Moving beyond dyadic buyer-supplier relationships: An extended view on sustainability and resilience in supply chain management

Inaugural dissertation

submitted to attain the academic degree

doctor rerum politicarum

(Doktor der Wirtschaftswissenschaften)

at the

ESCP Business School Berlin

by

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2023

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Day of disputation: June 29, 2023

To Tabeah – thank you for the numerous ways you show your love and support.

To my family and friends – who have always been there for me.

To Prof. Durach – this thesis would not have been possible without your invaluable support.

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List of abbreviations

CAS..... *Complex Adaptive Systems*

CVVV .....*Constant Variable Value Vignette*

GRI ..... *Global Reporting Initiative*

IÖW.....*Institut für ökologische Wirtschaftsförderung*

MTSC..... *Multi-Tier Supply Chains*

NAT ..... *Normal Accident Theory*

SCM .....*Supply Chain Management*

SSCM..... *Sustainable Supply Chain Management*

SST .....*Social System Theory*

1. Introduction

During the last decades, manufacturing firms have been exposed to drastic changes in their environments. Among others, major trends such as ongoing globalization, rapid technological innovation, changing customer demands, or rising market uncertainties significantly increased competitive pressures (Choi et al., 2002; Vogel & Lasch, 2016). They posed an almost impossible challenge for the affected firms: manufacturers had to introduce new and innovative products, while simultaneously reducing both time-to-market and cost (Choi et al., 2002). Unable to accomplish this task on their own, many manufacturing firms turned their attention to the upstream supply chain (ibid).

To develop and sustain competitive advantages, focal manufacturing firms increasingly resorted to strategic outsourcing. Suppliers were more and more entrusted with providing a wide range of different products and services to manufacturing firms (González-Benito, 2007; Gray et al., 2020). These were not limited to rather simple and recuring tasks, but also included strategically important activities that had previously been performed in-house; for example, the production of key components, R&D efforts, or supply chain coordination (Grimpe & Kaiser, 2010; Jüttner et al., 2003; Wu et al., 2010). In many cases outsourcing allowed manufacturers to cut cost and improve their overall performance (González-Benito, 2007; Gray et al., 2020); however, they also became more dependent on their upstream suppliers (Caniëls & Roeleveld, 2009). Given the more intertwined operations between a buyer and its supplier, modes of co-operation and information exchange between the two firms gained in importance (Choi et al., 2002). The management of buyer-supplier relationships became a strategically important discipline for practitioners and researchers alike.

The increasing importance of suppliers has led to an extensive and still growing body of academic literature dealing with so-called buyer-supplier dyads. In the dyadic context, supply relationships are formed by “suppliers (that) are typically lumped together as one node and the buyer as another node” (Choi et al., 2002, p. 119). Related studies sought to explore the

underlying characteristics of buyer-supplier relationships and their impacts for the buyer or the supplier, respectively. Among others, they examined 'classic' make-or-buy decisions (Cánez et al., 2000), criteria for supplier selection (Huang & Keskar, 2007), existing relationship types (Ahmed et al., 2017), means for supplier development (Humphreys et al., 2004), or the financial and operational performance implications of buyer-supplier relationships (O'Toole & Donaldson, 2002); thus providing valuable contributions to the academic discipline of supply chain management (SCM) (Beamon, 1998; Vonderembse et al., 2006).

Notwithstanding their valuable insights, the knowledge that can be gained from dyadic study designs remains limited. Few scholars emphasized that modern supply chains are best understood as complex and dynamic networks (Choi et al., 2001; Hearnshaw & Wilson, 2013; Kim et al., 2011). They are composed of numerous, autonomous entities that make individual choices, self-organize, and evolve over time (Choi et al., 2001); thereby, affecting each other in multiple ways (Mena et al., 2013; Pathak et al., 2007). For example, a buying firm might be less dependent on a specific supplier if the overall network includes an alternative supplier that can provide the same or a substitute component (Choi & Wu, 2009c); here, the dyadic buyer-supplier relationship is likely to be influenced by other suppliers or links in the network. Accordingly, we must acknowledge that dyads can only provide a rather basic understanding of supply networks. They neglect the fact that buyer-supplier relationships are embedded in a larger context; therefore, they do not allow for an investigation of a network's relational dynamics or the behavior of the various firms therein (Choi & Wu, 2009a, 2009b). It seems that other perspectives are needed to capture the essence of supply networks. My premise is that researchers should move beyond dyadic buyer-supplier relationships.

In this dissertation, I seek to contribute to our understanding of the relationships and impacts that exist beyond the buyer-supplier dyad. Focusing on sustainability and resilience ins supply chains, the enclosed manuscripts cover three different perspectives that extend the dominant dyadic view: (1) multi-tier supply chains, (2) supply chain dyads in a triadic context, and (3) supplier-supplier-relationships in a tetradic context (see Figure 1).

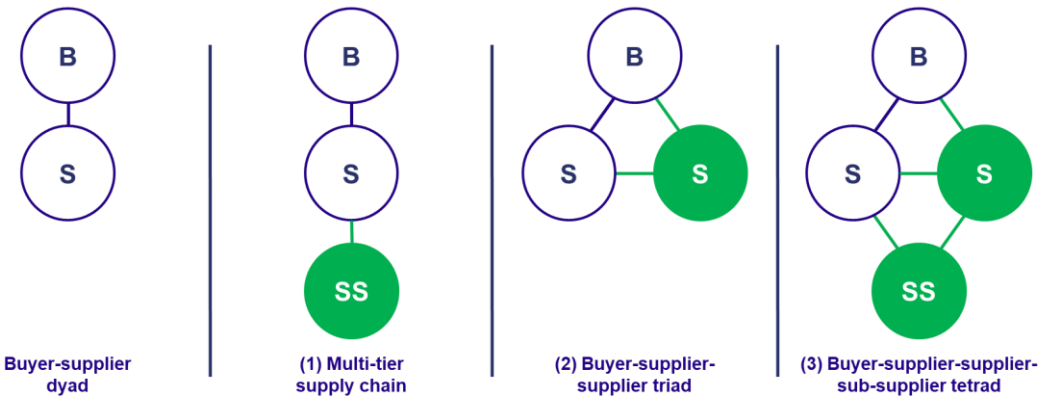

Figure 1: Extensions to the dyadic buyer-supplier view

Manuscript one examines multi-tier supply chains (MTSC) in the German automotive industry to investigate how sustainability measures are implemented and disseminated to upstream entities in a supply chain. Building on organizational change theory (i.e., Lewin, 1947), we inductively analyze a longitudinal sample of 54 sustainability reports (2014-2019) from three MTSC. Our coding procedure reveals the nature and sequence of the most prominently used sustainable supply chain management (SSCM) measures; from this, we develop an exemplary SSCM implementation framework. It adds to our knowledge on the SSCM implementation process and can be used by partitioners to turn their upstream suppliers into sponsors for sustainability.

Manuscript two examines buyer-supplier dyads in a triadic study context to explore how firm-level complexity affects the frequency of disruptions experienced by the buyer. While normal accident theory (NAT) considers complexity to be detrimental for a firm's resilience (Larsen et al., 2013; Perrow, 2011), social system theory (SST) lets us suspect that complexity is a key requisite for dealing with disruptions effectively (Luhmann, 1995; Schneider et al., 2017). Contrasting both theories, we collect and analyze data on 59 extended dyads in a triadic context (i.e., buyer-supplier-supplier triads). Our analysis results show that a supplier's internal and collaborative complexity leads the downstream buyer to experience more disruptions. We confirm our NAT-based assumptions and conclude that the supplier complexity should be

considered when selecting resilient suppliers, especially if the prospective buyer-supplier relationship is characterized by a low level of supplier dependence.

Manuscript three examines supplier-supplier links in a tetradic context to develop a robust measurement scale for horizontal coopetition in supply chains. Emphasizing the limitations of previous operationalizations of coopetition, we argue that horizontal coopetition cannot be assessed with a single construct, but requires the measurement of its two dimensions individually. Accordingly, we perform a systematic, two-phase scale development process to build two multilevel scales, i.e., (1.) *supplier-supplier cooperation* and (2.) *supplier-supplier competition*. Stage one includes a literature on supplier-supplier cooperation. review, structured expert interviews, and a systematic sorting process. Stage two tests our scales' management properties through a field study Therein, we confront participants with a tetradic supply chain disruption scenario (see Durach et al., 2020). The resulting scales – which tests indicate to be both reliable and valid – contribute to our understanding of horizontal coopetition in supply chains and may support related research in future.

The remainder of this dissertation is structured as follows. Section two provides a more profound understanding of the dominant dyadic view in SCM and its limitations. I then offer introduce perspectives that extend the buyer-supplier context. In section three, I provide a brief overview of the main content of each manuscript and show how the extended perspectives were applied. After summarizing the manuscripts' current state of publication in section four, subsequent section five discusses each manuscript's individual contributions and how they benefited from the extended perspectives. Finally, the work closes with a brief summary of the dissertation's findings, limitations, and potential for future research.

2. Literature review

Previous literature has often focused on dyadic buyer-supplier relationships, with related works laying the very foundation of the SCM domain. Notwithstanding their important contributions to our discipline, the examination of dyads incurs some rather strict limitations. The following section serves to highlight these limitations and to introduce alternative perspectives that extend the dominant dyadic view.

2.1. The dyadic view in supply chain management and its limitations

Buyer-supplier relationships involve two types of firms: (1.) *buyers* that purchase certain products or services to manufacture, further possess, market, or distribute their own products or services in later steps of the supply chain, and (2.) *suppliers* that sell the required materials, intermediate products, or services. Accordingly, dyads representing such relationships are built from two nodes (one for the buyer and one for the supplier) and the link connecting both firms (Choi & Wu, 2009b, 2009c). Related research usually investigated how one node affects the other, and vice versa (ibid).

Choi and Wu (2009b) emphasized that this dyadic research tradition contributed to our knowledge on the fundamental characteristics and mechanisms of supply chains, such as cooperation, trust, and commitment. Building on transaction cost economics, for example, we learned why and how transactions between buyers and suppliers occur in the first place (ibid) – in a similar manner, numerous other dyadic works have expanded our understanding on how supply chains operate (e.g., Ahmed et al., 2017; Cánez et al., 2000; Huang & Keskar, 2007; Humphreys et al., 2004; O'Toole & Donaldson, 2002). Even today, much can be learned by studying dyads (Dubois, 2009), unless the guiding research question demands a broader context (Choi & Wu, 2009a). Studies that particularly examine the dynamics between two parties only (e.g., how a buyer evaluates hi supplier's performance) can use dyads to block out unwanted complexity; thereby, focusing on the dyadic mechanism in which they are most interested (Choi et al., 2001; Dubois, 2009; Mena et al., 2013).

Notwithstanding the valuable insights and benefits of related research in the SCM domain (Beamon, 1998; Pathak et al., 2007; Vonderembse et al., 2006), the dyadic perspective remains subject to two essential limitations: (1.) dyads do not account for the relational dynamics caused by third parties inside a supply chain, and (2.) dyads cannot explain the behavior of individual firms within a network (Choi & Wu, 2009b, 2009c).

First, by limiting our investigation to dyadic buyer-supplier relationships, we automatically imply that these relationships do exist completely independent from any other entities or relationships within the supply chain (e.g., horizontal supplier-supplier links, or vertical supplier-sub-supplier links) (Choi et al., 2002). This overlooks the fact that both the buyer and the supplier are often embedded within a much larger supply network (ibid). As both firms are viewed in isolation (Choi & Wu, 2009b), we can neither obtain information on how a third party might affect the buyer, the supplier, or their joint relationship (Choi & Wu, 2009a; Mena et al., 2013); nor can we investigate how the buyer might actively manage such relational dynamics to its own advantage (Mena et al., 2013; Wu et al., 2010). Consequently, we ignore an essential part of the supply chain's true complexity (Choi & Wu, 2009b, 2009c). This is particularly problematic given that our modern supply chains are best understood as complex and dynamic networks (Choi et al., 2001; Hearnshaw & Wilson, 2013; Kim et al., 2011).

Second, by examining dyadic buyer-supplier relationships, we can gain little knowledge on how the firms themselves behave within a network (Choi & Wu, 2009b, 2009c). Choi and Wu (2009c) argue that "to capture the essence of a network, one must be able to study how a link affects another link […] (and) how a node affects another link that it is not directly connected to" (p. 10). Since dyads do not meet these minimum requirements, more than two firms are needed to illustrate the quintessential dynamics of a network (Choi & Wu, 2009b; Mena et al., 2013) – only then can we draw reliable conclusions about the behavior and decision-making of the self-autonomous firms therein (Choi & Wu, 2009c; Mena et al., 2013; Pathak et al., 2007). For example, a buyer's sourcing decision is likely to vary across different research contexts in which we either study only one available supplier or two alternative suppliers for the

same or substitutive components (Choi & Wu, 2009c). In each context, resource dependencies or power balances may differ (ibid), possibly leading to divergent firm behavior.

In summary, we acknowledge that we have learned much from previous dyadic SCM research (Pathak et al., 2007). Even today, there are few unanswered research questions for which a dyadic study design is well suited (Choi & Wu, 2009a; Dubois, 2009). However, as modern supply chains have turned into dynamic and complex networks (Choi et al., 2001; Hearnshaw & Wilson, 2013; Kim et al., 2011), the overwhelming focus on dyadic buyer-supplier relationships does not reflect the reality and the challenges managers face today (Choi & Wu, 2009b, 2009c). In fact, firms are affected by third parties within their supply chains and must act within a network context (ibid) – this requires an extended and more realistic view of supply relationships. Accordingly, researchers are recommended to move beyond the dyadic view in SCM (Choi et al., 2002).

2.2. Extended perspectives beyond the dyadic view

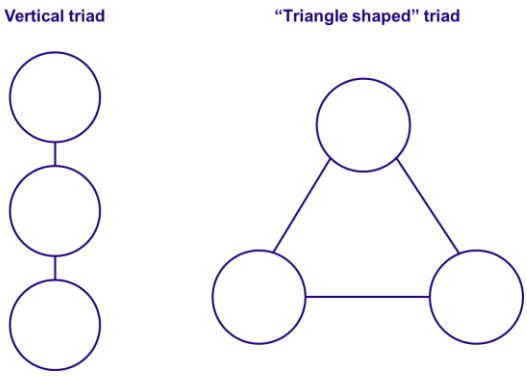

Figure 2: Structural arrangements of triads (see Mena et al., 2013)

Given the prevailing limitations of dyads, a growing number of scholars has advocated for the exploration of broader study settings that extend the dominant dyadic view (e.g., Choi & Wu, 2009b, 2009c; Durach et al., 2020; Madhavan & Gnyawali, 2004; Mena et al., 2013; Wu et al., 2010). In this regard, a particular focus has been placed on the study of so-called "triads"; that

is, the next logical extension of the dyad by including one more supply chain entity (Choi & Wu, 2009a) (see Figure 2).

The German sociologist Simmel (1950) was among the first to point out the differences between dyads and triads. Over time his theoretical arguments have been further developed by numerous scholars, with Caplow (1959, 1968) being one of the most influential contributors (Choi & Wu, 2009b). In essence, they argue that the relationship between two individuals (dyad) can be affected by a third individual that extends the previous setting and becomes an integral part of the emerging network (triad) (Caplow, 1968; Simmel, 1950). Within the triadic network, each entity acts self-autonomous, while the actions taken by one individual exert significant influence on the other individuals and their relationships with one another (Choi & Wu, 2009b, 2009c) – whether deliberately or without the intention to do so; thereby, these interdependencies significantly increase the network's complexity (ibid). Although this theory originally sought to explain an individual's behavior, many scholars have stressed that such triadic dynamics also apply to different organizational levels (i.e., to firms or nations) (Caplow, 1959, 1968; Choi & Wu, 2009b; Mills, 1954, 1958). Notwithstanding the fat that the application of theories from the social or psychological domain to the context of organizations should always be undertaken with due caution (see Whetten et al., 2009 for a discussion on the use of socio-psychological theory in organizational studies), some scholars have already contributed to our knowledge on supply networks by examining triads based on theoretical perspectives such as complex adaptive systems (CAS) theory (e.g., Choi et al., 2001; Pathak et al., 2007), game theory (Shi et al., 2014; e.g., Wu et al., 2010), balance theory (e.g., Choi & Wu, 2009c), or social exchange theory (e.g., Durach et al., 2020), among others. Triads could therefore be a useful tool to extend the dyadic view in SCM and account for the complex dynamics of today's supply networks (Choi & Wu, 2009b).

Indeed, triads offer some very distinct advantages over dyads. While they too avoid the overwhelming complexity of a complete supply network, triads do not inherit the downsides of dyads mentioned above (Mena et al., 2013). In line with the minimum requirements of a

network outlined by Choi and Wu (2009c), triads allows us to examine whether one link can affect other links in the network and whether one node can affect such links to which it is not directly connected to (ibid); thus, triads are the smallest unit of analysis available that can map the essential dynamics of a network (Choi & Wu, 2009a, 2009b). In other words, the triad allows us to examine how a third party within a supply chain can influence the other entities as well as their relationships among each other (ibid). It also allows us to make more reliable assumptions about the behavior and decision-making of firms in networks (Mena et al., 2013; Pathak et al., 2007). Using triads, we can for example examine whether cooperative efforts between two same-tier suppliers can protect their common buyer from upstream disruptions (Durach et al., 2020) (i.e., the buyer-supplier-supplier triad), or we can examine the buyer's in adapting supply chain sustainability measures across multiple tiers (i.e., the buyer-supplier-sub-supplier triad) (Wissuwa & Durach, 2021). Consequently, although triads still continue to be a simplified representation of the entire supply network (Dubois, 2009), they are more than "just" a conglomerate of two or three dyads (Choi & Wu, 2009a). Rather, by combining several dyads in a triad, we can explore entirely new network dynamics; accordingly, Choi and Wu (2009b) have argued that "triads […] are the fundamental building block of a network" (p. 265). They allow for a more nuanced and realistic view of supply chain relationships (Wu et al., 2010).

Given these advantages, a growing number of researchers started to theorize on and empirically investigate supply chain triads (Choi & Wu, 2009b, 2009c; e.g., Durach et al., 2020; Madhavan & Gnyawali, 2004; Pathak et al., 2007; Peng et al., 2010; Ried et al., 2021; Shi et al., 2014; Wu & Choi, 2005). Building on their novel groundwork, I distinguish between different contexts that extend buyer-supplier dyads: e.g., (1) multi-tier supply chains, (2) buyer-supplier-supplier triads, and (3) buyer-supplier-supplier-sub-supplier tetrads. Below, I will describe each of these three configurations in more detail and show how they have been applied in my research projects.

3. Description of the research projects

This cumulative dissertation comprises three research manuscripts (see Table 1). While the underlying research questions and methods differ for each manuscript, they all explore issues related to sustainability and resilience in SCM by adopting a perspective beyond the dominant dyadic view. In the following chapter, I will provide a brief overview the main content of each manuscript and outline how all three projects applied an extended supply chain perspective.

Nr.	Title	Authors	Journal	Status	Points
1	Turning German automotive supply chains into sponsors for sustainability	Wissuwa, F. Durach C.F.	Production Planning & Control	Published	**1,25**
2	Selecting resilient suppliers: Supplier complexity and buyer disruption	Wissuwa, F. Durach, C.F. Choi, T.Y.	International Journal of Production Economics	Published	**1,33**
3	Horizontal coopetition in supply chains: Scale development and empirical examination	Wissuwa, F. Durach C.F.	Working paper		
	Total Points				**2,58**

Table 1: Overview of the dissertation project

3.1. Sustainable supply chain management in multi-tier supply chains

3.1.1 Project summary. To develop and sustain competitive advantage, many focal manufacturing firms established highly efficient supply chains that can span all across the globe (Bozarth et al., 1998; Mol, 2003). While this development in many cases has proven to increase their financial performance (Skjott-Larsen et al., 2007), it has often also caused the focal firms' supply chains to become untransparent and vulnerable to sustainability breaches (Hofmann et al., 2014) – with potentially severe consequences for both a firm's reputation and performance (Hoejmose et al., 2014). The Volkswagen manipulation scandal may serve as a prime example for the undesirable effects of such sustainability breaches (Jung & Sharon, 2019). Being

convicted of the manipulation of emission values in 2014, the stock of Volkswagen AG lost 40% of its value within only two weeks. The firm incurred a loss of approximately 32 billion euro (Menzel, 2020) and moreover caused a substantial loss of customer and shareholder trust for the whole industry (Jung & Sharon, 2019).

Different structural changes in the German automotive industry led to this scandal. Exploring new segments and regional markets, car manufacturers were able to substantially increase their revenues, but at the same time also faced higher cost-pressures (Thun & Hoenig, 2011). As a consequence, the firms began to outsource large parts of their production and R&D activities to upstream suppliers (Jüttner et al., 2003). Moreover, manufacturing plants were relocated to low-cost countries and cost-efficient processes (e.g., just-in-time production) were widely implemented (Svensson, 2004; Thun & Hoenig, 2011). While these measures indeed increased the supply chain's efficiency on financial terms, the achieved cost advantages did come at a price. Both the relocation and restructuring of supply led to the formation of complex and untransparent supply chains (Christopher & Holweg, 2011). Although the focal firms more and more relied on their supply network, they possessed less knowledge about the upstream processes than ever before (Steven et al., 2014). Hidden from the focal firms' views new und unforeseen social risks arose, with German automotive supply chains becoming more vulnerable and prone to sustainability breaches (Hofmann et al., 2014; Thun & Hoenig, 2011).

Possibly as a response to this development and the emission scandal in 2014, many German automotive firms raised their efforts to implement SSCM practices in their upstream supply chains. According to Seuring and Müller (2008), SSCM practices aim for the "management of material, information and capital flows […] along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account" (p. 1700). As such, they might be a useful tool to address rising stakeholder demands (Dubey et al., 2017) and to avoid sustainability breaches in future. Unfortunately, however, their implementation represents a daunting task (Benn et al., 2014). It requires firms

to break up existing structures and to undergo a substantial change process (ibid). Notwithstanding this great challenge, research on SSCM implementation remains surprisingly scarce (Touboulic & Walker, 2015). Although a few studies to date have examined isolated measures (e.g., Gopal & Thakkar, 2016; Shibin et al., 2018; Zimon et al., 2019), our knowledge on the steps and the frequency of the overall SSCM implementation processes is strictly limited – practitioners are left with hardly any guidance on how to establish sustainable practices within their supply chains. Touboulic and Walker (2015) thus encouraged researchers to "develop our understanding of the implementation process of SSCM by farming it as change in organizational practice "(p. 35).

Answering their call, we utilized the fundamentals of organizational change theory to examine the steps and sequence of SSCM implementation in the German automotive industry. For this purpose, we systematically analyzed 54 sustainability reports (2014-2019) form three vertical supply chain triads (i.e., MTSC). We identified nine core measures and thereof developed a framework that depicts the most prominent phases and steps of the SSCM implementation process. The framework sheds light on the underexplored aspects of SSCM and may serve as an example for practitioners on how to turn their supply chains into sponsors for sustainability.

3.1.2 Extended perspective: To investigate SSCM implementation across multiple tiers, we collected data on buyer-supplier-sub-supplier triads (see Figure 3). Our MTSC were built by following a two-step sampling approach.

First, we aimed to identify focal firms that could serve as the head of the vertical triad. Next to operating in the German automotive sector, the firms were required to have published sustainability reports that adhered to the guidelines of the Global Reporting Initiative (GRI) from 2014 to 2019. Further, the focal firms had to be industry leaders in reporting their sustainability efforts – as stated in the 2018 CSR report ranking of the German Institute for Ecological Economy Research (IÖW) (Dietsche et al., 2019) – to facilitate the selection of information-

rich cases. Based on these requirements, we chose the OEMs *Volkswagen AG*, *Bayerische Motorenwerke AG*, and *Daimler AG* as our focal firms.

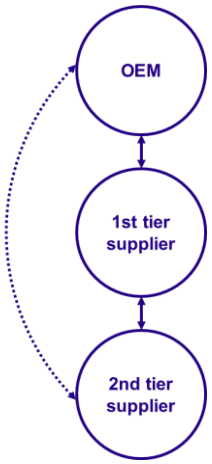

Figure 3: Vertical buyer-supplier-sub-supplier triad

Second, the OEMs' suppliers were identified by using the Bloomberg supply chain algorithm. The algorithm examines different data sources (financial, end market channel, or product-level data) to identify, list, and rank a firm's existing supply relationships. Of these, we chose one first-tier supplier each that (1) belonged to the respective OEMs top ten suppliers (as by the supplier's share of the OEMs overall purchasing volume), (2) was headquartered in Germany, and (3) published GRI sustainability reports in the period under examination. The suppliers *Continental AG*, *ZF Friedrichshafen AG*, and *Robert Bosch GmbH* adhered to these criteria and were thus added to our sample. Finally, we employed the Bloomberg algorithm again to select second-tier suppliers as well; however, this time the firm selection was based on the analysis of our already chosen first-tier suppliers. Matching firms again had to be headquartered in Germany. Moreover, they were not allowed to be simultaneously listed as a one of the ten most important direct OEM suppliers. Given these criteria, the second-tier suppliers *Infineon Technologies AG*, *Schaeffler AG*, and *Hella KGaA Hueck & Co.* completed our three MTSC.

The chosen MTSC study design gave us the opportunity to not only evaluate the focal firm's efforts to implement SSCM, but to also investigate how the SSCM requirements were

forwarded to more upstream supply chain entities. In other words, the triadic perspective allowed us to investigate the "middleman" role of the first-tier supplier, and in which cases the focal firm rather preferred to directly communicate with the second-tier supplier; thereby, we could explore the relational dynamics and the firm behavior across multiple tiers within the context of SSCM (Mena et al., 2013).

3.2. Supplier complexity in a triadic context

3.2.1 Project summary. As focal manufacturing firms started to outsource major parts of their value creation, they often managed to increase their performance; however, they also became highly dependent on their upstream supply network (González-Benito, 2007; Gray et al., 2020). While this dependence seems to be largely unproblematic in stable situations, disruptive events such as the recent COVID-19 crisis exemplified the potential downsides of this development. Caused by the pandemic, a majority of 90% of the German manufacturing firms struggled to maintain their productions due to severe supply shortages (Deloitte, 2022). For example, Volkswagen's production lines were interrupted as their Chinese suppliers were not able to provide required batteries and semiconductors in sufficient quantity and time (Sneci, 2021). Selecting a both efficient and resilient supplier that can withstand disruptions has thus emerged as an important task.

Supplier selection is a demanding challenge that already attracted much interest in the scientific community. Previous authors recommended selection criteria such as certifications, ethical standards, delivery lead times, financial stability, inventory and packaging cost, product price, strategic fit, and so forth (e.g., Adeinat & Ventura, 2018; Alikhani et al., 2019; Chai & Ngai, 2015; Govindan et al., 2018; Noori-Daryan et al., 2019; Sarkis & Talluri, 2002) (see Huang and Keskar (2007) for a good overview). Notwithstanding the importance of such selection criteria, previous research for the most part focused on indicators that improve firm performance in terms of quality, flexibility, and cost. Resilience in turn remained largely

neglected (Hosseini et al., 2019). We identified and examined one criterion in this regard that yet received little attention: the supplier's complexity.

According to Simon (1962), complexity can be determined by a system's structure and behavior. Following his argumentation, we conceptualize supplier complexity as a combination of the firm's internal structure (internal complexity) and the collaborative links established with another supplier (collaborative complexity). Internal complexity is assessed by the individual supplier's number of departments, hierarchical levels, and specialist roles (Blau & McKinley, 1979; Damanpour, 1996; Larsen et al., 2013), while collaborative complexity is assessed by the intensity of consolidated business activities, information exchange, and joint decision making that take place between two suppliers (Wu et al., 2010). We speculate that both types of complexity affect the firm's ability "to persist, adapt, or transform in the face of change" (Wieland & Durach, 2021, p. 316). Interestingly, two opposing, theoretical views to this relationship exist: while NAT lets us speculate that complex suppliers are more prone to disruptions (Perrow, 2011), SST denotes complexity a key requisite for the efficient handling of disruptions (Luhmann, 1995; Schneider et al., 2017).

Given these contrasting views, we investigate the effect of supplier complexity on buyer disruption. In other words, we ask if a buyer should select suppliers with either high or low complexity to better cope with occurring supply disruptions. Further, we examine whether the disruption efficacy is more important in supply relationships that are characterized by either high or low degrees of supplier dependence, respectively.

For this purpose, we collected dyadic data within a triadic study context that involves two horizontally connected suppliers and their joint buyer. In total, 59 extended buyer-supplier relationships were built from the responses of 118 German manufacturing firms. Performing a 2SLS IV Poisson regression, we found that internal and collaborative complexity each led to a higher number of disruptions experienced by the buyer. This effect was amplified in settings of low supplier dependence. We conclude that a supplier's number of hierarchies, specialist roles,

and collaborative actions constitute relevant supplier selection criteria, especially if prospective buyer-supplier relationships are characterized by low levels of supplier dependence.

3.2.2 Extended perspective: To explore the relationship between supplier complexity and disruption occurrence, we collected data on dyadic buyer-supplier relationships within a triadic study context (see figure 4). Our data collection was carried out in two steps: pre-screening and survey.

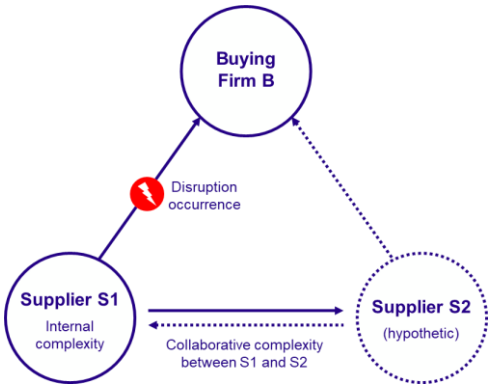

Figure 4: Buyer-supplier dyads in a triadic context

The pre-screening served to upfront identify a triadic relationship context. For this purpose, we first contacted the buyer directly. Given that the buyer's key informant worked in the firm's purchasing department and possessed at least two years of relevant work experience, he/she was asked to provide information in two same-tier suppliers that fulfilled the following three criteria: (1) both suppliers produce different, but complementary components that go into the same end-product of the buyer, (2) both suppliers are located in Germany, and (3), finally, both suppliers have established a business relationship that has existed for a minimum of two years. The first criterion was supposed to establish a context of collaboration between both firms. The second criterion ensured a similar cultural context, while the third criterion indicated a steady state of the relationship under investigation. Based on these requirements, buyers provided details on such triadic setting that existed in their own supply networks.

Once a feasible triadic context was identified, we proceeded with the actual data collection. First, the buyer's informant was provided with a link to the online survey, which covered

data on the buyer itself and on both of its suppliers. After we received a complete response, we sought to subsequently contact the named suppliers. Given existing data privacy regulations, the buyers' informants unfortunately were not allowed to share the suppliers' contact details without their prior consent; however, informants could directly forward the survey link to the supplier to ask for their participation in our study. Supplier respondents likewise needed to possess at least two years of relevant work experience. In addition, they were required to be knowledgeable about their firm's relationship with both the buyer and the other supplier. If both criteria were met, they were provided with a supplier-specific survey that also covered information on all three parties of the triad. The complete responses from the buyer and the supplier were merged to thereof develop datasets that covered the whole triadic supply chain context. In total, a dataset consisting of 59 triadic supply chain settings was built from the responses of 118 German manufacturing firms.

The triadic study context enabled us to not only assess the supplier's internal complexity but to also measure collaborative complexity and its impact on the buying firm. We found that collaborative complexity – which is only considered an indirect link to the buyer - affects the focal firm, just as internal complexity does. Moreover, these effects varied based on the degree of supplier dependence in the buyer-supplier link. Apparently, the different nods and links in the triad influenced each other in multiple ways. Our triadic perspective was imperative to uncover these complex dynamics and to provide reasonable guidance for firms to use supplier complexity as a selection criterion.

3.3. Supplier-supplier coopetition in a tetradic context

3.3.1 Project summary. Research and practice provided evidence that horizontal supply chain relationships matter, both for the supplier (e.g., Durach et al., 2020; Massari & Giannoccaro, 2021; Wu et al., 2010) and the buyer (e.g., Durach et al., 2020; Dyer & Nobeoka, 2000; Wissuwa et al., 2022; Wu et al., 2010; Wu & Choi, 2005). During the recent COVID-19 pandemic, for example, suppliers in the UK food industry joined forces to keep up supply (OECD,

2020). They shared information regarding stock levels, product shortages, or available logistic capacities. Doing so, they were able to pool resources as well as to limit and manage supply accordingly (ibid). In the same vein, a recent study from the German Fraunhofer institute too emphasized that close ties between suppliers increased their ability to withstand the turbulences caused by the pandemic (Nikelowski et al., 2021). It seems that harnessing the potential of horizontal relationships becomes a powerful tool to manage the "new normal" (ibid).

Previous research often examined horizontal relationships in supply chains from a so-called "coopetition" perspective (e.g., Choi & Hong, 2002; Durach et al., 2020; Wu et al., 2010). Coopetition is an artificial word that describes paradox inter-firm relationships which are characterized by the simultaneously existence of cooperation and competition (Brandenburger, 2011; Chai et al., 2019). It has been found to often occur in horizontal relationships between firms that are members of the same supply chain but compete for similar customers and markets at the same time (Durach et al., 2020; Wu et al., 2010). Accordingly, we define horizontal coopetition as a *relationship between two horizontally connected firms that is characterized by the simultaneous existence and interplay of two interrelated dimensions; namely, cooperation inside a supply chain and competition on markets outside of that supply chain*. Previous studies showed that such relationships can have both positive (e.g., information exchange, knowledge sharing, resource pooling) and negative (e.g., conflict, opportunism) implications for the involved firms (Fernandez et al., 2014; Liu et al., 2014). Nevertheless, we lack a sufficient understanding of the mechanisms and importance of coopetition, with the few related studies using different operationalizations of coopetition.

Although the simultaneous existence of cooperation and competition is commonly recognized as a core element of coopetition (e.g., Chai et al., 2019; Durach et al., 2020; Eriksson, 2008; Liu et al., 2014; Wu et al., 2010), its operationalizations in related SCM literature differ. Eriksson (2008) for example operationalized coopetition as a one-dimensional continuum. The continuum ranges from states of pure cooperation to pure competition, with mixed cooperation-competition combinations in between both extremes. Wu et al. (2010) in turn measured

coopetition as the collaborative efforts between competitors, while Liu et al. (2014) used a 2x2 matrix to assess and distinguish between distinct coopetition types. Without questioning the important contributions of these works, this study seeks to contribute to our knowledge on coopetition by highlighting the limitations of previous operationalizations. We offer a revised operationalization that addresses the existing limitations and can be used for the building, testing, and refining of coopetition theory in future.

For this purpose, we first develop four necessary conditions for the measurement of coopetition. We use these conditions to identify the limitations of existing operationalizations; and thereof, to present a revised operationalization. We argue that coopetition cannot be assessed by a single construct but requires two multiple scales – one for the cooperation and competition dimension respectively. Both scales are developed through a structured, two-stage approach. Stage one encompasses the review of previous SCM literature, structured expert interviews, and a sorting procedure. Stage two includes the replication of a previous coopetition study (Durach et al., 2020) to test the measurement properties of our new constructs. The two measurement scales – which tests indicate to be reliable and valid – contribute to the growing measurement stream in the supply chain domain. They can be used by other researchers to tap into the potential and risks of coopetition and to provide more reliable recommendation for managers in the long run.

3.3.2 Extended perspective: Our investigation followed the basic premise that horizontal relationships (e.g., supplier-supplier relationships) matter to both the supplier itself and to the buyer. Such complex interrelationships cannot be represented in a dyad but require a more complex context. Repeating the study of Durach et al. (2020), we employed a tetradic supply chain setting that involved a common buyer, two same-tier suppliers, and a hypothetical sub-supplier (see figure 5). Focusing on horizontal relationships we first selected cases of supplier-supplier coopetition and then expanded our perspective by providing a tetradic disruption scenario.

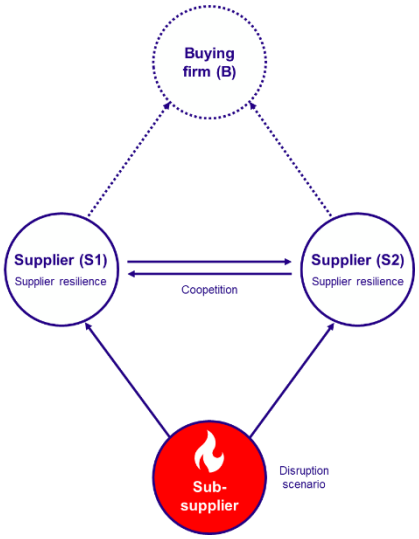

Figure 5: Horizontal supplier-supplier relationships in a tetradic context

Having obtained a verified address list from an external provider, we contacted manufacturing firms in the DACH region (of different size and industry) via e-mail or phone. Potential respondents were asked to name a firm [X] on the same tier-level that adhered to the following criteria: (1.) both firms must offer an at least partly similar product portfolio, and (2.) both firms must have a joint history of collaboration. While we acknowledge that these criteria did not ensure certain states of coopetition, they might still have facilitated the selection of coopetition relationships. In addition, the respondents themselves were required to be actively involved in purchasing decisions, possess no less than two years of relevant work experience, and be knowledgeable about firm [X]. If all criteria were met, the respondents received a link to the online survey that included our measurement scales and the disruption scenario.

While we started with the selection of horizontal dyads, the developed disruption scenario extended our context to a tetradic supply chain setting. In the given constant variable value vignette (CVVV), the respondents were confronted with a disruption that originated from an upstream sub-supplier and affected both the two suppliers and their downstream buyer (Ambulkar et al., 2015; Chowdhury & Quaddus, 2016; Durach et al., 2020). The scenario was described as follows: *"At 11:00 p.m. on a Saturday night in late August, a fire hits the production facilities of a supplier that is common to you and firm [X]. You consider the supplier a key*

supplier as it supplies critical parts that go into your product for customer [C]. The fire, caused by a faulty electrical outlet and the lack of safety features at the supplier (i.e., fire detection and suppression systems), spread across the entire plant. Consequently, the supplier will be down for at least five months". Based on this CVVV, the respondents were asked how well they could handle the described event – if feasible through joint efforts with firm [X].

Our tetradic study design offered an opportunity to investigate horizontal supplier-supplier relationships and their influence in case of an occurring disruption. By adding an upstream sub-supplier who triggered the disruption scenario, we were able to create a more realistic CVVV that accounts for the dependencies between firms along different supply chain levels. Moreover, we could examine how firm behaviors such as horizontal coopetition mitigated the impacts of the fire outbreak. Our results showed that horizontal cooperation improved firm resilience, while simultaneous market competition obstructed this effect. It appears that interactions between suppliers on the same tier-level influence processes along the supply chain. They matter and should – potentially with the help of our developed scales – be examined in more detail, which requires perspectives beyond the dyadic buyer-supplier view.

4. Overview of the research manuscripts

In this chapter, I briefly outline the specifications and publication status of each project.

4.1. Research manuscript 1

Abstract: In recent decades, supply chains have become a critical source of competitive advantage. Yet, in the German automotive industry, supply chains have turned out to be untransparent and prone to sustainability breaches, with the recent Volkswagen manipulation scandal exemplifying the financial and reputational consequences. Many firms today, therefore, focus on what is called *sustainable supply chain management* (SSCM). While drivers, barriers, and performance implications of SSCM have been widely explored, little is known about its implementation process. Building on the foundations of organizational change, this study inductively analyzed 54 sustainability reports from three German automotive triads between 2014 and 2019. Our results led to an SSCM implementation framework that sequentially employed the nine most prominent implementation stages and related change measures. The framework expands our knowledge on the SSCM implementation process; furthermore, it serves as an example for industry experts aiming to turn their supply chains into sponsors for sustainability.

Research manuscript 1	
Title:	Turning German automotive supply chains into sponsors for sustainability
Authors:	Florian Wissuwa, Christian F. Durach
Conferences:	none
Status:	Published in *Production Planning & Control*
Journal ranking:	2 (Comité National de la Recherche Scientifique [CNRS], June 2020)
Citation:	Wissuwa, F., & Durach, C. F. (2021) Turning German automotive supply chains into sponsors for sustainability*. Production Planning & Control*, 290(1), pp.1-14.
DOI:	https://doi.org/10.1080/09537287.2021.1893405

Table 2: Publication status of research manuscript 1

4.2. Research manuscript 2

Abstract: Supplier selection has long-term performance and competitive consequences for the buying firm – it affects businesses in stable situations and in times of uncertainty. Our discipline has thus sought to identify selection criteria to choose both efficient and resilient suppliers. One unnoticed criterion in this regard is supplier complexity and the relationship between firm-level complexity and disruption occurrence. Normal accident theory suggests that complex firms are more susceptible to disruptions; by contrast, social system theory considers firm-level complexity a key requirement for disruption prevention. Recognizing these two opposing viewpoints, this study explores whether and how supplier complexity af-fects disruptions experienced by downstream buyers. We collected survey data from buyer-supplier dyads in the triadic context from 118 German manufacturing firms. The results show that both a supplier's internal complexity and its collaborative complexity with another supplier drive disruption frequencies experienced by the buyer. High levels of supplier dependence dampen this effect. These findings introduce firm complexity as a relevant supplier selection criterion, especially in supply relationship that are characterized by low supplier dependence.

Research manuscript 2	
Title:	Selecting resilient suppliers: Supplier complexity and buyer disruption
Authors:	Florian Wissuwa, Christian F. Durach, Thomas Y. Choi
Conferences:	28th EurOMA Conference (held online)
Status:	Published in *International Journal of Production Economics*
Journal ranking:	1 (Comité National de la Recherche Scientifique [CNRS], June 2020)
Citation:	Wissuwa, F., Durach, C. F., & Choi T. Y. (2022) Selecting resilient suppliers: Supplier complexity and buyer disruption. *International Journal of Production Economics*, 108601.
DOI:	https://doi.org/10.1016/j.ijpe.2022.108601

Table 3: Publication status of research manuscript 2

4.3. Research manuscript 3

Abstract: Practice and research suggest that supplier-supplier relationships matter to both the suppliers themselves and to their buyer. These relationships have often been described as a "coopetition"; however, our knowledge on how coopetition affects firms and their supply chain is still rudimentary, which in parts might be due to the different operationalization used. In this study, we seek to contribute to our knowledge on the relevance and traits of coopetition. We introduce four necessary conditions for the measurement of coopetition which are used to evaluate three coopetition operationalizations of previous empiri-cal works. A revised operationalization that addresses existing limitations is provided. We then perform a two-stage approach to develop two corresponding measurement scales. The first stage encompasses a literature review, structured expert interviews, and a sorting pretest. The second stage aims to test the measurement properties of our scales by replicating a study on supplier-supplier coopetition. The test results show that our new scales have sufficient psy-chometric properties. As reliable and valid metrics are a pre-requisite for theory development and testing, our measurement scales might help other researchers to build, test, or refine sup-ply chain strategy paradigms. They add to the growing SCM measurement stream and can be applied in future empirical studies on coopetition in supply chains; thereby, facilitating more reliable normative implications for academics and managers in the long run.

Research manuscript 3	
Title:	Supplier-supplier coopetition in supply chains: Scale development and empirical examination
Authors:	Florian Wissuwa (corresponding author), Christian F. Durach
Conferences:	none
Status:	Working paper
Journal ranking:	n.a.
Citation:	n.a.
DOI:	n.a. (available upon request)

Table 4: Publication status of research manuscript 3

5. Discussion

Given the existing limitations of dyads, all three research projects included in this dissertation took an extended perspective on supply chain relationships. In particular, they examined contexts of MTSCs, buyer-supplier-supplier triads, and tetradic disruption scenarios. In the following, I will briefly outline each projects individual finings and contributions. Thereafter, I highlight how the extended perspectives in these studies helped to overcome the limitations of dyads.

5.1. Main contributions of each project

5.1.1 Project one: In the first research project, we examined how firms in the German automotive industry implemented SSCM practices within their supply chains. For this purpose, we analyzed 54 sustainability reports from three different MTSCs. Our results led to the identification of nine prominent measures that served to develop an exemplary SSCM implementation framework (see figure 6).

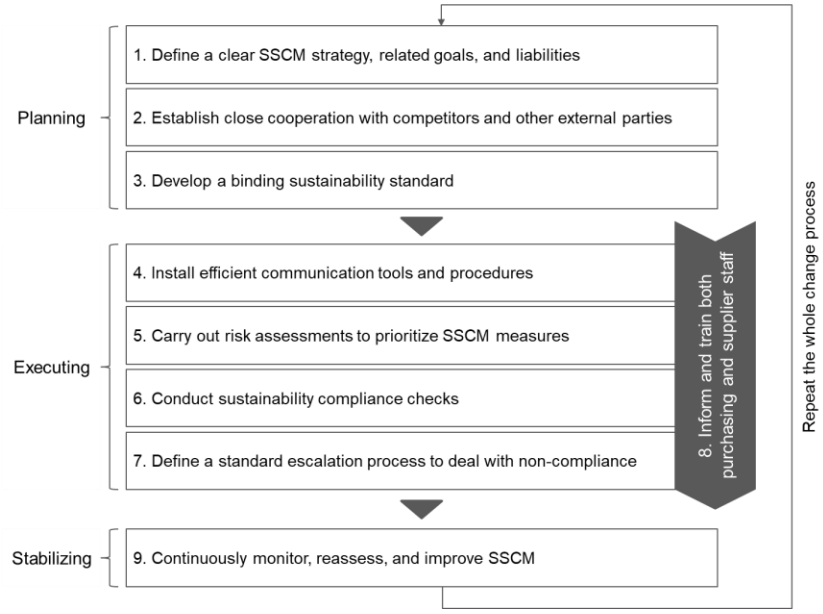

Figure 6. SSCM implementation framework

The framework is subdivided into three different phases: planning, executing, and stabilizing. The “planning stage” marks the start of the SSCM implementation process and serves to break up existing structures, routines, and beliefs to prepare the upcoming change (Burke,

2018). It consists of the following three steps: (1) define a clear SSCM strategy, related goals, and liabilities; (2) establish a close cooperation with competitors and other external parties; and (3) develop a binding sustainability standard. The subsequent “executing stage” includes the intermediate measures needed to perform the desired change. Its goal is to familiarize all affected parties – both internal and external – with the newly developed guidelines and processes (Burke, 2018; Lewin, 1947). It consists of the following five steps: (4) install efficient communication tools and procedures; (5) carry out risk assessments to prioritize SSCM measures; (6) conduct sustainability compliance checks; (7) define a standard escalation process to deal with non-compliance; and (8) inform and train both purchasing and supplier staff. Finally, the “stabilizing phase” concludes the SSCM implementation process as it aims to deeply anchor the new beliefs, goals, and processes within the organization (ibid). It consists of one step: (9) continuously monitor, reassess, and improve SSCM. Having performed these steps, the overall change process needs to be repeated and put to the test regularly – it constitutes a recurring cycle of evaluation and adaption.

The developed framework contributes to both theory and practice. First, it enriches our limited knowledge on the steps and sequence of the SSCM implementation process. While we can confirm previous research that identified singular implementation measures (such as conducting supplier assessments (Xu et al., 2019; Zimon et al., 2019) or the training of employees (Brix-Asala & Seuring, 2020; Wu & Pagell, 2011)), our results also point at yet under-explored aspects of the change process. Among others, this includes the important role of cooperation between competitors (i.e., coopetition), the development of governance structures, the formulation of countermeasures against non-compliant behavior, and the ongoing verification of initial SSCM tools and practices. We encourage other research to examine these aspects, whereby they could deepen our understanding of SSCM implementation. Second, the developed framework can serve as an example for managers that need to implement or retrospectively assess and improve their own SSCM implementation efforts. It supports executives with

a structured, chronological sequence of implementation measures as well as different practice examples that demonstrate how to turn their own supply chains into sponsors for sustainability.

5.1.2 Project two: In the second research project, we introduced supplier complexity as a relevant criterion for the selection of resilient suppliers. Having analyzed 59 dyads in a triadic buyer-supplier-supplier context, we found that both internal and collaborative complexity increased the number of buyer disruptions; thereby, we confirmed our NAT-based assumption that complexity harms the supplier's ability to handle upstream disruptions (Larsen et al., 2013; Perrow, 2011). Interestingly, our robustness checks further showed that not all dimensions of internal complexity influence disruption numbers equally. While horizontal and functional complexity alone yielded more disruptions, vertical complexity did not report such effects. We recommend a more differentiated view on complexity when selecting suppliers, especially in settings of low supplier dependence.

Both theoretical and practical implications can be drawn from the above findings. We assessed a firm's internal complexity by its number of hierarchies, specialist roles, and departments (Blau & McKinley, 1979; Damanpour, 1996; Larsen et al., 2013). We find that, all else being equal, higher numbers of internal units cause a higher number of disruptions to be forwarded to the buyer. We speculate that this effect is caused by inefficiencies, delays, misinterpretations, or conflicts that arise from the information exchange across multiple unit boundaries (A. Marley et al., 2014; Larsen et al., 2013; Perrow, 2011); hence, the establishment of lean structures and practices is recommended to reduce firm-level complexity (Ahmed & Huma, 2021; Wieland, 2021). In this regard, we suggest focusing on the reduction of departments and specialist roles as these showed the strongest impacts. In addition, collaborative complexity, which results from the cooperation between two suppliers, should be considered too. Notwithstanding the potential advantages of cooperation (e.g., information exchange, resource pooling, knowledge sharing (Wu et al., 2010)), related activities such as joint scheduling, product development, or problem-solving also require higher communication and coordination efforts. As relevant information must cross firm-borders, it becomes prone to miss-

interpretation and delay (Larsen et al., 2013; Perrow, 2011). This in mind, collaborative efforts should be used with caution. In summary, we introduce internal and collaborative complexity as two relevant supplier selection criteria. We argue that purchasing managers should favor suppliers that possess simple internal structures and operate independently from other supply chain members. This way, buyers might be able to select more agile suppliers, harness their resilience capabilities, and – in the end – reduce the number of upstream disruptions.

5.1.3 Project three: In the third research project, we first introduced four necessary conditions to discuss the limitations of previous coopetition operationalizations. From this discussion, we offered a revised operationalization that assessed horizontal coopetition based on the simultaneous occurrence of its two individual dimensions. Performing a two-stage scale development process as suggested by Menor and Roth (2007), we built two multilevel scales. Stage one included a literature review, structured expert interviews, and a sorting pre-test. Stage two served to test the management properties of our scales by replicating parts of a previous supplier-supplier coopetition study (see Durach et al., 2020). Our efforts resulted in two multilevel scales: i.e., *supplier-supplier cooperation* and *supplier-supplier competition*.

Two main contributions are offered by this study. First, reliable and valid metrics have been described as a pre-requisite for theory development and testing (Rosenzweig & Roth, 2007; Sethi & King, 1994). As the SCM domain often lacks uniform constructs and measures, further advancements in this regard are limited (Rosenzweig & Roth, 2007). We addressed this gap by pointing at the limitations of previous coopetition measurement and thereof provided a revised operationalization. Combining insights from both literature and practice, we performed a two-stage scale development process that resulted in two multilevel scales. The scales – which our tests procedures indicated to be reliable and valid – add to the growing SCM measurement stream and can be used for the future building, testing, and refinement of supply chain strategy paradigms. Second, our constructs and scales can be applied by other researchers to investigate horizontal coopetition relationships. Both real-life evidence (OECD, 2020) and related research (Durach et al., 2020; Wu et al., 2010) stressed the importance of

horizontal relationships in supply chains. Horizontal coopetition exerts significant influence on the buyer and the supplier; hence, it is essential for academics and practitioners alike to know how to leverage such relationships. Future research in this regard can benefit from the use of our scales. Building on our operationalization, researchers might be able to further explore the true effects and dynamics of coopetition – not only when examining supplier-supplier relationships but also in other literature streams related to triads, organizational learning, or complex adaptive systems.

5.2. Relevance of extended supply chain perspectives

A significant share of these contributions was only made possible by examining extended supply chain contexts. Recalling the main arguments of chapter two, especially two major limitations were identified: (1.) dyads rule out any direct or indirect effects through third parties and (2.) dyads do not allow for any assumptions on how firms behave in supply networks (Choi & Wu, 2009b, 2009c). Both these limitations were addressed in the present research projects.

First, the projects' extended perspectives offered few examples of third-party influence in the supply chain:

In project two, supplier complexity was assessed by two dimensions, namely the firm's internal and collaborative complexity (Schneider et al., 2017; Simon, 1962). While buyer-supplier dyads could be used to examine the internal complexity of a supplier (i.e., hierarchies, departments, specialist roles) (Blau & McKinley, 1979; Damanpour, 1996; Larsen et al., 2013), they cannot map the collaborative links between horizontally connected suppliers. Such relationships, however, entail a greater need for communication and coordination on the firm-level (Larsen et al., 2013); thereby, they add to the supplier's overall complexity as well. Although the supplier's collaborative complexity is "only" considered to be an indirect link to the focal firm, it increases the number of upstream disruptions a buyer must cope with – just as internal complexity does. Internal and collaborative complexity alike determine the complexity of a

supplier and its impact on the buyer; therefore, both represent important criteria for the selection of resilient suppliers.

In a similar manner, project three offered additional support for the impact of horizontal supplier-supplier relationships on dyads. Investigating coopetition dynamics between suppliers, we found that cooperative interactions yield synergies and increase firm resilience. Simultaneously occurring competitive pressures, however, resulted in conflict and tensions that in turn obstructed these effects. Whether having positive or negative effects respectively, coopetition dynamics from the interactions between suppliers influence the supplier's resilience, yet again demonstrating a third party influence on dyad member firms. In summary, both projects provide examples on how dyads are affected by a third party and its links outside of buyer-supplier relationships. As such interrelations cannot be reflected in dyadic settings (Choi & Wu, 2009b, 2009c), an extended view beyond the dyad is needed.

Second, the extended perspectives enabled us to study firm behavior in more network-like supply chain settings:

In project one, we examined how focal firms implemented SSCM in the upstream supply chain. Depending on its respective position in a MTSC, each firm demonstrated different behavior. Given the focal firms' proximity the to end-customer, they acted as a bridge between the upstream supply chain and the marketplace. While experiencing strong customer pressures (Dubey et al., 2017), buyers used their unique position to derive relational power and initiate the implementation of SSCM (Mena et al., 2013). Acting as a "pioneer", they developed sustainability standards and procedures that served as guidelines for upstream supply chain entities. First-tier suppliers were the main addressees of these specifications. In addition, they fulfilled an important "middleman" role. Their task was to not only implement SSCM within their own firm but to also ensure the adherence of any further upstream supply chain members. While there is a close cooperation between the buyer and its first-tier supplier, more upstream firms beyond the buyer-supplier dyad are hardly recorded. The buyer concentrates its SSCM

implementation efforts to its immediate surrounding, while further upstream parts of the supply chain largely evolve without its direct influence and control (Choi & Wu, 2009a). One noteworthy exception in this regard is the involvement of particularly risky sub-suppliers. If for example a second-tier supplier processes critical raw-materials or operates in countries that are especially prone to poor working conditions, buyers tended to seek direct control over those firms. Focal firms thus use both direct and indirect links to influence the sub-suppliers' behavior. While the investigation of dyads would have shed light on the direct interplay between the buyer and the supplier as well; behavior related to the "middleman" role of the supplier and the direct interaction between the buyer and the sub-supplier would have remained largely undetected.

Projects two and three investigated the collaborative interactions between same-tier suppliers; thereby, providing another example of firm behavior in supply networks. Activities of joint product development, capacity sharing, or information exchange are not limited to vertical buyer-supplier links. Quite on the contrary, firms on the same tier-level can engage in collaborative efforts as well, with such relationships potentially being subject to even more complex dynamics that result from the mutual existence of cooperation and competition. Weighing individual and joint interests, the supplier's behavior and decision-making is likely affected by tensions and synergies that result from the horizontal supplier-supplier relationship. For example, a supplier might be able to pursue alternative disruption mitigation measures, if it can harness the information and resources of another supplier (Durach et al., 2020). In a similar manner, buyers were found to be able to influence such indirect links in their favor (Wu et al., 2010). It appears that both the buyers' and the suppliers' behavior is influenced by horizontal relationships in the supply network. This supports the need of investigating more complex supply chain settings such as triads or tetrads.

In summary, all three projects highlighted a few of the numerous research opportunities that lie beyond the dominant dyadic view in SCM. When investigating a supply chains, it appears indispensable to also account for the relational dynamics that arise from third parties

outside of a given buyer-supplier dyad. Such third parties have shown to significantly influence the dispersion of SSCM measures within a supply chain, the selection of resilient suppliers, or the choice of different modes of cooperation and competition – each with relevant implication for the supply chain's resilience and sustainability.

6. Conclusion

The present dissertation was motivated by the overrepresentation of dyadic buyer-supplier research in the SCM domain (Choi & Wu, 2009b). Notwithstanding the important insights gained by studying dyads, we must acknowledge that their ability to represent the complex dynamics of modern supply chain networks is strictly limited (Choi et al., 2001; Hearnshaw & Wilson, 2013; Kim et al., 2011). Dyads neither allow researchers to examine how members of a supply chain are affected by third parties or indirect links. Nor do they provide insights into how firms themselves behave within a network (Choi & Wu, 2009a, 2009b). Given these limitations and the increasing complexity of supply networks, I introduced three extended perspectives beyond the dyadic view. The enclosed research projects examined MTSC, triadic, or tetradic supply chain settings, respectively. Each project contributed to our understanding of the complex dynamics of sustainability and resilience in supply. Moreover, they provided different examples of third-party influence and firm behavior in networks, with these findings demonstrating the need for and benefits of extended supply chain perspectives. While dyads have been and will also continue to be helpful tools for investigating supply chains in future, this work indicates that modern supply structures often require a much broader view of the supply chain. I am convinced that MTSCs, triadic, or even tetradic study contexts – as presented in this dissertation – can help deepen our understanding of the relational dynamics in supply networks and the firms' behavior therein. I thus encourage other researchers to help balance the dominant dyadic view in SCM by likewise moving beyond the examination of buyer-supplier dyads in future.

Irrespective of the need for and the advantages of extended supply chain perspectives, the presented studies are subject to some limitations that must be considered for their interpretation. In this regard, a detailed description of each studies' individual limitations is provided in the attached research manuscripts. In addition, I would like point at two more general downsides that equally apply to most studies that take an extended supply chain perspective. First, collecting empirical data on a sufficient scale often presents a major challenge for the researcher (Choi & Wu, 2009b). While the collection of dyads can already result in significant drop-out rates, these typically grow exponentially when even more complex supply chain settings are examined. For example, if only one respondent of a given triad is unwilling to participate in the study or submits an uncomplete or otherwise invalid response, no complete triad can be built from the remaining two responses. The assembly of triads or similar units of analysis thus often turns out to be both lengthy and costly. At the same time, strict requirements with regards to data privacy, anonymity, and confidentially – which are essential for conducting scientific research – must be fulfilled when it comes to the collection and consolidation of data. As a result, related research often remains on the conceptional level. Empirical studies are scarce and might encompass rather small sample populations which can limit their findings' reliability and generalizability. We sought to partly address these issues by embedding the responses of selected supply chain members into a broader context (e.g., identify a triadic context and pose corresponding questions to the buyer/supplier, confront participants with a tetradic disruption scenario). We also tried to use widely available data from the Bloomberg database and sustainability reports to assemble MTSC. While such proceedings always represent a trade-off between the quality and quantity of data – as in any research project – they might present interesting examples on how to reconcile existing data requirements. Using similar approaches, other researchers could likewise investigate extended supply chain settings. Among others, this could include MTSC that span across different industries, countries, or cultures; studies on triads at different stages of a supply chain (e.g., two OEMS and their end-customer); or single case studies that take on the challenge to map complete supply networks.

Second, I have argued that dyads neglect large parts of the supply chain's overall complexity and recommended the use of triads instead. However, it is also true that triads fail to capture a significant part of that complexity as well (Dubois, 2009). In fact, many modern supply chains encompass various stages of value creation from the raw-material stage to the end-customer. At the same time, supply chains might include three or more firms in each stage. This can result in highly complex supply networks, whose dynamics can hardly be mapped completely – certainly not with triads. Nevertheless, triads still offer many advantages over dyads. As emphasized by Choi and Wu (2009a) they are the "smallest network unit where we can observe how a link affects a link or a node affects a link either directly or indirectly" (p. 269). Triads are more than the simple combination of dyads as they can depict the quintessential of network dynamics, yet they remain a strong simplification of an overall supply network. Consequently, as it is the case with dyads, researchers that want to use a triadic or other extended supply chain context should always ensure that the chosen unit of analysis fits the research purpose. Depending on the guiding research question, scholars could for example conduct case studies that investigate the dissemination of SSCM up to the raw-material stage. Other studies might benefit from the consideration of the external environment a triad is embedded in; thereby, accounting for dynamics that stem from outside the supply chain. In either case, such extended views would likely help balancing the dominant dyadic view of buyer-supplier dyads and enrich our limited knowledge on the complex dynamics of supply chains.

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