levels of necessity of entrepreneurial ecosystems elements. *Small Business Economics*, *59*(1), 29-45.

Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015). Supply chain resilience: Definition, review and theoretical foundations for further study. *International Journal of Production Research*, *53*(8), 5592–5623.

van der Valk, W., Sumo, R., Dul, J., & Schroeder, R. G. (2016). When are contracts and trust necessary for innovation in buyer–supplier relationships? A necessary condition analysis. *Journal of Purchasing and Supply Management*, *22*(4), 266–277.

Van Echtelt, F. E., Wynstra, F., Van Weele, A. J., & Duysters, G. (2008). Managing supplier involvement in new product development: A multiple-case study. *Journal of Product Innovation Management*, *25*(2), 180–201.

Vis, B., & Dul, J. (2018). Analyzing relationships of necessity not just in kind but also in degree: Complementing fsQCA with NCA. *Sociological Methods & Research*, *47*(4), 872–899.

Wang, C. L., & Ahmed, P. (2007). Dynamic capabilities: A review and research agenda. *International Journal of Management Reviews*, *9*(1), 31–51.

Wankmüller, C., & Reiner, G. (2020). Coordination, cooperation and collaboration in relief supply chain management. *Journal of Business Economics*, *90*, 239-276.

Wieland, A. (2021). Dancing the supply chain: Toward transformative supply chain management. *Journal of Supply Chain Management*, *57*(1), 58–73.

Wieland, A., & Durach, C. F. (2021). Two perspectives on supply chain resilience. *Journal of Business Logistics*, *42*(3), 315–322.

Wieland, A., Durach, C. F., Kembro, J., & Treiblmaier, H. (2017). Statistical and judgmental criteria for scale purification. *Supply Chain Management: An International Journal*, *22*(4), 321–328.

Wieland, A., Stevenson, M., Melnyk, S. A., Davoudi, S., & Schultz, L. (2023). Thinking differently about supply chain resilience: What we can learn from social-ecological systems thinking. *International Journal of Operations & Production Management*, *43*(1), 1–21.

Wieland, A., & Wallenburg, C. M. (2013). The influence of relational competencies on supply chain resilience: A relational view. *International Journal of Physical Distribution & Logistics Management*, *43*(4), 300–320.

Wieland, A., & Wallenburg, C. M. (2012). Dealing with supply chain risks: linking risk management practices and strategies to performance. *International journal of physical distribution & logistics management*, *42*(10), 887-905.

Williams, B. D., Roh, J., Tokar, T., & Swink, M. (2013). Leveraging supply chain visibility for responsiveness: The moderating role of internal integration. *Journal of Operations Management*, *31*(7), 543–554.

Williams, L. J., & McGonagle, A. K. (2016). Four research designs and a comprehensive analysis strategy for investigating common method variance with self-report measures using latent variables. *Journal of Business and Psychology*, *31*, 339-359.

Winter, S. G. (2003). Understanding dynamic capabilities. *Strategic management journal*, *24*(10), 991-995.

Yin, W., Ran, W., & Zhang, Z. (2024). A configuration approach to build supply chain resilience: From matching perspective. *Expert Systems with Applications*, *249*, 123662.

Zinn, W., & Goldsby, T. J. (2019). Supply chain plasticity: Redesigning supply chains to meet major environmental change. *Journal of Business Logistics*, 40(3), 184–186.

APPENDIX 1: Perceptual scales

Variable	Reliability Test: Congeneric Reliability (ρ_C)	Reliability Test: AVE	Item	Factor Loading
Supply Chain Resilience Borrowed from Ambulkar et al. (2015)	*.86*	*.59*	We are able to cope with the changes brought about by a supply chain disruption.	*.819*
			We are easily able to adapt to a supply chain disruption.	*.827*
			We are able to provide a quick response to a supply chain disruption.	*.804*
			We are able to maintain high situational awareness at all times.	*.613*
Supply Chain Visibility Borrowed from Williams et al. (2013)	*.77*	*.49*	We are always aware of the firms engaged in our supply chain.	*.804*
			We are well aware of the locations of our supply chain members.	*.772*
			We always have complete information, such as inventory availability, lead times, and delivery dates, in our supply chain.	*.632*
			The location and status of our main product are always visible throughout the distribution network.	*.557*
Supply Chain Responsiveness Borrowed from Hallavo (2015) and Bernardes (2010)	*.76*	*.50*	A supplier's speed in addressing our needs is important to us when selecting suppliers.	*.613*
			We invest aggressively in ways to reduce our lead time.	*.803*
			The primary purpose of our supply chain is to respond quickly to demand in order to minimize stockouts, forced markdowns, and obsolete inventory.	*.806*
			Our supply chain responds quickly to our special requests.	*.595*
Supply Chain Flexibility Borrowed from Kurniawan et al. (2017)	*.80*	*.58*	Switching the purchase of items from one supplier to another is possible.	*.811*
			Different modes of transportation are available in delivering products to customers.	*deleted*
			Changing the quantity of a supplier's order with short notice is possible.	*.779*
			The production capacity of our supplier is sufficient to accommodate an increase in demand.	*.730*
			Overtime or temporary work is available to cope with short-term demand fluctuation.	*deleted*
			Our supplier is capable of producing a small quantity because of relatively low setup costs.	*.736*
Supply Chain Collaboration Borrowed from Cai et al. (2016) and Richey & Autry (2009)	*.83*	*.57*	We and our supply chain members work together toward common goals.	*.727*
			We and our supply chain members work together to take advantage of new opportunities.	*.843*
			We and our supply chain members work together to share new ideas.	*.823*
			We and our supply chain members frequently share proprietary information with one another.	*.712*
			We have joint decision-making activities with our supplier.	*.667*

TABLE 1: Alternative perspectives on causality (from Dul, 2024)

Perspective	Sufficiency (if X then Y)	Necessity (if not X then not Y)
Deterministic	If X then always Y	If not X then always not Y
Probabilistic	If X then probably Y	If not X then probably not Y
Typicality	If X then typically Y	If not X then typically not Y

TABLE 2: Summary of hypotheses

Antecedent	**Relationship with the capacities required to build resilience as a dynamic capability**	**Why the Antecedents is Necessary for Resilience**	**Hypothesis**
Supply chain visibility	Supply chain visibility contributes to the *sensing* capacity required for building supply chain resilience.	Without supply chain visibility, firms lack the critical capability needed to collect data about their operational status, particularly in relation to potential disruptions, thereby weakening the sensing capacity essential for supply chain resilience.	H1: Supply chain visibility is a necessary condition for building supply chain resilience in multi-tier and independently structured supply chains.
Supply chain responsivenes s	Supply chain responsiveness contributes to the *seizing* capacity required for building supply chain resilience.	The absence of responsiveness impairs a firm's ability to make quick decisions during a disruption, thereby weakening the seizing capacity essential for supply chain resilience.	H2: Supply chain responsiveness is a necessary condition for building supply chain resilience in multi-tier and independently structured supply chains that compete in time-sensitive markets and cannot rely on excessive slack or monopoly power.
Supply chain flexibility	Supply chain flexibility contributes to the *resource reconfiguration* capacity required for building supply chain resilience.	A lack of flexibility can lead to firms only having access to a set of resources that can be used for a single purpose. This diminishes the resource reconfiguration capacity required for supply chain resilience.	H3: Supply chain flexibility is a necessary condition for building supply chain resilience in multi-tier and independently structured supply chains that do not have access to excessive slack or monopoly power.
Supply chain collaboration	Supply chain collaboration contributes to the *sensing, seizing, and resource reconfiguration capacities* required for building supply chain resilience.	Without collaboration, firms may lack the necessary information, resources, or insights needed to respond effectively to disruptions, thereby compromising the sensing, seizing, and resource	H4: Supply chain collaboration is a necessary condition for building supply chain resilience in multi-tier and independently structured supply chains.

		reconfiguration capacities required for building supply chain resilience.	

TABLE 3: Descriptive statistics of the sample

Category	Number of firms	Percentage
Industry		
Food, Beverage and Tobacco	118	19.80
Textile, Leather, Clothing and Footwear	13	2.18
Wood and Furniture	37	6.21
Pulp, Paper and Converted Paper	10	1.68
Printing and Publishing	35	5.87
Petroleum and Chemical	83	13.93
Polymer and Rubber	25	4.19
Non-Metallic Mineral Product	43	7.21
Metal	15	2.52
Fabricated Metal Product	12	2.01
Transport Equipment	14	2.34
Machinery and Equipment	60	10.07
Others	133	22.32
Annual sales revenue		
Under AU$100 million	171	28.69
AU$ 101–500 million	54	8.89
AU$ 501–1000 million	44	7.38
AU$ 1001–5000 million	53	8.72
Over AU$ 5000 million	276	46.31
Number of employees		
Less than 5 employees	39	6.54
5-19 employees	69	11.41
20-199 employees	122	20.30
200 or more employees	368	61.74

TABLE 4: NCA results

Construct	Effect Size	*P* value	Celling Accuracy
Supply Chain Visibility	0.08	0.175	99.6%
Supply Chain Responsiveness	0.29	**0.000**	99.6%
Supply Chain Flexibility	0.04	0.429	99.8%
Supply Chain Collaboration	**0.19**	**0.000**	98.1%

TABLE 5: Bottleneck analysis of the necessary conditions for supply chain resilience

Supply Chain Resilience	Supply Chain Responsiveness	Supply Chain Collaboration
0	**NN**	**NN**
10	**NN**	**NN**
20	**NN**	**NN**
30	1.4	**NN**
40	12.2	3.5
50	22.9	12.9
60	33.7	22.2
70	44.4	31.6
80	55.1	41.0
90	65.9	50.3
100	76.6	59.7

FIGURE 1: Scatter plots of hypothesized necessary variables against supply chain resilience