Dealing with the unpredictable: supply chain resilience
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1. Dealing with the unpredictable: supply chain resilience

1.1 Introduction

It is estimated that almost three quarters of organisations experience a supply chain disruption each year (BCI, 2018), i.e. an event that impacts the flow of goods, materials and/or services (Craighead et al., 2007), thereby limiting the ability of an organisation to serve the end consumer (Jüttner, 2005). The disruptions felt by supply chains are wide ranging. For example, while some originate from within the supply chain, such as a production line break down, IT problems, demand fluctuations, sustainability issues or quality problems, others are external and due, amongst other causes, to labour strikes, regulatory changes, weather conditions, financial turbulence, terrorism and counterfeiting. This breadth of threat also reminds us that disruptions can be man-made and somewhat controllable or a result of the natural environment and consequently more unpredictable. Meanwhile, the performance impact of such events is also dependent on the severity and duration of the disruption as well as on the supply chain’s competency and experience in dealing with disruptions and threats.

Some organisations are better able to reduce the severity and duration of disruptions to their supply chains than their competitors; and it is argued that this is because they are more resilient (Christopher and Peck, 2004; Sheffi and Rice, 2005). Supply chain resilience (SCRes) can be an important strategic weapon in the current competitive environment and is at the heart of contemporary supply chain management thinking and research (Melnyk et al., 2014; Pettit et al., 2019). SCRes is the capability of supply chains to operate in the face of disturbances and disruptions with or without a limited decrease in their performance (Christopher and Peck, 2004). The review by Tukamuhabwa et al. (2015, p. 8) defined SCRes not only in terms of the ability of “a supply chain to prepare for and/or respond to disruptions, to make a timely and cost effective recovery, and therefore progress to a post-disruption state of operations” but also in terms of its ability to re-emerge in “ideally, a better state than prior to the disruption” thereby gaining ground on the competition by bouncing back or taking advantage of new opportunities better than other firms that were affected.

The concept of SCRes has received significant attention in recent years from practitioners. For example, a survey by the World Economic Forum (2013) revealed that more than 80 per cent of companies are concerned about the resilience of their supply chains; and the Business Continuity Institute found that disruptions cost 10 per cent of firms more than €1m per year and as much as €101–250m (BCI, 2018). Consequently, SCRes has become a topic of significant academic attention (e.g. Sheffi, 2005; Brandon-Jones et al., 2014; Ambulkar et al., 2015; Hohenstein et al., 2015; Scholten and Schilder, 2015; Stevenson and Busby, 2015; Kamalahmadi and Parast, 2016; Purvis et al., 2016; Tukamuhabwa et al., 2017; MacDonald et al., 2018; Scholten et al., 2019). Further, resilience as a theme has become important not only in industries such as insurance, food, automotive, and electronics but also as an area for governmental and inter-governmental attention, as reflected in calls for H2020 projects on, for instance, city resilience. Hence, achieving and increasing SCRes is high on the agenda of researchers, organisations, supply chains, industries, governments, and economic institutions.

2. Aims of the special issue

Despite the attention, growth in publications and the research progress made in SCRes to date, it has been highlighted that the empirical base and exploration of SCRes is limited so far (e.g. Tukamuhabwa et al., 2015) and that a considerable part of the available SCRes literature...
is conceptual in nature (e.g. Ponomarov and Holcomb, 2009). At the same time, several recent literature reviews on the topic (e.g. Hohenstein et al., 2015; Tukamuhabwa et al., 2015; Kamalahmadi and Parast, 2016; Ali et al., 2017; Kochan and Nowicki, 2018; Stone and Rahimifard, 2018) have shown that SCRes research has established supply chain principles that underpin resilience (Christopher and Peck, 2004; Sheffi, 2005); identified and explored formative elements of resilience (e.g. Jüttner and Maklan, 2011) and their interrelationship (e.g. Brandon-Jones et al., 2014; Scholten and Schilder, 2015; Gligor et al., 2019); studied SCRes in specific contexts, such as disaster relief (e.g. Day, 2014; Scholten et al., 2014) and the agri-food industry (Leat and Revoredo-Giha, 2013); related resilience to sustainability (e.g. Fahimnia and Jabbarzadeh, 2016; Ivanov, 2018); and begun to examine the impact of big data analytics and innovative technologies on resilience (e.g. Papadopoulos et al., 2017; Dubey et al., 2019; Min, 2019). Notwithstanding the above contributions, there remains much scope for further work. For example, we know relatively little about what constitutes SCRes beyond top-level generic supply chain strategies; how strategies for building SCRes relate to one another; if and how SCRes can be measured before the unexpected happens; how SCRes relates to other supply chain concepts that help to improve performance, including supply chain integration, sustainability, quality management and lean; and there is limited understanding of behavioural aspects of building resilience. Further, most studies to date have focussed on resilience at the organisational level rather than looking more closely at the individuals within firms that make decisions or, importantly, looking truly at the level of the supply chain or beyond. Moreover, the literature has thus far made limited use of existing theory frames to further our understanding of SCRes. The most notable theory frames used to date are the resource based view (e.g. Ponomarov and Holcomb, 2009; Blackhurst et al., 2011), systems theory (e.g. Erol et al., 2010; Blackhurst et al., 2011), contingency theory (e.g. Brandon-Jones et al., 2014), dynamic capabilities (e.g. Brusset and Teller, 2017; Chowdhury and Quaddus, 2017), social capital theory (Gölgeci and Kuivalainen, 2019) and complex adaptive systems theory (e.g. Day, 2014). Using other theory frames may provide additional explanatory power and further our understanding of SCRes. Finally, given the very nature of SCRes, it seems natural to import insights from other disciplines into Operations Management to better understand SCRes (Van der Vegt et al., 2015).

In the light of the above, we called for papers seeking contributions that extended the literature and expanded the knowledge base in order to further develop our understanding and strengthen the theoretical underpinning of SCRes. Our ambition was to gain insights into, for example, how SCRes impacts performance; if and how SCRes links to other concepts, such as sustainability or SC integration; how specific or one-off disruptions, such as an economic crises, Brexit or flooding, influence supply chains and what strategies companies and supply chains use to mitigate these disruptions or their inherent risks; SCRes in under-represented contexts, including developing countries and small and medium sized enterprises to improve understanding of SCRes, its antecedents, and impact; and SCRes in the overall supply chain through chain-wide research. Ultimately, this special issue is comprised of four papers that fit the call and satisfied the publication standards required by *IJOPM* – although the initial number of submissions would have been enough to fill a whole volume of *IJOPM* (around 70 formal submissions from 18 different countries). Reflecting upon these papers and their content as well as on a number of interesting recent papers and the subject of some of the rejected papers, we recognise that SCRes as a supply chain construct needs to be considered at different levels of aggregation and analysis, as depicted in Figure 1 – a four-level framework for SCRes. The four levels depicted in Figure 1 are unpacked in the following section, which also introduces and positions the four special issue papers in terms of their contributions to one or more levels of the framework.
3. Four levels of SCRes and the contributions of the special issue papers

3.1 SCRes level 1: individuals and teams

Supply chain management is human-centric and almost all studied contexts contain and revolve around people. Indeed, the success of tools and techniques, and the accuracy of theories, relies heavily on the individuals and teams making decisions or improving processes (Bendoly et al., 2006; Croson et al., 2013). This also holds true in the specific area of SCRes. The origins of the concept of resilience lie in the field of psychology where the individual and their resistance to adversarial events is a central point of concern and attention (van der Vegt et al., 2015). Yet, while there is some acknowledgement of the role of individuals and teams in the SCRes literature (e.g. Fahimnia et al., 2019), SCRes is mainly seen as a system characteristic rooted in concepts of engineering and ecological science (van der Vegt et al., 2015). In contrast, this special issue includes three papers that begin to contribute novel insights to the individual/team level of building SCRes.

The paper by Vanpoucke and Ellis (2020) provides a behavioural perspective on the development of supply-side resilience, focussing on the decisions made by managers. It is thus focussed on the individual and his/her influence on decisions relating to the resilience of the supply chain. Primary data are collected from 113 buyers using two experimental scenarios featuring supply-side disruptions of low and high probability. The paper shows that risk propensity affects the type of risk mitigation strategy employed by buyers, providing an insight into how risk propensity influences the risk mitigation decision-making process. The work expands the literature by offering an insight into how buyers actually make decisions to build resilience. In addition, it provides a new methodological approach within the SCRes literature: while experimental approaches are widely used in the risk literature, to date they are scarce in the field of SCRes. The paper may provide a springboard for further experimental research considering other characteristics of supply chain disruptions, other strategies for building resilience and their deployment, and work that goes beyond the supply-side decisions of the buyer towards a more supply chain view.

Moving from the individual to a team-based perspective, the paper by Rubbio et al. (2020) in this special issue draws on dynamic capabilities theory to explore how surgery wards in two Italian hospitals employ resilient behaviour to solve operational failures and improve patient safety. As such, it studies the effect of team decisions – a ward’s nurses and physicians – within a larger organisation. Employing an in-depth case study approach, the authors identify five dynamic capabilities related to individual and team behaviour, knowledge, and experience. The findings show that resilience practices are not necessarily linked to an organisational routine or a managerial process, and thus the work emphasises the importance of individual and team level contributions to SCRes. While contributing new

![Figure 1. A four-level framework for supply chain resilience](image-url)

Notes: Level 1: Individuals and teams; Level 2: Organisational; Level 3: Supply chain and Network; Level 4: Sector, national, and supranational
insights at this lowest SCRes level, the paper also provides a rare insight into how digital technologies can support such behavioural capabilities.

Finally, the paper from Polyviou et al. (2020) includes some new insights on this first level of analysis. The authors explore how resources or capabilities enhance SCRes and find that particularly internal social capital, comprised of interpersonal relationships, commitment, respect and employee tenure, matters. As such, it provides an insight into resilience-enhancing resources that are not rooted in a firm’s supply chain operations but in its human resources.

3.2 SCRes level 2: organisational
Resilience to supply chain disruptions can be built at an organisational level by, for example, keeping redundancies in the form of spare capacity or additional inventory, or by creating visibility in processes and routines (e.g. Jüttner and Maklan, 2011). To date, much of the SCRes research has focussed on this level of analysis, i.e. on how a focal company can or should deal with disruptions in their supply chain for its own gain, either by developing specific capabilities and/or by restructuring their supply chain, and in terms of how it can deal with suppliers (e.g. Ambulkar et al., 2015). The insights that have been provided to date are largely generic and while these are valuable there has been limited attention to date on specific organisational factors such as the size, culture or nature of an organisation or how these factors affect resilience.

The paper by Polyviou et al. (2020) in this special issue provides an organisational level study of SCRes based on four case studies of manufacturing organisations. The paper is novel in its focus on medium sized firms, highlighting the particular challenges they face in applying existing generic SCRes insights. For example, on the one hand, such firms do not have the resources, scale, or influence to develop multiple resilience-enhancing capabilities in the same way as large firms while, on the other hand, they are too large to obtain the support offered to small firms. As described above, the paper draws attention to internal social capital and the role of a firm’s human resources (Level 1) for building organisational level SCRes (Level 2). As such, it also provides valuable insights into the interactions between different levels of our framework for building SCRes.

3.3 SCRes level 3: supply chain and network
Similar to the fields of supply chain integration (Frohlich and Westbrook, 2001; Flynn et al., 2010) and sustainability, where a multi-tier approach has been advocated (e.g. Hartmann and Moeller, 2014; Tachizawa and Won, 2014), it is argued that resilience is not something to be pursued at the organisational level only. Ultimately, the resilience of the supply chain as a whole depends on the capability of the individual chain partners and on the broader network, even including competitors (Scholten and Schilder, 2015). To date, most contributions to Level 3 of the SCRes framework have been limited to a dyadic focus, i.e. on a buyer organisation and its immediate tier one suppliers. This is perhaps understandable given that first-tier suppliers are the predominant source of supply chain disruptions (BCI, 2018). Yet, this narrow focus might neglect opportunities and threats beyond the dyadic relationship (see also literature on the bullwhip effect, e.g. Lee et al., 1997). A broader focus could, for example, identify the transformation or migration of a risk from one point in the network to another, as has been shown by Tukamuhabwa et al. (2017). As such, supply chains that are disrupted and aim to be resilient could reframe where redundancy can be located in their chain, specifically if it relates to additional inventory. Such a question can be compared to the location of inventories for normal functioning chains where concepts such as vendor managed inventory help to reduce stocks and improve chain performance.

The paper by Martins de Sá et al. (2020) in this special issue studies two supply chains over three tiers and how these supply chains were prepared for, responded to and recovered from a supply chain disruption. The authors provide a rare study of how each node contributes to the overall process of building resilience; and they note that investigating SCRes from the
perspective of the focal firm only may omit consequences for the overall supply chain. In the context of supply chains with low interdependence between actors, the authors find that resilience is mainly built at the organisational level (Level 2), where firms implement isolated solutions rather than strategies for building SCRes in the overall chain/network. At the same time, the authors also find that despite no evidence of resilience at the most upstream node, both of the supply chains they studied were resilient. This suggests that SCRes is not dependent on the overall chain but rather on specific nodes. More specifically, the authors conclude that resilience is more dependent on the capacity of downstream actors who are responsible for delivery to the end consumer than on upstream nodes. This may seem somewhat counter-intuitive when considering previous literature suggestions and would not have been identified if a supply chain level approach had not been taken. There is potential to build on the contribution of this paper in future studies and to conduct similar investigations in supply chains with greater levels of interdependence between actors.

3.4 SCRes level 4: sectors, national and supranational

It is important that management practice and research takes account of the wider context; this is also important to research on SCRes (Leat and Revoredo-Giha, 2013), which should consider the broader context in which individuals, firms and supply chains are embedded and how they can contribute to resilience at a higher level of aggregation. Indeed, building SCRes can require organisations and supply chains to contribute to resilience at an industry, national or supranational level. The paper by Rubbio et al. (2020) contained in this special issue is a starting point for such research. To the best of our knowledge, it is the first to extend SCRes to the healthcare sector. The authors find that healthcare knowledge in relation to experience, clinical knowledge and organisational dynamics are antecedents of readiness, flexibility and collaboration, which are dynamic capabilities required for exhibiting resilient behaviour. Resilience at the firm level becomes an antecedent for building the resilience of the sector.

There is also a need to consider how organisations and supply chains can be resilient to threats that have consequences for entire industries, countries or more. Here, research has begun to examine the resilience of supply chains to constitutional changes that affect an entire sector or are nationwide, including the effects of Brexit on agri-food supply chains in the UK (Hendry et al., 2019) and how energy supply chains build resilience with implications for the support mechanisms that should be introduced or improved by the European Union (Urciuoli et al., 2014). At the same time, research has called for the impact of transnational phenomena such as the belt and road initiative on SCRes to be examined (Thürer et al., 2019). The paper by Martins de Sá et al. (2020) in this special issue adds further insight to agricultural SCRes, as previously explored by Leat and Revoredo-Giha (2013) and synthesised by Stone and Rahimifard (2018), by studying a sugarcane and an orange supply chain.

Other existing literature at this fourth level of analysis takes a more extreme point of view. It focusses on humanitarian logistics and disaster management (Kovács and Spens, 2007; Kunz et al., 2017), often studying a specific disaster and its effect on managing a supply chain that delivers services to affected populations (e.g. Perry, 2007; Holguín-Veras et al., 2014; Dufour et al., 2018). The paper by Martins de Sá et al. (2020) also focusses on a particular natural disaster – an extreme drought in 2014/2015 – and how it affected the resilience of two supply chains. As such, it departs from the regular disaster management literature in studying the effect of a slow onset disaster on ongoing commercial supply chains rather than those of humanitarian organisations. The authors’ findings highlight the importance of information sharing about Level 4 aspects such as climate across Level 3, i.e. the supply chain, to increase risk awareness and willingness to adapt. At the same time, the broader network (Level 3) is found to be important as associations, cooperatives, and government organisations are relevant to fostering knowledge and training across the supply chain.
4. Supply chain resilience: where to next?

The papers included in this special issue are testament to the novel, interesting and high quality SCRes research being undertaken at different levels of aggregation and analysis. The intersection of these different levels is depicted in the framework contained in Figure 1. We hope that, together with this framework, the contributions of the papers in this special issue spark further ideas and research in the future. There remains much scope for expanding our understanding of SCRes, as also recently identified in a review by Pettit et al. (2019), especially in the more underrepresented areas of the framework described in this introductory essay.

We conclude by providing a few examples of areas that would be interesting to study further in the coming years in the context of SCRes:

- **Level 1**: the role of individual managers, including their risk perceptions and approaches to decision making, and their effect in order to identify personality characteristics and behaviours that help in enhancing resilience; and the composition and effective decision making structure of teams, including both regular management teams for responding to “everyday” disruptions and emergency teams for responding to crises and unpredictable threats.

- **Level 2**: interactions between teams within an organisation in building resilience; the role of cross-functional teams and their effect on resilience; the nature of an organisation (e.g. for-profit vs not-for-profit) and how this affects the threats a firm faces and how it approaches resilience using its resource base; different organisational cultures; and other organisational theories.

- **Level 3**: the value of relationships between buyers and suppliers not only at an organisational level but also at an interpersonal level (individual/team) in building resilience; the role of the broader network, including competitors, in responding to disruptions that have a broad resonance; supply chain structural components, such as upstream and downstream tiers or the length of a supply chain and their effect on resilience; and different levels of interdependencies between actors across the chain or network.

- **Level 4**: the study of different contexts and industry regulations and their effect on SCRes using relevant theories, including of institutional theory and embeddedness; and the role of policy in supporting the enhancement of SCRes.

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Building supply-side resilience – a behavioural view

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Abstract

Purpose – To build resilient supply chains, buyers should implement risk mitigation tactics. The purpose of this paper is to provide insights into the risky decision-making process that underlies buyers’ decisions to adopt supply risk mitigation tactics for creating supply-side resilience.

Design/methodology/approach – The authors employ experimental scenarios to simulate supply disruptions of low and high likelihood. The authors then assess buyers’ decisions to adopt supply risk mitigation tactics in response to these scenarios.

Findings – The authors find that buyers’ perceptions of supply disruption likelihood are positively related to their adoption of buffer- and process-oriented risk mitigation tactics and preference for process-oriented risk mitigation tactics. Conversely, risk propensity negatively affects buyers’ adoption of buffer- and process-oriented mitigation tactics.

Originality/value – Beyond risk perceptions, the authors consider how risk propensity also affects the risky decision-making process. Moreover, whereas previous studies often focus on a single mitigation tactic, the authors study buyers’ adoption of multiple buffer- and process-oriented risk mitigation tactics to create supply-side resilience.

Keywords Supply risk, Risk propensity, Multilevel model, Risk mitigation, Supply-side resilience

Paper type Research paper

1. Introduction

Supply chain disruptions, and their mitigation, represent a pressing concern for today’s purchasing and supply managers (i.e. “buyers”). In fact, the average firm copes with roughly 14 supply chain disruptions each year (Bode and Wagner, 2015). Research also shows that these disruptions can be costly. While supply chain disruptions decrease firms’ stock prices by 10 per cent, on average (Hendricks and Singhal, 2005), the most severe disruptions reduce firm share price by 30 per cent and take years to recover (Wildgoose et al., 2012). Recent well-known examples of such supply chain disruptions include the tsunami in Japan, which caused disruptions in the production of cars at Toyota and resulted in a 25 per cent decrease in worldwide production for five months (Tomlin, 2014), and the months-long flooding in Thailand, which led to losses of $1bn in sales for Intel because of its inability to source hard drives.

While some firms experience severe losses, other firms are better able to withstand supply chain disruptions. For example, during the Japanese tsunami, Nissan quickly sourced direct materials with alternate suppliers to resume operations and recover “lost market share more quickly than Toyota” (Melnyk et al., 2015). Similarly, through initial investments in robust resources, continuous external monitoring and quick reactions to facilitate recovery, General Motors’ Thailand operations were able to stem losses during the 2011 Thailand floods (Melnyk et al., 2015). Christopher and Peck (2004) attribute such performance in the face of disruptions to supply chain resilience – an adaptive capability that prepares the supply chain for unexpected events and enables it to respond to disruptions and to recover faster (Ponomarov and Holcomb, 2009).
Recent research more narrowly focuses on upstream resilience capabilities, showing that supply-side resilience positively affects operational performance (Dabhilkar et al., 2016). The normative view of supply-side resilience intimates that buyers should align investment in mitigation capabilities with the supply risks that they face to improve performance (Blackhurst et al., 2011; Pettit et al., 2010). Extant research suggests two overarching approaches for supply risk mitigation – i.e., buffer- and process-oriented mitigation strategies (Zsidisin and Ellram, 2003). The buffer-oriented mitigation strategy is comprised of tactics that generally rely on investments in redundant resources, such as inventories and suppliers, to protect the firm from the detrimental effects of disruptions. Such tactics enable a firm to continue its operational activities despite a disruption (Brandon-Jones et al., 2014). Alternately, the process-oriented mitigation strategy consists of relational tactics with the goal of improving supplier and/or process performance and creating visibility in the supply chain. These relational tactics increase supply chain flexibility enabling a quicker, more efficient return to normal operating performance after a disruption (Bode et al., 2011; Zsidisin and Ellram, 2003).

Despite their performance implications, prior research provides little insight into the complex decisions to adopt buffer- and/or process-oriented mitigation tactics to build supply-side resilience. Therefore, we apply risky decision-making theory to advance a model of supply-side resilience to address this gap. The focal dependent variable of risky decision-making theory is risk behaviour (Sitkin and Pablo, 1992), which we conceptualize as the adoption of and preference for buffer- and process-oriented mitigation tactics. The theory advances two predictors of risk behaviour: risk perception – i.e., the judgement of the potential loss inherent in a situation and risk propensity – i.e., the predisposition to adopt more risky behaviour (Sitkin and Pablo, 1992). Adopting the buyer as our unit of observation, our application of risky decision-making theory to the study of supply-side resilience motivates the following research question:

**RQ1.** How do buyers’ risk perceptions and risk propensity affect their adoption of and preference for buffer- and process-oriented mitigation tactics?

Our empirical investigation of this research question, which is based on the analysis of primary response data from 113 buyers who adopt specific mitigation tactics in response to risky situations described in two experimental scenarios, has several salient theoretical implications. Notably, our study integrates two largely dissociated streams of literature separately focused on risky decision-making and resilience. This integration enables a new application domain for risky decision-making theory: whilst traditional decision-making studies examine the selection of a single alternative from a set that varies in terms of uncertainties and gains (e.g. Kahneman and Tversky, 1979), our application explicitly considers buyers’ decisions aimed at minimizing losses through the potential adoption of multiple mitigation tactics. Similarly, in contrast to traditional studies of resilience, which tend to focus on a singular mitigation tactic (Ellis et al., 2010) or view individual tactics as alternatives in response to a disruption (Talluri et al., 2013), our study examines buyers’ simultaneous adoption of potentially multiple tactics culled from buffer- and process-oriented mitigation strategies. Moreover, our integrated approach motivates the consideration of key behavioural variables – i.e., likelihood of supply disruption and risk propensity (Sitkin and Pablo, 1992) – as determinants of buyers’ risk-mitigating behaviours. Our results provide new insights into the factors that affect how buyers build supply-side resilience.

2. Literature review
A growing body of literature demonstrates the positive effects of resilience finding that agility and robustness (Wieland and Wallenburg, 2013), flexibility and agility (Gunessee et al., 2018),
response capabilities (Su and Linderman, 2016), and proactive and reactive supply mitigation strategies (Dabhilkar et al., 2016) positively affect operational, firm and supply chain performance. Inherent in these studies is the essential notion that supply chain resilience is underpinned by adaptive capability (Ponomarov and Holcomb, 2009) – i.e., a supply chain’s “latent ability to develop different responses to match the nature of the threats it faces” (Tukamuhabwa et al., 2015, p. 5599). Consistent with this logic, Pettit et al. (2010) explicitly recognize resilience as a balance between vulnerabilities and capabilities. Central to Pettit et al.’s (2010) conceptualization is that supply chain vulnerabilities result from external changes and firms should adopt sets of mitigation capabilities which are best able to overcome realized vulnerabilities and achieve “balanced resilience”; in so doing, firms may align investment and risk. As Pettit et al. (2010) argue, the issue of balance is essential to firm performance: whereas vulnerabilities in the excess of capabilities unduly expose the firm to financial losses, excessive investment in capabilities also erodes firm profitability.

Extending resilience-as-balance logic, Gunasekaran et al. (2015) hold that resilient supply chains maintain sufficient capabilities that reduce exposure to a wide range of potential disruptions; accordingly, their study advances a supply chain capability management framework in which resilience is premised on understanding global sourcing complexities and adopting supply management approaches to overcome these complexities. Whereas several case (e.g. Scholten et al., 2014) and survey-based studies (e.g. Brusset and Teller, 2017) advance a similar perspective, Talluri et al. (2013) develop an empirically grounded supply chain simulation to assess the relative efficiencies of risk mitigation tactics for situations with varying risk profiles; their simulation results support the resilience-as-balance perspective by showing that particular mitigation tactics are optimal for select risk profiles.

Whilst the resilience-as-balance view is often applied at the supply chain level, several studies (e.g. Blackhurst et al., 2011; Dabhilkar et al., 2016; Gunasekaran et al., 2015) more narrowly focus on supply-side resilience – i.e., adaptive capabilities or practices that enable firms to react to or withstand upstream vulnerabilities. These studies conceptualize vulnerabilities as supply disruptions, which refer to unforeseen events that interfere with the normal flows of goods and/or materials between firms (Craighead et al., 2007, p. 132) and reflect undesirable events ranging from extreme weather to operational obstacles (Wagner and Bode, 2008; Bode and Wagner, 2015). Generally, supply disruptions may be classified according to their probability and consequences (Sheffi and Rice, 2005). Infrequent disruptions that interrupt supply for long durations and recurrent disruptions having a limited impact are among the two most studied disruption categories in the literature. For example, Tomlin (2006) recognizes these types of disruptions by categorizing long-but-rare disruptions and short-but-frequent disruptions in planning mitigation strategies. Building on these categorizations, Tang (2006) advances a typology that classifies supply disruptions as global or operational. Global disruptions refer to major, high-impact disruptions that occur with low frequency (Tang, 2006) and include natural disasters (e.g. tsunamis, earthquakes, hurricanes and disease outbreak) as well as economic crises (e.g. excessive public debt, banking system failures and exchange controls) and social unrest (e.g. terrorism and worker strikes) (Ellis et al., 2011). These disruptions occur when the supply chain is unexpectedly and radically upset through unavailability or failure of resources or capabilities (Talluri et al., 2013). In contrast, operational disruptions occur more frequently, have a less severe impact (Tang, 2006) and generally reflect a supplier’s temporary inability to deliver high-quality inputs in a timely manner (Manuj and Mentzer, 2008). Moreover, operational disruptions reflect delays and distortions that can occur when supply chain system parameters, such as lead time or order quantity, stray from their expected value (Talluri et al., 2013).

According to the resilience-as-balance view, the threat of supply disruptions motivates buyers to create resilient supply chains by adopting supply risk mitigation tactics – i.e.,
actions to decrease the likelihood and/or negative consequences of a supply disruption (Kim et al., 2015). While firms may proactively invest in mitigation capabilities, they more often increase their resilience by selecting new mitigation tactics after experiencing a disruption. As Bode et al. (2011) suggest, risk mitigation decisions are shaped from past experiences and evolve as a response to a disruption. This disruption-response sequence is governed by two intertwined mechanisms: the pursuit of stability and the extra resources required to create this stability (Bode et al., 2011). Each time a disruption happens, managers must consider new mitigation tactics to cope with an ever-changing environment and bolster supply chain resilience.

While extant literature identifies many types of mitigation tactics, Zsidisin and Ellram (2003) assert that supply risk mitigation tactics can be classified into buffer- and process-oriented strategies. The buffer-oriented strategy attenuates negative effects by establishing safeguards that protect a firm from disruptions in the supply of goods. Tactics that comprise the buffer-oriented strategy largely rely on excess or redundant resources (Sheffi, 2005). While effective in curbing the magnitude of supply loss, the buffer-oriented strategy does little to reduce the likelihood of disruption and increases inefficiencies (Wagner and Bode, 2008; Talluri et al., 2013). Additionally, increasing product variety and decreasing product cycle times can lead to a significant rise in costs of tied-up capital and obsolescence when buffer-oriented risk mitigation tactics are used (Tang, 2006). The buffer-oriented strategy includes mitigation tactics such as holding safety stock, sourcing from multiple suppliers and/or asking suppliers to hold extra inventory (Zsidisin and Ellram, 2003).

The process-oriented strategy mitigates uncertainty by facilitating “boundary-spanning” and “boundary-shifting” actions with a supplier (Bode et al., 2011). Firms can improve their ability to detect potential disruptions through activities such as auditing, monitoring and certifying suppliers. For example, regularly evaluating the financial viability of suppliers may help buyers avoid the negative consequences of supplier default, insolvency or bankruptcy (Milne, 2009). Also, closer buyer–supplier relationships create additional mechanisms for sensing what is happening at the supplier, providing advanced notice and enabling a faster reaction to disruption (Chen et al., 2013). For instance, supplier certification and supplier development activities increase buyer–supplier interaction, leading to extra opportunities to learn, exchange information and informally monitor suppliers’ behaviours. Moreover, these process-oriented tactics reduce the likelihood of disruption through buyers’ intentional efforts to improve suppliers’ performance and capabilities (Celly and Frazier, 1996; Talluri et al., 2013). In addition, as Eisenhardt (1989) suggests, these process-oriented approaches reduce the risks of moral hazard (i.e. lack of supplier effort) and adverse selection (i.e. inaccurate assessment of supplier capabilities).

The attributes of buffer- and process-oriented mitigation strategies suggest that the decision to adopt a particular strategy is complex. Focusing solely on a buffer-oriented mitigation strategy can have detrimental effects on a firm’s profitability due to the capital devoted to inventories and increased transaction costs associated with managing multiple suppliers for the same purchases (Zsidisin and Ellram, 2003; Talluri et al., 2013). Yet, a process-oriented mitigation strategy may not always provide the intended results and it requires substantial buyer investment in relationship-building mechanisms, which is often not possible for all supplier relationships. Accordingly, neither of these mitigation strategies is universally superior. Adding further complexity, buyers’ risk mitigation decisions are subject to time and other resource constraints.

Our review of the resilience literature highlights four salient findings: resilience is important – it positively affects performance-based outcomes (e.g. Wieland and Wallenburg, 2013); resilience requires the effective balancing of vulnerabilities and mitigation capabilities (Pettit et al., 2010); individual mitigation tactics are more or less efficient at...
building resilience (Talluri et al., 2013); and selecting one or more buffer- or process-oriented mitigation tactics to build resilience can be difficult (Bode et al., 2011). Given these findings, it is surprising that there is little research that examines how managers actually make complex decisions to build resilience. The risky decision-making literature has long asserted the importance of studying what managers do; specifically, this line of research enables analyses of the deviation between what managers should and actually do, helps managers understand how to make better decisions and facilitates the development of risk-taking (or risk-mitigating) policies that align managerial behaviours with firms’ goals (Das and Teng, 2001; Slovic and Lichtenstein, 1971). Accordingly, we apply risky decision-making theory to the study of supply-side resilience.

Risky decision-making theory advances a process view of the cognitive decision-making process (Yates and Stone, 1992) and focuses on the prediction of “an individual decision-maker’s behavioural responses” to situations characterized by varying levels of risk (Sitkin and Pablo, 1992, p. 25). As summarized by Sitkin and Pablo (1992), the central assertion of this theory is that risk behaviour – i.e., an individual’s selection of a particular behaviour from many risky alternatives – is determined by two factors: risk perception and risk propensity. Risk perception refers to individuals’ estimates of the risk – i.e., the down-side possibilities or potential loss – inherent in a situation (Das and Teng, 2001). To determine loss, individuals assess projected outcomes associated with alternate behaviours relative to a target outcome – i.e., “an outcome a person actively works to obtain” (Yates and Stone, 1992, p. 8). Risky decision-making theory predicts that individuals prefer and subsequently adopt behaviours having projected outcomes that maximize gains or minimize losses relative to their target outcome (Lopes, 1987). Alternately, risk propensity is an individual attribute characterizing the cumulative general “tendency to take and avoid risk” (Pablo et al., 1996; Sitkin and Weingart, 1995, p. 1575). In accordance with risky decision-making theory, it predisposes individuals to accept certain risks and adopt riskier behaviours than others (Bromiley and Curley, 1992). Importantly, these basic precepts of risky decision-making theory suggest it is particularly well-aligned with the resilience-as-balance view: the complexities and consequences of adopting mitigation tactics qualify this choice as a risky decision (Bode et al., 2011); analogous to gambles with differing payoffs (Kahneman and Tversky, 1979), mitigation tactics have varying efficiencies (Talluri et al., 2013); and both risky decision-making theory and the resilience-as-balance view highlight the formative role of risk perception in determining behaviour (Pettit et al., 2010).

3. Model development
To facilitate our conceptual development, we adopt the purchase of a particular direct material from a specific supplier as the context of our study. We apply risky decision-making theory to advance a model which examines situational and dispositional factors that affect buyers’ decisions to adopt mitigation tactics to build supply-side resilience. The focal dependent variable of our conceptual model is risk behaviour which we operationalize as buyers’ adoption of both buffer- and/or process-oriented mitigation tactics and buyers’ preference of buffer- vs process-oriented mitigation tactics. Whereas the former operationalization enables insights into buyers’ overall mitigation behaviours to build “balanced” supply-side resilience, the latter facilitates a test of the fundamental question posed within the risky decision-making literature: given a set of potential behaviours that vary in terms of inherent risk, which alternative (i.e. mitigation strategy) do individuals (i.e. buyers) prefer to create supply-side resilience? Consistent with risky decision-making theory, we hypothesize that buyer’s risk behaviour is influenced by buyers’ risk perceptions, operationalized as the likelihood of supply disruption, and buyers’ risk propensity.
3.1 Risk perception

Risk perceptions are formed when an individual constructs a personal characterization of a situation and it is this characterization that drives an individual's actions (Yates and Stone, 1992). Drawing from Yates and Stone (1992), Ellis et al. (2010) examine buyer behaviour and suggest that the effect of the situation on individual action is mediated by three risk perceptions: the likelihood of supply disruption, the magnitude of supply disruption and overall supply risk. Whereas likelihood of supply disruption refers to the probability that a given event will disrupt the flow of supplies, magnitude of supply disruption reflects the potential impact that the given event will have on performance (Sheffi and Rice, 2005). Ellis et al. (2010) find empirical support for a cognitive process in which buyers' judgments of the likelihood and magnitude of supply disruptions are aggregated to form overall evaluations of supply disruption risk, which, in turn, drive buyers' mitigation behaviour. Importantly, similar to Kahneman and Tversky (1979), they conclude that buyers' perceptions of the likelihood of supply disruption have twice the effect on their mitigation behaviour as compared to their perceptions of the magnitude of supply disruption. Hence, similar to the approach of Talluri et al. (2013), we adopt the likelihood of supply disruption as the focal risk perception considered within our study.

Risky decision-making theory advances conceptual argumentation that links buyers' perceptions of the likelihood of supply disruption with their adoption of mitigation tactics. Yates and Stone (1992) assert that, ceteris paribus, individuals will select alternatives that minimize loss. Ellis et al. (2010) apply this logic and find that buyers who perceive high levels of supply disruption risk develop alternate suppliers to mitigate such risk. Consistent with the premise of "balanced" supply-side resilience, these studies suggest that vulnerabilities drive the adoption of mitigation tactics. More broadly, we suggest that, motivated by their innate desire to minimize loss when faced with a threat, buyers' perceptions of the likelihood of supply disruption drive their increased adoption of mitigation tactics:

\[ H1a. \] The likelihood of supply disruption is positively related to the adoption of mitigation tactics.

We assert that buyers prefer buffer-oriented mitigation tactics when supply disruptions are unlikely and process-oriented mitigation tactics for situations in which the likelihood of supply disruption is high. Three explanatory mechanisms account for this relationship: the level of equivocality inherent in a risky situation, the certainty with which the strategy will mitigate the risk and the ease of implementing the mitigation strategy. Equivocality reflects the extent to which "multiple meanings are linked to a particular situation" rendering "the relative superiority of a particular meaning [...] ambiguous" (Ellis et al., 2011, p. 82). As Bode et al. (2011) intimate, infrequent disruptions provide little opportunity for learning; as such, buyers neither accrue knowledge of nor experiences with the causes, conditions and consequences of infrequent disruptions. Lacking sufficient knowledge, buyers face difficulties in determining adequate responses leading to the application of simple rules of thumb (Bode et al., 2011). This motivates buyers' adoption of buffer-oriented mitigation tactics, like holding inventory and maintaining multiple suppliers, to mitigate risk. Notably, these approaches provide a given level of certainty, are relatively easy to implement and require little information about the disruption to be effective (Zsidisin and Ellram, 2003). For example, inventory can mitigate a disruption in accordance with the number of days of stock on-hand. Similarly, purchases can be immediately diverted to an alternate supplier that is at-the-ready. Moreover, even when knowledge of the type or source of the supply disruption is limited, buffer-oriented tactics can be effective with little inter-organizational coordination or effort. Hence, a buffer-oriented mitigation strategy is particularly suitable for low-likelihood supply disruptions, where learning is impaired by the...
infrequency of the disruption. Alternately, more frequent supply disruptions create buyers’ awareness, sensitize buyers and help to resolve buyers’ equivocality by enabling buyers’ enhanced understanding of sources and types of disruptions through repeated experiences (Bode et al., 2011). This enhanced understanding enables the use of process-oriented mitigation tactics, like supplier development and certification that generally require higher levels of product and process knowledge to be effective (Chen et al., 2015). Moreover, the prospect of frequent supply disruptions motivates buyers’ commitment to resolve the underlying cause of supply discontinuities to prevent disruptions from recurring (Choi and Hartley, 1996). Such commitment is necessary to support the increased investment in inter-organizational coordination and problem-solving efforts required for the implementation of process-oriented mitigation tactics (Krause, 1999). Hence, in line with the notion of “balanced resilience”, supply disruptions characterized by higher likelihood motivate buyers’ use of a process-oriented mitigation strategy to create supply-side resilience:

\[ H1b. \] The likelihood of supply disruption is negatively related to the preference for buffer-oriented mitigation tactics.

3.2 Risk propensity

As a personality trait, risk propensity reflects an individual’s general predisposition towards risk-taking behaviour, which ranges from risk-averse to risk-seeking (Sitkin and Weingart, 1995). Given a set of payoff alternatives of equal expected value, risk-aversion is associated with uncertainty avoidance and the preference for payoffs characterized by higher likelihood but lower magnitude. In contrast, when presented with the same alternatives, risk-seeking individuals tolerate greater uncertainty; that is, they embrace a low likelihood of payoff in the pursuit of higher payoffs (Kahneman and Tversky, 1979). Similarly, risk-seeking individuals tend to more heavily weigh data associated with opportunity as compared to loss when making decisions; the opposite is true for those who are risk-averse (Sitkin and Pablo, 1992; Sitkin and Weingart, 1995).

Consistent with risky decision-making theory, we posit that buyers’ risk propensity affects their adoption of risk mitigation tactics as a result of two causal mechanisms: uncertainty tolerance and information filtering. In particular, we assert that risk-averse buyers, who are conservative in nature, have little tolerance for losses stemming from supply disruptions and therefore increasingly invest in tactics to mitigate such risks. Moreover, risk-averse buyers filter information to emphasize potential losses stemming from supply disruptions; this further motivates risk-averse buyers’ adoption of risk mitigation tactics. In contrast, risk-seeking buyers, who embrace uncertainty and tend to emphasize the magnitude of potential gains, are less likely to adopt mitigation tactics:

\[ H2a. \] Risk propensity is negatively related to the adoption of mitigation tactics.

We posit that risk-averse buyers prefer buffer-oriented mitigation tactics and, alternately, risk-seeking buyers opt for process-oriented mitigation tactics. We advance two explanatory mechanisms to support our assertion: the level of certainty that the employed strategy will mitigate the supply disruption and the ancillary relational benefits that can also be obtained through the adoption of the mitigation strategy. Buffer-oriented mitigation tactics, such as holding inventory, “provide an additional measure of protection from risk”, suggesting with increased certainty that such tactics will effectively mitigate risk (Zsidisin and Ellram, 2003, p. 18). While successful implementation requires relatively little buyer effort, buffer-oriented strategies do not yield ancillary relational benefits. In fact, in the absence of disruptions, these tactics increase costs but lack utility (Sheffi and Rice, 2005). Despite these drawbacks, risk-averse buyers adopt buffer-oriented mitigation tactics to assure greater certainty of supply thereby employing a more defensive approach to
restore stability and protect their operations. Alternately, process-oriented mitigation tactics offer several ancillary relational benefits: sole sourcing allows buyers to aggregate volumes with key suppliers and access benefits, such as advanced supplier innovations, that are reserved for customers of choice (Ellis et al., 2011); supplier development enables closer supplier relationships and enhanced supplier and buyer performance (Chen et al., 2016); and supplier certification programs increase product quality while reducing product costs (Larson and Kulchitsky, 1998). However, successful implementation of process-oriented mitigation tactics cannot be assured as it requires intensive inter-organizational efforts that are difficult to coordinate and that are time-consuming (Choi and Hartley, 1996). Moreover, successful implementation is conditioned not only upon buyers’ efforts but also suppliers’ behavioural compliance. Accordingly, risk-seeking buyers, who are predisposed to willingly risk more uncertain outcomes to maximize potential gains (Kahneman and Tversky, 1979), are well-suited to cope with the relational uncertainties associated with the adoption of process-oriented tactics (Heide, 1994; Zsidisin and Ellram, 2003):

\[ H2b. \] Risk propensity is negatively related to the preference for buffer-oriented mitigation tactics.

### 3.3 Control variables

Drawing from risky decision-making theory, our hypotheses suggest that risk perception and risk propensity represent primary behavioural factors that motivate buyers’ adoption of and preference for risk mitigation tactics. Yet, extant literature suggests that firm- and dyadic-level variables also influence buyers’ decisions to implement such mitigation tactics. Therefore, we control for firm size, geographic location and cross-country exchange.

The link between firm size and the adoption of risk mitigation tactics is supported by a practical consideration: mitigation tactics require organizational resources. For example, buffer-oriented risk mitigation tactics require investments in redundant resources before disruptions occur and, in the absence of disruption, often go unused (Tomlin, 2006). This suggests that the use of buffer-oriented risk mitigation tactics requires sufficient financial resources. Moreover, process-oriented mitigation tactics are also human resource-intensive (Kleindorfer and Saad, 2005). Specifically, process-oriented tactics rely on the development of collaborative supplier relationships, which involve intensive interaction between buyers and suppliers over time (Heide, 1994; Zsidisin and Ellram, 2003). Hence, large firms are better positioned to enact both buffer- and process-oriented risk mitigation tactics.

Geographic location affects the specific regulations, environments and cultural values that impose standards for the mitigation of risk (Jannings and Zandbergen, 1995; Tang and Zimmerman, 2013). Accordingly, Jackson and Apostolakou (2010) assert that firms in Western European countries with strong institutionalized stakeholder involvement and performance pressures are more likely to achieve higher levels of performance in the economic dimension of corporate social responsibility, which includes risk and crisis management. By extension, we suggest that buyers in western countries, which have stakeholders with demanding requirements for delivery and quality performance as well as mature risk management systems, maintain a strong risk orientation and are more likely to adopt a comprehensive approach to risk mitigation. Moreover, firms with mature risk management approaches are likely to possess the requisite knowledge and skills to implement process-oriented mitigation tactics. In contrast, non-western firms with less mature risk management capabilities likely adopt buffer-oriented mitigation tactics, such as holding inventory, due to the ease of implementation (Tomlin, 2006).

Cross-country exchange involves complex international supply chains and cross-cultural collaborations; these factors complicate risk mitigation efforts (Manuj and Mentzer, 2008). In cross-country exchange, firms cope with a greater number of unknowns and, with
diminished visibility, disruptions are more difficult to detect. One way to cope with these uncertainties is to implement process-oriented mitigation tactics, such as supplier development and supplier certification practices. However, differences in language and culture associated with cross-country exchange render these process-oriented mitigation tactics, which typically require inter-firm collaboration (Zsidisin and Ellram, 2003), more difficult to effectively implement. These circumstances suggest that buffer-oriented tactics are particularly useful in mitigating disruptions when exchange spans countries’ borders.

4. Methodology

4.1 Research design

To test our hypotheses, we developed a research instrument that includes two experimental scenarios and sets of questions that measure buyers’ risk propensity, adoption of buffer- and process-oriented mitigation tactics, and other control variables. The instrument instructed buyers to identify a product and supplier that they manage and to consider the scenarios with respect to this product and supplier relationship. The scenarios describe supply disruptions and facilitate a single experimental manipulation in which the likelihood of supply disruption is varied to assume high and low values. In both scenarios, the magnitude of disruption is held constant at a high level. In our research design, we purposefully focus on high-impact disruptions since interview feedback from buyers consistently indicated that disruptions having little impact on business performance receive little attention and do not motivate investments in supply-side resilience. As presented in the Appendix, Scenario 1 presents a situation having a high likelihood of supply disruption in which the supply of a product is interrupted due to a machine breakdown at a supplier. Alternately, Scenario 2 assumes a low likelihood of supply disruption, advancing a situation in which a severe winter storm results in electricity failures at a supplier and causes an interruption in supply. In both scenarios, the disruption impacts a significant portion of the buyer’s total purchase volume. For our analyses, the likelihood of supply disruption reflects the experimental manipulation in the scenarios; it is coded as a dichotomous variable such that 0 represents the low likelihood of supply disruption (i.e. Scenario 2) and 1 reflects the high likelihood of supply disruption (i.e. Scenario 1).

The development of our risk mitigation scales was guided by the conceptual work of Zsidisin and Ellram (2003), iterative interviews and pre-testing. Specifically, we interviewed buyers, purchasing managers and directors in the supply management organization of a Tier 1, global automotive supplier to understand the type of risk mitigation strategies used in practice. These interviews were supplemented with those from Tier 2 automotive suppliers. Importantly, our interviews employed an iterative process such that risk mitigation tactics (and other supply risk constructs) were identified and refined over the repeated discussion. Then, we pre-tested the risk mitigation tactics using an approach whereby the risk mitigation tactics were embedded in a survey questionnaire, buyers completed the questionnaire under our supervision and at the end of the risk mitigation section, buyers were invited to modify the wording of existing tactics or identify new tactics to ensure that the instrument included a comprehensive set of well-understood risk mitigation tactics employed in practice.

The finalized risk mitigation items (see Appendix) were presented in the research instrument following each scenario. To facilitate response, research participants were instructed to select the tactic or tactics, using a binary yes/no response scale, that they would implement to mitigate the supply risk presented in each scenario. Buffer-oriented mitigation tactics included holding safety stock at the supplier’s premises, holding buffer stocks at your own (i.e. buyer’s) premises, establishing multiple supply sources and avoiding risks by divesting from certain markets or discontinuing the exchange relationship with the supplier. The process-oriented risk mitigation strategies were presented as
certifying suppliers, implementing quality management programs for suppliers, supplier development initiatives and controlling, sharing or transferring risk. The buffer- and process-oriented tactics were randomly ordered and comingled in the list so that these overarching risk mitigation strategies were not readily apparent to respondents.

To facilitate analyses, we created formative scales to indicate buyers’ adoption behaviours. Specifically, the adoption of mitigation tactics (as referenced in \( H1a \) and \( H2a \)) reflects the sum of all mitigation tactics selected in response to each scenario. The adoption of buffer- and process-oriented mitigation tactics reflects the number of buffer- and process-oriented mitigation tactics, respectively, selected for each scenario; together, these measures are used to assess buyer’s preference for buffer-oriented mitigation tactics (as posited in \( H1b \) and \( H2b \)). It is important to acknowledge that though we employ similar risk mitigation tactics and strategies, our approach contrasts with Zsidisin and Ellram (2003) who model buffer- and process-oriented mitigation tactics as reflective scales. This difference is attributable to our relatively finer-grained unit of analysis. Whereas Zsidisin and Ellram (2003) assess buyers’ general engagement in mitigation activities for all suppliers and situations using continuous response scales, we alternately focus on buyers’ (yes/no) adoption of mitigation tactics in response to experimental scenarios – i.e., specific disruptions incurred with a singular supplier and purchased product.

We adopt the risk propensity scale developed and validated by Weber et al. (2002). As shown in the Appendix, this scale is comprised of 12 items that capture risk-taking tendencies associated with investment, gambling, safety, recreation, ethics, among others. Each item was rated using a five-point Likert response scale. To avoid possible response biases, we positioned this scale near the end of the survey, i.e., after the questions on risk mitigation tactics.

As listed in the Appendix, the research instrument also includes measures of the control variables. Firm size reflects the number of employees. Geographic location is coded as two dichotomous variables contrasting respondents located in Western Europe vs those in the USA and non-Western Europe vs those in the USA. Cross-country exchange reflects the location of the buyer as compared to the location of the supplier; it is coded as a dichotomous variable where supply relationships that span countries’ borders assume a value of “1” and those involving domestic exchange are set to “0”.

4.2 Sample and data collection

While the unit of analysis for this study is a supply risk event, our unit of observation is the individual buyer; this enables us to draw conclusions on how buyers make risk mitigation decisions. As such, our target population consists of experienced and active purchasing professionals who are responsible for the operational and strategic tasks of the buying process for a national or international service or manufacturing company. Accordingly, our sample frame is comprised of experienced, active purchasing managers who subscribe to a procurement group on LinkedIn. This procurement group was set up exclusively for “experienced” professionals having more than five years of experience in the procurement field. To ensure that our sample frame consists of “active” purchasing professionals, we only invited purchasing professionals who actively participated in the discussion group in the two weeks preceding survey administration. In addition, we targeted professionals who worked for organizations with more than 50 employees and held functional titles related to purchasing at the strategic level of their organizations. Consultants and HR professionals were omitted from our study. Accordingly, 82.3 per cent of our respondents have more than five years of work experience in purchasing. We set up a web-based questionnaire which was easily accessible by our sample who received a direct link. Reminders were sent two weeks after the initial invitation to participate in the study. In total, the questionnaires reached 287 respondents during the data collection period; 113 questionnaires were completely filled out. This corresponds to a response rate of 39.37 per cent.
5. Data analysis
Since our unit of analysis is a supply risk event, 113 complete questionnaires result in 226 cases that served as the basis of our analyses. Within our sample, 74.3 per cent of the respondents are male. In addition, 26.5 per cent of the respondents work for companies located in the USA, while 42.5 and 31 per cent of the respondents are employed by firms in Western European and non-Western European countries, respectively.

Table I presents the descriptive statistics and correlations for between- and within-group variables. For the between-group variables, our results show several positive and significant correlations among adoption of buffer-oriented mitigation tactics, process-oriented mitigation tactics and (total) mitigation tactics for Scenario 1 (e.g. BAH, PAH and MAH, respectively) and Scenario 2 (e.g. BAL, PAL and MAL, respectively); these significant correlations across scenarios are consistent with the nested structure of the data. The analysis of within-group variables shows that, overall, buyers tend to adopt more buffer-oriented (mean = 1.50, SD = 0.90) than process-oriented mitigation tactics (mean = 1.18, SD = 1.16). Further, the bivariate correlations show that, consistent with H1a, the likelihood of supply disruption is significant and positively correlated with the buyers’ adoption of mitigation tactics (r = 0.30, p < 0.05).

5.1 Common method and non-response bias
Cross-sectional, survey-based research may be subject to a common method and non-response bias. Following the guidance of Podsakoff et al. (2003), we adopted several measures in our research design to mitigate the potential effects of common method bias. In particular, we employed interviews and a pre-test to facilitate the elimination of ambiguous and unfamiliar terms in our questionnaire. Also, we minimized the effects of the consistency motif by adopting dissimilar items and response scales and using dissimilar types of measurement scales (e.g. formative and reflective scales). Moreover, to reduce desirability bias, we rendered the questionnaire anonymous and indicated to managers that there are no right or wrong questions. To test for the possible effects of common method bias, we use the marker variable approach developed by Lindell and Whitney (2001). Consistent with their approach, we employ a theoretically unrelated item, “the supplier is on the lookout for a buyer to replace us”, as our marker variable and assess the correlation of this marker variable with each other variable in our model. Our results show that the marker variable maintains a negligible correlation with risk propensity (r = −0.006). This finding suggests that common method bias does not threaten the validity of our study. We also assess the potential for non-response bias by comparing early vs late responders across several demographic variables, including the number of employees, revenues and locations of respondents’ firms (Armstrong and Overton, 1977). Our results, which show no significant differences (p > 0.05) across groups, suggest that non-response bias is not problematic.

5.2 Scenario and measurement validity
To examine the efficacy of our experimental manipulation, we followed the general approach of Sitkin and Weingart (1995) and asked respondents to assess the likelihood of disruption associated with each scenario and then contrasted response data across scenarios. As expected, results from our test of mean difference show that respondents perceive the likelihood of disruption as significantly greater in the first scenario as compared to the second scenario (t = 7.864, p < 0.001). Consistent with prior behavioural studies (e.g. Bachrach and Bendoly, 2011; Rungtusanatham et al., 2011), we also asked respondents to rate the realism of each scenario using a three-item scale; the mean for each of these items was above the midpoint of the response scale indicating that respondents indeed perceive the scenarios to be realistic. These findings validate our experimental manipulation and, consequently, our measure of the likelihood of supply disruption.
## Table I. Descriptive statistics and correlations

<table>
<thead>
<tr>
<th>Variable Type</th>
<th>Mean</th>
<th>SD</th>
<th>BAL</th>
<th>PAL</th>
<th>MAL</th>
<th>BAH</th>
<th>PAH</th>
<th>MAH</th>
<th>RP</th>
<th>FS</th>
<th>WE</th>
<th>NE</th>
<th>CE</th>
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<td><strong>Between-group variables</strong></td>
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<tr>
<td>Buffer adoption-low LSD (BAL)</td>
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<tr>
<td>Process adoption-low LSD (PAL)</td>
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<td>0.10</td>
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<td>Mitigation adoption-low LSD (MAL)</td>
<td>2.20</td>
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<td>0.69</td>
<td>0.79</td>
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<td>Buffer adoption-high LSD (BAH)</td>
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<td>Process adoption-high LSD (PAH)</td>
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<td>Mitigation adoption-high LSD (MAH)</td>
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<td>−0.18</td>
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<td>−0.03</td>
<td>−0.04</td>
<td>−0.02</td>
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<td>0.10</td>
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<td>0.02</td>
<td>−0.20</td>
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<td>0.13</td>
<td>0.08</td>
<td>0.01</td>
<td>−0.58</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cross-country exchange (CE)</td>
<td>0.45</td>
<td>0.50</td>
<td>0.05</td>
<td>0.11</td>
<td>0.11</td>
<td>−0.02</td>
<td>0.15</td>
<td>0.10</td>
<td>0.04</td>
<td>−0.19</td>
<td>0.30</td>
<td>−0.11</td>
<td>1</td>
</tr>
<tr>
<td><strong>Within-group variables</strong></td>
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<td>(n = 226)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood of supply disruption (LSD)</td>
<td>1.50</td>
<td>0.90</td>
<td>0.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Process adoption (PA)</td>
<td>1.18</td>
<td>1.16</td>
<td>0.28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitigation adoption (MA)</td>
<td>2.67</td>
<td>1.55</td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Bold indicates \( p \leq 0.05 \) (two-tailed); bold and italics indicate \( p \leq 0.01 \) (two-tailed). *Low LSD = low likelihood of supply disruption (Scenario 2); high LSD = high likelihood of disruption (Scenario 1).
We employ both formative and reflective scales to measure the focal constructs of our theoretical model. We adopt formative scales to measure buffer- and process-oriented mitigation strategies; consistent with the formative approach, each scale consists of a comprehensive set, i.e., “census”, of tactics that inform each strategy (Bollen and Ting, 2000; Wilcox et al., 2008). As described in the Research Design section, scale development involved an extensive literature review, comprehensive interviews and a pre-test; moreover, our pre-test and final survey administration provided open response prompts following each scenario for respondents to adopt mitigation tactics not listed in the instrument. This multi-step approach facilitates valid construct definitions and an inclusive set of formative indicators that fully represent the conceptual domain of each formative construct thereby establishing two important requirements for valid formative scales – i.e., content specification and indicator specification (Diamantopoulos et al., 2008). For our reflective scale, we assess the reliability of risk propensity using Cronbach’s $\alpha$; our result ($\alpha = 0.70$) establishes the convergent validity of this scale. To support the discriminant validity of the risk propensity measure, we find that the average variance extracted for this scale exceeds its squared correlation with each other scale. In aggregate, our instrument development approach and empirical findings support the validity of our formative and reflective measurement scales.

5.3 Results

We test our hypotheses using general structural equation models (GSEMs) with multilevel latent variables in STATA (v15). In this approach, we employed multilevel latent variables to account for the hierarchical structure of our data in which scenarios are nested within individuals. Alternately, GSEMs allow for the estimation of simultaneous equations – i.e., the assessment of effects for multiple dependent variables in a single estimation – while also accounting for the hierarchical structure of our response data. Following the recommendations of Heck et al. (2014) for multilevel analyses, we initially estimated the null (random intercept) model to assess the distribution of between- and within-group variance, and compute the intraclass correlation coefficient (ICC) for each dependent variable in our analyses. Our results show that ICCs for the adoption of mitigation tactics (ICC = 0.409, $p < 0.05$), the adoption of buffer-oriented mitigation tactics (ICC = 0.298, $p < 0.05$) and the adoption of process-oriented mitigation tactics (ICC = 0.402, $p < 0.05$) are significantly greater than 0. These results confirm that our data are nested and therefore require a multilevel approach to properly account for the correlation of error terms within individuals.

We rely on model fit indices to determine our specific estimation approach for the random effects. Specifically, for each dependent variable, we compare the Akaike information criterion (AIC) and Bayesian information criterion (BIC) for random intercept estimation and random intercept and slope estimation. The results show that random intercept estimation yields better model fit (i.e. lower AIC and BIC) for the adoption of mitigation tactics, the adoption of buffer-oriented mitigation tactics and the adoption of process-oriented mitigation tactics. Hence, we use the simpler random intercept approach to estimate random effects in the subsequent analyses.

To assess $H1a$ and $H2a$, we estimate the effects of the likelihood of supply disruption, risk propensity and control variables on the adoption of mitigation tactics. Table II, which reports the fixed effects, shows that the likelihood of supply disruption ($B = 0.938$, $p < 0.001$) is significantly and positively related to the adoption of risk mitigation tactics. Consistent with $H1a$, as the likelihood of disruption increases from Scenario 2 to Scenario 1, buyers increasingly adopt mitigation tactics. Our results also support $H2a$: risk propensity ($B = -0.493$, $p = 0.010$) is significantly and negatively related to the adoption of mitigation tactics.
We employ a two-step approach to test $H1b$ and $H2b$ – i.e., the effects of the likelihood of supply disruption and risk propensity on the preference for buffer-oriented mitigation tactics. For these hypotheses, preference may be intuitively modelled as the difference of the adoption of buffer-oriented mitigation tactics minus the adoption of process-oriented mitigation tactics. However, as Edwards (1995) argues, the use of a difference score as a dependent variable is problematic because it results in biased estimates. To address this issue, Edwards (1995) mathematically derives an alternate approach in which the difference score is divided into its constituent elements, which serve as the dependent variables for subsequent analysis; the effects of independent variables on each dependent variable are assessed simultaneously; and significant differences in effects for the same independent variables across simultaneous equations indicate that these independent variables significantly affect the difference in dependent variables.

Following the approach developed by Edwards (1995) and implemented by Mullins et al. (2014), we initially estimate the simultaneous effects of the likelihood of supply disruption, risk propensity and control variables on the adoption of buffer-oriented tactics and the adoption of process-oriented tactics. The fixed effects listed in Table III show that the likelihood of supply disruption is significantly and positively related to the adoption of buffer- ($B = 0.301, p = 0.002$) and process-oriented mitigation tactics ($B = 0.637, p < 0.001$). In addition, we find that risk propensity significantly and negatively affects the adoption of buffer- ($B = -0.192, p = 0.077$) and process-oriented mitigation tactics ($B = -0.300, p = 0.039$). Next, we conduct post-hoc Wald tests to assess the differential effects of the likelihood of supply disruption and risk propensity on buffer- and process-oriented mitigation tactics, respectively. Specifically, for $H1b$, we test whether the effect of the likelihood of supply disruption on the adoption of buffer-oriented mitigation tactics ($B = 0.301$) is equivalent to the effect of the likelihood of supply disruption on the adoption of process-oriented mitigation tactics ($B = 0.637$). The result of the Wald test supports $H1b$ ($\Delta \chi^2(1) = 5.73, p = 0.0167$): as the likelihood of supply disruption increases (from Scenario 2 to Scenario 1), buyers adopt significantly less buffer- as compared to process-oriented mitigation tactics. To test $H2b$, we apply the Wald test to similarly contrast the effect of risk propensity on the adoption of buffer- ($B = -0.192$) vs process-oriented mitigation tactics ($B = -0.300$). We find no support for $H2b$ ($\Delta \chi^2(1) = 0.35, p = 0.5516$); this finding suggests that as risk propensity increases, there is no significant difference in the buyers’ adoption of buffer- vs process-oriented mitigation tactics.

### 6. Discussion

This study advances the resilience-as-balance perspective which suggests that resilience reflects the alignment of mitigation capabilities with vulnerabilities faced by a supply chain. In the context of supply-side resilience, which focuses on the upstream supply chain, we

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>SE</th>
<th>t-value</th>
<th>Two-tailed p-value</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>4.115</td>
<td>0.516</td>
<td>7.99</td>
<td>&lt; 0.001</td>
<td>3.105 – 5.124</td>
</tr>
<tr>
<td>Likelihood of supply disruption</td>
<td>0.938</td>
<td>0.131</td>
<td>7.17</td>
<td>&lt; 0.001</td>
<td>0.682 – 1.194</td>
</tr>
<tr>
<td>Risk propensity</td>
<td>-0.493</td>
<td>0.191</td>
<td>-2.58</td>
<td>0.001</td>
<td>-0.866 – -0.119</td>
</tr>
<tr>
<td>Firm size</td>
<td>0.084</td>
<td>0.073</td>
<td>1.15</td>
<td>0.249</td>
<td>-0.059 – 0.227</td>
</tr>
<tr>
<td>Geographic location (Western Europe)</td>
<td>0.119</td>
<td>0.033</td>
<td>3.90</td>
<td>0.000</td>
<td>0.047 – 0.713</td>
</tr>
<tr>
<td>Geographic location (non-Western Europe)</td>
<td>0.754</td>
<td>0.096</td>
<td>2.44</td>
<td>0.015</td>
<td>0.149 – 1.359</td>
</tr>
<tr>
<td>Cross-country exchange</td>
<td>0.429</td>
<td>0.244</td>
<td>1.76</td>
<td>0.078</td>
<td>-0.049 – 0.907</td>
</tr>
</tbody>
</table>

**Table II.** The adoption of mitigation tactics – multilevel general structural equation model

**Note:** aModel fit: log likelihood = -379.99221
The adoption of buffer- and process-oriented mitigation tactics – multilevel general structural equation model

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Adoption of buffer-oriented mitigation tactics</th>
<th>Adoption of process-oriented mitigation tactics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>SE</td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood of supply disruption</td>
<td>2.038</td>
<td>0.308</td>
</tr>
<tr>
<td>Risk propensity</td>
<td>-0.192</td>
<td>0.109</td>
</tr>
<tr>
<td>Firm size</td>
<td>0.006</td>
<td>0.042</td>
</tr>
<tr>
<td>Geographic location (Western Europe)</td>
<td>0.124</td>
<td>0.173</td>
</tr>
<tr>
<td>Geographic location (non-Western Europe)</td>
<td>0.462</td>
<td>0.176</td>
</tr>
<tr>
<td>Cross-country exchange</td>
<td>0.049</td>
<td>0.139</td>
</tr>
</tbody>
</table>

Notes: Bold denotes significant difference (post-hoc Wald test, \( p \leq 0.05 \)) in estimates across simultaneous equations. *Model fit: log likelihood = -603.31855
conceptualize mitigation capabilities as supply risk mitigation tactics and vulnerability in terms of the likelihood of supply disruption. We apply risky decision-making theory to the study of supply-side resilience by considering buyers’ adoption of and preference for particular mitigation tactics as risky decisions influenced by the likelihood of supply disruption and risk propensity. Integrating the resilience-as-balance perspective and risky decision-making theory, our experimental approach effectively assesses how buyers actually align, or “balance”, their selection of one or more mitigation tactics with the vulnerabilities described in the scenarios. Using this approach, our study advances an important theoretical contribution by conceptually integrating two previously disparate streams of research – i.e., the supply chain resilience and the risky decision-making bodies of literature.

Our integrated approach contributes to the advancement of risky decision-making theory in two important ways. First, we extend the generalizability of this theory by demonstrating its applicability in the context of supply-side resilience. In so doing, our study offers novel conceptualizations of the focal dependent variable of this theory – i.e., risk behaviour. For example, whereas the risky decision-making literature has a rich history of exploring gambles and potential winnings (as summarized by Das and Teng, 2001), our application instead motivates the consideration of risk behaviours largely intended to attenuate losses. Moreover, our application of risky decision-making theory prompts the operationalization of risk behaviour as the sets of related actions (i.e. tactics) that comprise risk mitigation strategies; this contrasts with the traditional applications of risky decision-making theory which largely focus on a singular decision, such as whether or not to continue an information systems project (Keil et al., 2000). Hence, our novel context and operationalization of risk behaviour extend the domain (Whetten, 1989) and boundaries (Bacharach, 1989) in which risky decision-making theory applies. Second, we find that risk propensity is significantly and negatively related to the adoption of risk mitigation strategies ($B = -0.493$, $p = 0.010$). The importance of this finding is underscored by Sitkin and Pablo’s (1992) seminal research, which asserts that risk behaviour is determined by two factors: risk perception and risk propensity. Yet, previous empirical studies (e.g. Keil et al., 2000; Sitkin and Weingart, 1995), which simultaneously assess the effects of risk perception and risk propensity on risk behaviour, conclude that risk propensity does not directly affect risk behaviour. Hence, our study provides initial empirical validation for a key aspect of Sitkin and Pablo’s (1992) conceptualization of risky decision making. Additionally, our results suggest that prevailing behavioural models of risk mitigation and resilience, which do not incorporate risk propensity, may be theoretically incomplete.

Our study also enables us to build upon the emerging supply chain resilience literature. Recent studies consider many predictors of resilience, including inventory management systems (Boone et al., 2013), inventory pooling (Liu et al., 2016), visibility (Brandon-Jones et al., 2014), supplier integration, collaboration and investments (Durach and Machuca, 2018; Wieland and Wallenburg, 2013), and resources and capabilities (Ambulkar et al., 2015; Brusset and Teller, 2017). Yet, notably, extant research offers little insight into how buyers actually make decisions to build resilience; hence, we explicitly consider the formative roles of the likelihood of supply disruption and risk propensity in this decision-making process. Our findings show that the likelihood of supply disruption is significantly and positively associated with the buyers’ adoption of mitigation tactics ($B = 0.938$, $p < 0.001$). This result is consistent with that of Ellis et al. (2010), who empirically show that the likelihood of supply disruption is positively related to the search for alternate suppliers. However, whereas Ellis et al. (2010) consider a single mitigation tactic, our study broadens consideration to include sets of related mitigation tactics that comprise buffer- and process-oriented mitigation strategies. Accordingly, our theoretical model may more accurately approximate the realities that buyers face.
Our results additionally show that the likelihood of supply disruption is significantly and positively associated with buyers’ preference for process- rather than buffer-oriented mitigation tactics ($\Delta \gamma^2_{13} = 5.73, p = 0.0167$). Accordingly, our findings suggest the important role of equivocality and experiential learning in buyers’ decisions to build supply-side resilience. In the development of hypotheses, we contend that infrequent supply disruptions provide little opportunity for experiential learning; the resulting equivocality motivates buyers to adopt buffer-oriented mitigation tactics which require little knowledge of the root cause of the disruption, are capable of attenuating the impact of supply disruption with relative certainty and can effectively address a wide range of vulnerabilities with relatively little effort. Alternately, supply disruptions characterized by higher likelihood enable buyers’ learning processes enabling the understanding of the sources, types and causes of disruptions; with this enhanced understanding, buyers are better positioned to implement process-oriented mitigation tactics that generally leverage product and process knowledge, require supplier coordination, and are more complex and time-consuming for buyers to implement. Hence, our results complement the findings of Talluri et al. (2013), who consider the effects of risk likelihood on mitigation tactic efficiency, by advancing empirical support for logic that explains how the likelihood of supply disruption affects buyers’ decisions to adopt mitigation tactics. Moreover, the integration of our results with those of Talluri et al. (2013) provides insights into how buyers should vs actually do adopt mitigation tactics.

Another contribution of our study centres on risk propensity, as this dispositional factor is notably absent from prior behavioural studies of risk mitigation and resilience. Our results show that risk propensity is significantly and negatively related to the buyers’ adoption of buffer- and process-oriented mitigation tactics ($B = -0.493, p = 0.010$), but is not related to buyers’ preference for buffer-oriented mitigation tactics ($\Delta \gamma^2_{11} = 0.35, p = 0.5516$). The former finding follows directly from risky decision-making theory: in contrast to risk-seekers, risk-averse buyers are more sensitive to potential losses and, therefore, aggressively seek to minimize potential losses through the adoption of mitigation tactics. The latter finding fails to support our theoretical explanations based on the relative levels of certainty and the ancillary benefits inherent in buffer- vs process-oriented mitigation tactics. As indicated by our results, risk-averse buyers do not prefer the enhanced certainty of mitigation through the selection of buffer-oriented tactics; rather, they are equally likely to adopt both buffer- and process-oriented tactics to protect their operations. Conversely, we find that risk-seeking buyers are not attracted to the ancillary benefits attainable through process-oriented mitigation tactics; instead, they similarly refrain from adopting both buffer- and process-oriented tactics.

Arguably, the most salient theoretical implication of our findings concerns the resilience-as-balance perspective. In particular, the positive relationship between the likelihood of disruption and the adoption of mitigation tactics supports the resilience-as-balance view: buyers increase their mitigation capabilities in accordance with the vulnerabilities that they face. However, risk propensity can distort this balance. Statistically, our results show that when the likelihood of supply disruption is held constant, buyers having differing risk propensities will be more or less likely to adopt mitigation tactics. The resulting imbalances threaten supply-side resilience and, ultimately, firm performance (Pettit et al., 2010). For example, risk-averse buyers may overly invest in buffer- and process-oriented mitigation tactics and, subsequently, bear excessive costs that reduce firm profitability (Pettit et al., 2010). Alternately, risk-seeking buyers may fail to pursue buffer- and process-oriented mitigation tactics, thereby exposing the firm to vulnerabilities. Hence, our results show how buyers may build or fail to build supply-side resilience.

These findings also serve to caution managers: the likelihood of supply disruption and risk propensity may motivate risk-mitigating behaviours that are misaligned with...
organizational goals. For example, in cases where risk-seeking buyers historically experience few supply disruptions, they are predisposed to adopt fewer risk mitigation tactics and, when implemented, these tactics tend to be buffer-oriented. Moreover, risk-seeking buyers tend to adopt fewer mitigation tactics. Yet, for organizations in which supply continuity is mission-critical, such behavioural tendencies may expose the organization to unacceptable supply risk. Additionally, the preference for buffer-oriented mitigation tactics may inhibit organizational goals aimed at establishing closer relationships with strategic suppliers through collaborative inter-organizational efforts. For these cases, our results intimate the importance of individual incentives and general policies that align buyers’ actual behaviours with both supply risk conditions and organizational goals.

7. Limitations and future research

Whilst our study makes important contributions to theory and practice, it is subject to potential limitations. The descriptive statistics for the risk propensity scale suggest that the respondents to our study are relatively risk-averse. While risk-aversion may be a common attribute of purchasing professionals, this finding may also be influenced by the phrasing of measurement items that include terms such as “never” and “forging” and that might be viewed by respondents as extreme. However, this potential limitation may be minimal as the risk propensity scale was validated previously by Weber et al. (2002) and within our study. Further, as noted earlier, our reliance on a single respondent for the measures of risk propensity and the adoption of risk mitigation tactics raises concerns that our results may be influenced by common method bias. However, we incorporate the recommendations of Podsakoff et al. (2003) into our research design to mitigate this effect. Moreover, the results of our assessment, which is based on the marker variable approach of Lindell and Whitney (2001), suggest that the actual effect of this potential bias is negligible (i.e. near 0).

Despite these potential limitations, our study provides a fruitful platform for multiple streams of future research. First, whereas our study incorporates a single dimension of supply disruption – i.e., likelihood of supply disruption, future experimental research may incorporate more variants of risky situations such as the magnitude, source and type of disruption to develop a more comprehensive view of the factors that necessitate resilience. Second, whereas our study focuses on the different types of mitigation tactics that buyers adopt in response to a risky situation, future research should also consider the relative intensity with which each tactic is implemented. Finally, future research may extend the behavioural studies of resilience beyond the supply side to advance a comprehensive, true “supply chain” view of resilience by also considering internal- and customer-facing mitigation capabilities and vulnerabilities. These proposed studies may build upon our research to further refine our understanding of how buyers’ actual behaviours affect supply chain resilience.

References


Appendix. Instructions, scenarios and measurement scales

Scenarios
Please picture yourself in both of the two following scenarios. Indicate for each scenario what risk mitigation strategy you would choose in that particular situation (multiple strategies per scenario are possible). Furthermore, please consider the same product and supplier for both scenarios.

Scenario 1. The product you are purchasing from a certain supplier is of great importance for your company, the transaction volume is reasonably large (it accounts for 10 per cent of the total purchasing volume of your company). However, recently the supplier experienced a machine breakdown which stopped the production and, therefore, also the supply of this product for five days. Furthermore, there are no alternative suppliers for that particular product and your safety stock of this product lasts only for three days. In addition to that, you expect that this kind of problem is very likely to happen again in the future.

Scenario 2. The product you are purchasing from a certain supplier is of great importance for your company, the transaction volume is reasonably large (it accounts for 10 per cent of the total purchasing volume of your company). However, recently the production of the supplier was affected by electricity failure (caused by an uncommonly severe winter storm). This electricity failure stopped the production and, therefore, also the supply of this product for five days. Furthermore, there are no alternative suppliers for that particular product and your safety stock of this product lasts only for three days. In addition to that, you expect that this kind of problem is not very likely to happen again in the future.

Please refer to the scenario (above) and answer the following questions

Risk mitigation strategies
The instruction
Please indicate which strategies you would choose; multiple strategies are possible.

Buffer-oriented mitigation strategy (Formative Scale, Source: Zsidisin and Ellram, 2003)*
- require supplier to hold safety stock;
- establish multiple supply sources;
- avoid risk (e.g. divest from a certain market or discontinue relationship with supplier); and
- deploy buffer stocks.

Process-oriented mitigation strategy (Formative Scale, Source: Zsidisin and Ellram, 2003)*
- certify supplier (and its ability to meet predefined requirements);
- implement quality management programs (to measure and improve abilities of suppliers);
- develop supplier (improve its performance and capabilities); and
- control/share/transfer risk (e.g. vertical integration and determination of risk responsibility).
Risk likelihood
Please answer the following overall questions concerning your risk propensity.

Risk perception (Manipulation Check, Source: Ellis et al., 2010)\(^d\)
What is the likelihood of this supply problem?

Scenario realism (Scenario Realism Check, Source: Rungtusanatham et al., 2011)\(^e\)
The scenario reviewed above and the expected decisions are realistic.
In my past experience, I have encountered similar decision-making scenarios.
I took my assumed responsibility and decision-making seriously while answering these survey questions.
\(^a\)Response scale: 0 = no and 1 = yes
\(^b\)Response scale: 1 = very unlikely to 7 = very likely.
\(^c\)Response scale: 1 = less than 50, 2 = 50-99, 3 = 100-499, 4 = 500-999, 5 = 1,000-10,000, 6 = more than 10,000.
\(^d\)Response scale: 1 = very unlikely to 7 = very likely.
\(^e\)Response scale: 1 = strongly disagree to 7 = strongly agree.

Risk propensity (Reflective Scale, Source: Weber et al., 2002)\(^b\)
Please indicate your likelihood of engaging in this activity or behaviour.
- investing 10 per cent of your annual income in a very speculative stock;
- going down a ski run that is too hard or closed;
- gambling a week's income at a casino;
- using office supplies for your personal business;
- smoking a pack of cigarettes per day;
- asking your boss for a raise;
- co-signing a new car loan for a friend;
- deciding to share an apartment with someone you do not know well;
- never wearing a seatbelt;
- forging somebody's signature;
- trying bungee jumping; and
- betting a day's income at the horse races.

Firm size: how many employees are employed in your organization enterprise wide?\(^c\)
Geographic location: what is your nationality?\(^c\)
Cross-country exchange: where is the supplier you considered in the above-mentioned scenarios located?\(^c\)

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Digital health technology enhances resilient behaviour: evidence from the ward

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Abstract

Purpose – In the healthcare management domain, there is a lack of knowledge concerning the role of resilience practices in improving patient safety. The purpose of this paper is to understand the capabilities that enable healthcare resilience and how digital technologies can support these capabilities.

Design/methodology/approach – Within- and cross-case research methodology was used to study resilience mechanisms and capabilities in healthcare and to understand how digital health technologies impact healthcare resilience. The authors analyze data from two Italian hospitals through the lens of the operational failure literature and anchor the findings to the theory of dynamic capabilities.

Findings – Five different dynamic capabilities emerged as crucial for managing operational failure. Furthermore, in relation to these capabilities, medical, organizational and patient-related knowledge surfaced as major enablers. Finally, the findings allowed the authors to better explain the role of knowledge in healthcare resilience and how digital technologies boost this role.

Practical implications – When trying to promote a culture of patient safety, the research suggests healthcare managers should focus on promoting and enhancing resilience capabilities. Furthermore, when evaluating the role of digital technologies, healthcare managers should consider their importance in enabling these dynamic capabilities.

Originality/value – Although operations management (OM) research points to resilience as a crucial behavior in the supply chain, this is the first research that investigates the concept of resilience in healthcare systems from an OM perspective, with only a few authors having studied similar concepts, such as “workaround” practices.

Keywords Resilience, Dynamic capabilities, Absorptive capacity, Digital health technology, Healthcare operations management, Operational failure

Paper type Research paper

1. Introduction

A thought-provoking study from Makary and Daniel (2016) estimates that medical errors are the third leading cause of death in the USA. The same authors predict that medical errors that threaten patient safety are under-recognized in many other western countries. Despite the fact that common sense would suggest focusing mostly on physicians and/or nurses as the causes of adverse events, it is commonly recognized that adverse events are largely “the tip of the iceberg” (Reason, 2000) and are caused by a number of operational failures that occur during the care process (Tucker, 2004). Thus, improving patient safety must also be related to the management of such operational failures. Operational failures in healthcare can be classified into: problems that disrupt the normal patient-care workflow because, for instance, employees need something they do not have at the right time (Tucker and Edmondson, 2003) and, consequently, they cannot continue to follow standard tasks; and errors that result from the execution of unnecessary or incorrect tasks (Tucker, 2004).

Within the field of operations management (OM), a number of techniques and tools have been developed to improve patient safety. The majority of these techniques can be
found in the literature on clinical risk management, quality management and lean management (Gowen et al., 2006; McFadden et al., 2006; McFadden et al., 2015) and aim at reducing the risk of harm in terms of the probability of the event, e.g. through the implementation of guidelines, protocols and statistical or quality process control, which help to find and categorize all the possible errors and failures that can occur during care processes. Healthcare operations have the typical characteristics of professional service operations: high customer contact and customization, high service process variation and substantial external influence on service providers (Dobrzykowski et al., 2016). These characteristics make it difficult to forecast all the possible operational failures that can occur and even when it is possible to anticipate their occurrence, it is not always possible to prevent them. For these reasons, on a day-to-day basis, healthcare operators and the entire healthcare system need to adapt, improvise, react and solve the failures that occur: being resilient is the only key for guaranteeing patient safety in these cases.

The British Standard Institution (2014) defines organizational resilience as “the ability to anticipate, prepare for, respond and adapt to events – both sudden shocks and gradual change; that means being adaptable, competitive, agile and robust.” The concept of resilience has been widely explored in other management fields, such as supply chain management (Linnenluecke, 2017). However, it has not been considered in healthcare OM research, even though in practice, we observe physicians and nurses regularly implementing actions that can be classified as resilience practices, e.g. when “a lack of support staff (housekeepers, secretaries) caused inefficiencies and interruptions for physicians and nurses who had to perform support staff functions (e.g. answering phones, cleaning rooms) themselves” (Tucker et al., 2008, p. 1815). The need to study resilient practices in healthcare systems is also stated in the resilience engineering (RE) literature (Patriarca et al., 2017). RE is considered to be a safety management paradigm for different domains and healthcare is one of those domains that mostly use RE (Righi et al., 2015). Although RE is defined as “the deliberate design and construction of systems that have the capacity of resilience” (Fairbanks et al., 2014, p. 381), scholars typically use this acronym to refer only to resilience (Bergström et al., 2015). RE acknowledges that performance in healthcare settings, both high and low, is mainly due to the capacity of operators to make adjustments in their everyday clinical work (Hollnagel, 2014). These adjustments, caused by the difference between the work as it should be carried out – work-as-imagined – and how it is really executed – work-as-done, lead scholars to assess the opportunity to learn from everyday clinical work (Sujan et al., 2017) without stigmatizing every behavior or task that differs from how it was designed.

Given the crucial role that being resilient against operational failures has on patient safety, we wonder if and how healthcare systems develop and promote their resilience capabilities. Furthermore, in this paper, we also focus on the role of digital health (DH) technologies in enabling such capabilities. As in other industrial sectors, in healthcare, we observe a general trend in implementing technology that supports operations (Bayo-Moriones et al., 2015; Sharma et al., 2016). The improvements that are achievable by implementing DH are highly distinct because of their peculiarity and variability. For example, the electronic health record (EHR) allows physicians and nurses to manage patient information in a more orderly and effective way, while telemedicine can reduce waiting times for patients. Although recent studies have provided evidence of the risk that digital technologies in healthcare may threaten patient safety (Kim et al., 2017), we found anecdotal evidence that physicians and nurses also use these technologies when managing operational failures but no study has explored how they use these technologies for this purpose and if they are effective. In other words, if and how digital technology enables and supports the resilience capabilities in a healthcare setting is not precisely known.
In sum, our research questions are:

*RQ1.* How do healthcare providers employ resilient behavior to solve operational failures and improve patient safety?

*RQ2.* How do digital technologies support such a resilient behavior?

To answer these questions, we conducted a double case study (see Yin, 2013) in the surgery wards of two Italian hospitals.

2. **Theoretical foundation**

2.1 **Operational failures in healthcare**

One of the most critical challenges in healthcare is dealing with patient safety (Li and Benton, 2006; McFadden et al., 2009), which can be defined as “freedom from accidental injury” (Kohn *et al.*, 2000). Accidental injuries are caused by adverse events, namely, “an undesired patient outcome that may or may not be the result of an error” (Thomas and Brennan, 2001, p. 32). Adverse events have an extremely strong effect in terms of the harm caused to patients and, in extreme (but not rare) cases, human life (Kohn *et al.*, 2000; James, 2013). Additionally, their economic impact is not negligible, as evidenced by the amount of money spent to resolve correlated harm and damage claims (Van Den Bos *et al.*, 2011).

According to the system approach theory (Reason, 2000), failures that cause adverse events during the workflow progress are due, above all, to “upstream systemic factors.” These factors, which potentially affect patient safety, are well represented in the Systems Engineering Initiative for Patient Safety model developed by Carayon *et al.* (2006). Grounded in systems engineering, the model focuses on the interactions between people and their surroundings. At the center of the model, we find a person (a hospital worker or a patient) who performs various tasks using different tools or technologies and respects the organizational conditions within a physical environment. All these factors interact with each other and influence processes and outcomes. Disruptions to interactions between the factors of the work system that can affect patient safety are referred to as “operational failures” (Tucker *et al.*, 2008).

A comprehensive definition of operational failure can be found in Tucker (2004). The author distinguishes between problems, i.e. anything that disrupts the normal workflow and hinders employees from executing expected tasks (such as a missing syringe) and system errors, defined as the execution of a task that is subsequently determined to be unnecessary or wrong. In a further study, the same author classified operational failures according to different categories, the six most recurrent of which are equipment/supply, facility, communication/documentation, staffing/staff development, medication and process/policy (Tucker *et al.*, 2008). In line with other healthcare related studies (Spear and Schmidhofer, 2005; Stevens and Ferrer, 2016), in this paper, we use the categorization proposed by Tucker (2004) and Tucker *et al.* (2008) to investigate how healthcare providers manage operational failures.

2.2 **Resilience practices in healthcare**

The RE literature has already contextualized resilience in the healthcare setting. RE researchers define resilience as “the intrinsic ability of an organization (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress” (Hollnagel *et al.*, 2007, p. 16). Over the years, researchers have tried to specify the scope of RE. In their literature review, Patriarca *et al.* (2017) categorized RE research according to four different subcategories, one that was more theory-oriented (the theory of RE in healthcare) and three that were
more practice-oriented (RE for designing technological devices, modeling RE in healthcare and RE in practice).

However, we found no studies in the RE literature that anchor the observed resilient practice to the operational failure that requires it. This is a significant gap because recognizing what kind of event triggers a given resilience practice or, the other way around, what resilience practice can counteract a specific operational failure, would enable the creation of a framework that helps to promote resilience in practice.

On the other hand, the literature on OM widely recognizes the importance of error management in healthcare (Kessels-Habraken et al., 2010; Kessels-Habraken and van der Schaaf, 2010; Kansse et al., 2006; Parnes et al., 2007): “100% safety cannot be achieved because errors will surely arise” (Kessels-Habraken et al., 2010, p. 1301). Two types of practices related to the management of operational failures have been largely analyzed for this purpose, namely, workaround and error-handling practices. A comprehensive definition of workaround is: “a goal-driven adaptation, improvisation, or other change to one or more aspects of an existing work system in order to overcome, bypass, or minimize the impact of obstacles […] that are perceived as preventing that work system or its participants from achieving a desired level of efficiency, effectiveness, or other organizational or personal goals” (Alter, 2014, p. 1044). This kind of practice has been largely subjected to criticism in the healthcare domain because of the risk entailed in the negative effects that may originate from its implementation (Tucker, 2004; Halbesleben et al., 2008). Error-handling refers to errors that occur, e.g. when a task is executed incorrectly. According to Kontogiannis (2011) conceptualization, the phases of error-handling are: error detection, i.e. the operator realizes that an error is about to occur or suspects that an error has occurred, explaining the error, i.e. the operator identifies the nature of the error and explains why it occurred, and correcting/recovering from the error, i.e. the operator modifies an existing plan or develops a new one to compensate.

Even if working-around and error-handling have in common the management of an unexpected event, their main difference lies in when the operational failure is detected. In fact, problems directly affect the standard activities that healthcare operators have to execute, causing a “block” such that nurses and physicians are unable to execute their standard activities, forcing them to stop and work around the block. In this case, the detection is immediate (Tucker, 2004). Errors are different because they may not be evident until the resulting adverse event occurs, e.g. during the drug delivery process, an error could occur that is the result of a nurse taking the wrong drug from the shelf but the detection may not occur until after the wrong drug has been delivered to the patient and she/he begins to disgorge. This difference becomes more evident when analyzing problems and errors in terms of their effect on the workflow. A problem interrupts the workflow and, as a result, workers have to deviate and generate a solution in order to solve it. An error does not necessarily cause an interruption and a deviation from the normal workflow; this depends on the ability to detect the error and to take counter-measures. Even if these two kinds of practices have been analyzed separately in the literature, it is clear to us that both workaround and error-handling practices can be considered two important mechanisms of being resilient.

2.3 Resilience and dynamic capabilities

We have discussed how the research on the resilient behavior of healthcare systems mainly falls within the RE paradigm and workflow-related resilience mechanisms and practices (workaround and error-handling). In the RE context, few studies look at resilience in terms of the “ability” owned by people or by the organization as a whole. Hollnagel et al. (2007) identify four abilities (knowing what to do, learning from experience, monitoring the work environment for changes and anticipating demand
in the future), while Cuvelier and Falzon (2011) identify coordination as a further resilience ability.

As a matter of fact, the concept of resilience has been largely examined in other management fields in terms of “capabilities” (Linnenluecke, 2017). Supply chain management is one of the fields in which the concept has been more amply investigated (Spring et al., 2017). The characteristics of a resilient supply chain consist of being able to respond to unexpected events by “maintaining continuity of operations at the desired level of connectedness and control over structure and function” (Ponomarov and Holcomb, 2009, p. 131). Over the last five years, the operations and supply chain management research community has focused a great deal of effort on identifying the dimensions that constitute the resilience capability of a supply chain. Among them, the framework defined by Chowdhury and Quaddus (2017), which includes most of the dimensions also proposed by other authors (e.g. Linnenluecke, 2017; Pettit et al., 2010; Wieland and Wallenburg, 2013) – is probably the most complete. The authors analyze the resilient behavior of a supply chain from the perspective of dynamic capabilities and they identify three main resilience dimensions: proactive capability, reactive capability and supply chain design quality. The authors also identify a number of sub-dimensions: flexibility for proactive capability, response for reactive capability and complexity for design quality. Finally, for every sub-capability, the authors identify different variables that can be seen as operational practices that originate from the relative dynamic capability. In the healthcare management literature, there is an increasing number of studies that observe healthcare settings by using the theory of dynamic capabilities (Anand et al., 2009), especially when dealing with patient safety (Dobrzykowski et al., 2016).

In conclusion, there is a consensus among scholars that resilience should be considered as composed of different dynamic capabilities and that resilience studies should be grounded in dynamic capability theory (Teece et al., 1997; Zollo and Winter, 2002). In line with this trend, this paper observes and studies the adoption of resilience behavior in healthcare through the lens of dynamic capabilities and, specifically, by investigating the day-to-day practices implemented by nurses and physicians that are potentially related to different dynamic capabilities. This approach is also consistent with the recent literature that focuses on exploring the nature of the relationship between dynamic capabilities and operational practices (Winter, 2003). For example, Dabhilkar et al. (2016) operationalize supply chain resilience by defining four different clusters of “practice bundles,” achieved by analyzing the resilience dimensions with which they are linked. Finally, Birkie et al. (2014) find five different operational resilience core functions, each linked to both dynamic capabilities and operational routines.

2.4 DH technology and resilience capabilities

The digital revolution (also known as Industry 4.0) is offering different industries, including healthcare, the opportunity to reform the service delivery process and to improve it in terms of quality, efficiency and effectiveness. DH is a broad term that includes several different information technologies that encompass health IT, mHealth, eHealth, etc. (US Food and Drug Administration, 2017). In particular, DH not only includes information and communication technologies – aimed mainly at improving the storage, processing and transmission of data – but also the so-called digital technologies that enhance connectivity among a number of different physical devices with a high degree of automation (Bloom et al., 2014). Digital technologies include, for example, wireless medical devices, telematics and wireless health and, as in other industrial sectors, these are influencing hospitals’ processes and work practices.

Recent studies have attempted to evaluate the impact of DH on quality performance in healthcare (Chaudhry et al., 2006); however, the results are often contradictory. This may be
explained with regard to different factors. For example, researchers focus on a limited number of technologies and, consequently, it is not easy to grasp the positive effects that may be obtained thanks to their integration (Sharma et al., 2016) and it is difficult to draw general conclusions about DH effects. On the other hand, some scholars have provided evidence of the risk of negative effects associated with DH, thus making the debate on DH and quality more complex. For instance, Froehle and White (2014) find that communication technologies (e.g. using smartphones for mailing and messaging) can be a distraction and can slow down work. More generally, Kim et al. (2017) show that health IT-related harms are increasing.

Moreover, given that the analyzed dimension of quality is often patient safety, authors instinctively focus only on those technologies that are strictly and directly linked to clinical risk management. For example, in order to diminish the likelihood of future re-occurrences, Gardner et al. (2015) study how DH improves the capability of managing a large amount of data related to errors during a patient care process and Holden and Karsh (2009) demonstrate the advantage of DH for patient safety by focusing on the relationship between the level of usage of medical error/incident reporting systems and patient safety.

In contrast, in this paper, we argue that analyzing the way in which DH is used during care operations (e.g. technologies needed during surgery) may produce significant results in terms of patient safety improvements. A recent study of Wani and Malhotra (2018) empirically demonstrates that the “meaningful” adoption of healthcare digital technology (in particular, EHR) improves patient outcome. Meaningful use of digital technology means “[…] capturing patient information electronically, using patient information to track key clinical conditions, integrating test and imaging results and using decision support tools, communicating the information to all providers for the purposes of care coordination […]” (Wani and Malhotra, 2018, p. 2). DH support healthcare decision making, for example, by facilitating integration of patient health history for planning safe and proper treatment (Kohli and Tan, 2016). We also expect that DH may thus support the urgent need of patient information and the real-time decision-making process of line professionals and managers when an operational failure occurs, making them capable of responding quickly and in an informed manner to problems that threaten patient safety and processing outcomes.

Furthermore, in other industry sectors, it has already been demonstrated that these technologies can enable companies to introduce new work practices that require less job standardization and more specialization (Ramirez et al., 2007; Bayo-Moriones et al., 2015). Given the non-standardizable nature of workaround, error-handling and resilience work practices in general, in this paper, we are interested in understanding how DH technologies can support the resilience capability of the healthcare system. This is in line with the idea that “operations management, information systems and healthcare management have the potential for synergistic results that improve efficiency and quality” (Devaraj et al., 2013, p. 182). In their literature review, Patriarca et al. (2017) acknowledge the importance of designing and developing technological devices and information systems to make resilience a characteristic of the whole healthcare system, rather than one of a single operator.

Resilience capabilities are necessary to obtain improvements in terms of patient safety and digital technologies can influence the way healthcare operators develop resilience capabilities.

2.5 Healthcare knowledge and absorptive capacity (ACAP)

Technical expertise and knowledge represent the foundations on which healthcare employees execute their daily tasks (von Nordenflycht, 2010). The high level of service customization in response to the characteristics of particular patients (Dobrzykowski et al., 2016) and the intrinsic uncertainty of the healthcare environment demands a number of real-time decision-making activities during most healthcare processes
(Dy and Purnell, 2012) and the ability to make the right decision in each phase of the process is strengthened by different kinds of knowledge (Chakravarty, 2014), from general clinical knowledge to specific patient-related knowledge.

Seen as a dynamic capability, ACAP is defined as the capability of an organization to acquire and exploit knowledge in order to obtain a competitive advantage (Cohen and Levinthal, 1990; Zahra and George, 2002). This concept was initially used to better explain the mechanisms underlying the acquisition and exploitation of knowledge in R&D settings. Aside from this, in the last few years, the ACAP concept has been used in healthcare environments to explore the relationship between organizational learning and experience and hospital performance, e.g. in Harvey et al. (2015) and Ding (2014).

In the context of resilience, the concept of ACAP is useful for comprehending two important phenomena. The first is the importance of easy and fast access to knowledge when facing an operational failure. In the healthcare setting, acquiring useful patient-related knowledge as quickly as possible may potentially enable the line professional to deliver more appropriate treatments to patients and to promptly find solutions to problems. The second phenomenon is the importance of transforming and exploiting knowledge. As mentioned earlier, when errors or problems occur, the line professional has to be able to make a quick decision in order to avoid the failure that transforms into harm to the patient. ACAP, meant as a combined learning and acting mechanism, has the potential to influence the organization’s resilience.

3. Research methodology

We decided to implement the methodology of case research to provide a deep insight into the concept of resilience mechanisms and capabilities in healthcare and, moreover, to understand how DH technologies impact healthcare resilience. In order to increase the knowledge regarding resilience, which is viewed as comprising a number of dynamic capabilities, we focused on an empirical examination of practices implemented by employees in the field. In fact, studying dynamic capabilities, as constituted by various practices, may “help to develop a deeper understanding” (Dabhilkar et al., 2016, p. 2). Consequently, a case research approach was chosen because it is a suitable method for attaining as much information as possible from operational activities and tasks for the purpose of theory building (Voss et al., 2002).

On the one hand, the lack of research concerning workaround and error-handling, seen as a bundle of practices that form an expression of resilience capabilities, and, on the other hand, the lack of studies related to the effect of digital technologies on resilience capabilities, forced us to undertake an exploratory approach. Case research calls for dealing directly with nurses and physicians, observing their behavior and talking to them with the aim of gathering as much useful information as possible. Moreover, the strict relations and collaboration with healthcare operators during the development of the study allowed us to absorb tacit knowledge about the phenomenon from the perspective of their experience (Sherman and Webb, 1988).

3.1 Sampling

The unit of analysis in our research is the ward. We decided to focus on a ward rather than the entire hospital for at least three reasons. First, the high complexity of a hospital, grounded in a large number of wards and their substantial differences, does not allow us to become sufficiently experienced in the activities carried out by the different employees in the different hospital wards. To better understand the research context and the dynamics of the ward’ teams (nurses and physicians), we believed that looking “within the ward” would be more effective. Second, we selected the ward (specifically the surgery ward) because, in this setting, the patient interacts with healthcare operators and has an active role during the
execution of care processes (e.g. taking prescribed drugs by her/himself) and because there is a great deal of process variation due to, for example, the different inherent physical characteristics of the patients, influencing the surgical operation workflow. Finally, the breadth of surgeons’ knowledge significantly influences their day-to-day activities but also gives them enough power to minimize management’s intervention in controlling the workflow. All of these characteristics made the surgical ward particularly suitable for our exploratory analysis.

Given that in this phase of the study there is no reason to think that the healthcare provider’s geographical location is a discriminatory variable for studying healthcare resilient behavior, we selected our sample from one of the regions in the south of Italy – Sicily – to facilitate the data collection process. We also wanted to conduct our case research as thoroughly as possible and, therefore, we selected only two hospitals. The two selected cases were very different in terms of the intensity of DH adoption. The way in which we assessed the intensity of DH adoption is described in the next section. In contrast, during the sample selection process, we were unable to make an initial distinction or differentiation in terms of the hospitals’ resilient behavior. Given the nature of public healthcare in Italy, the two hospitals under study, as well as other healthcare providers located in the same region, depend, institutionally, on the same regional healthcare agency whose role basically consists of strategic control. However, from an operational point of view, hospitals have a good level of autonomy; hence, being located in the same region does not weaken our choice.

The construction of the first hospital (Hospital A) was completed in the early 1990s but, beginning in 1995, the facility was equipped with modern equipment and medical devices that, today, make it a state-of-the-art hospital. The hospital provides services for a population of nearly 31,000 units across an area of 206.4 km².

The second hospital (Hospital B) was established in 1997 as a public/private international joint venture. Thanks to the involvement in the project of an important medical center from an American university, it is also widely considered as a center of excellence for transplantation in Italy, which, over the years, has brought experience, professionalism and specialization to the hospital. Hospital B is the first hospital in Southern Italy to receive Joint Commission International accreditation. Healthcare data on the hospitals are shown in Table I.

### 3.2 Data collection and analysis

Two different semi-structured interview protocols were used for the collection of data (Appendix 1). This kind of approach allows the researcher to investigate the components of the conceptual framework by asking related questions but, at the same time, it allows the researcher to comprehend interesting aspects, which, due to the novelty of the subject, were not sufficiently appreciated. The creation of two different protocols, one for head physicians

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Beds</th>
<th>Ordinary admissions</th>
<th>Average ordinary hospitalization (days)</th>
<th>Bed occupancy rate (%)</th>
<th>Case-mix index (Italy CMI = 1)</th>
<th>DH adoptiona</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>136</td>
<td>6,943</td>
<td>5.94</td>
<td>83.52</td>
<td>1.04</td>
<td>Medium (in line with Italian hospitals)</td>
</tr>
<tr>
<td>B</td>
<td>78</td>
<td>2,778</td>
<td>9.6</td>
<td>93.7</td>
<td>2.7</td>
<td>High</td>
</tr>
<tr>
<td>Italy average</td>
<td>116.18</td>
<td>4,883.5</td>
<td>6.86</td>
<td>79.2</td>
<td>1</td>
<td>–</td>
</tr>
</tbody>
</table>

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**Note:** aBased on opinions of head managers of the information systems

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**Table I.** Hospitals A and B healthcare data (2016)
and head nurses and one for physicians and nurses, is justified because of the different operational failures they may incur. For example, a physician generally implements a resilience practice if he/she makes a mistake or if he/she is missing a particular piece of equipment to complete the activity. Thus, he/she is resilient toward operational failure that directly affects the job. In contrast, a head physician incurs operational failures that are more related to the organization of hospital work practices or are caused by other physicians or nurses. Hence, he/she may take the role of solving the problems of others. Consequently, in order to properly assess the capability to manage the operational failures that are the responsibility of these two different professional categories, we adopted two different perspectives. We asked management professionals questions about how they manage situations where the line professionals under their supervision manage operational failures and we asked line professionals questions directly linked to how they manage operational failures. Furthermore, in order to avoid influencing and conveying preconceptions about resilience capability and the corresponding role of DH to the respondent, the interviews were built around operational failures: we asked for real instances of operational failures and about “what happens next?” Every work practice related to resilience behavior is a reaction to an operational failure, therefore, exploring employees’ reactions to operational failures – including the use of any DH – allowed us to obtain as much information as possible. In building the two protocols, we were inspired by the work of Tucker et al. (2008), who classified operational failures according to different categories and we focused on these categories and asked specific questions.

Data collection took place from May to November 2017. Prior to beginning, the interviews, we organized a meeting with the clinical risk manager and the head information systems manager in each hospital in order to explain the aim of the research and why we needed to interview employees from the surgical wards. During the meeting, we first showed the head information systems manager a list of technologies (Table AI). In fact, to assess the DH adoption levels of the two hospitals in relation to the average level of use in Italy (Table I), we directly asked the head information systems manager of each hospital (both of whom had a great deal of experience within IT departments in different hospitals in Italy). More specifically, after showing this wide list of technologies, we then asked them to provide us with an estimate as to the level of DH adoption in their hospital with respect to the Italian average. IT managers’ statements, but also our perception after the on-site visits and after reading hospital documentation (e.g. the annual report on performance and quality) clearly showed that Hospital B definitively presents a quite high level of information technology adoption in respect to the Italian average. Hospital B was one of the first hospitals in Italy to implement patient care process digitalization, and in 2010, its digitalization level was acknowledged by the Healthcare Information and Management System Society at level 6 out of 7 (consider that in North America only 6 percent of hospitals reach the level 7, www.himssanalytics.org). In 2012, Hospital B also received the prestigious “Italian innovation prize for ICT in healthcare” under the category “business intelligence systems” from the Healthcare ICT Observatory of the School of Management of the Politecnico di Milano.

We later held a focus group with the head physician and the head nurse of each of the two wards in order to explain why we needed to interview both them and the physicians and the nurses from the wards. We asked if they would accompany us on a look around the ward in order for us to better understand the context we were going to analyze and to be able to focus the interviews on the most interesting things from our observations. In total, 18 interviews, 9 from Hospital A and 9 from Hospital B, were planned and then conducted. These included four interviews with head physicians and head nurses (one head physician and one head nurse from each hospital), six with physicians (three from Hospital A and three from Hospital B) and eight with nurses (four from Hospital A and four from Hospital B).
Furthermore, we analyzed documentation and carried out direct observations in situ in order to obtain confirmation (Yin, 2013) and additional information that could be compared with that generated from the interviews. The interviews lasted from 30 to 70 min, were audio-recorded, transcribed and analyzed using ATLAS.ti® software. Finally, we performed within-case and cross-case analyses.

4. Case analysis
Through open, axial and fixed coding (Strauss and Corbin, 1998) and within-case analyses, five different capabilities emerged as crucial for managing operational failure. Furthermore, in relation to these capabilities, the medical, organizational and patient-related knowledge of the operator involved in the operational failure-solving surfaced as a major enabler. In the first step of the coding process, we summarized in a few words the pieces of text related to counter-measures against operational failures, e.g. “head physician tells a nurse to execute a task he shouldn’t” or “asking the head physician for help if you have doubt.” In axial coding, the aim is to group codes representing similar ideas or concepts, e.g. the two codes noted above were grouped into the collaboration between head physician and nurse code. Finally, using selective coding, we found a more general concept that may be understood as capabilities, e.g. collaboration between head physician and nurse and collaboration between head physician and physician are grouped within the vertical collaboration capability.

For the sake of clarity and to show the chain of evidence that led us to the coding activity, Table AIII reports the frequency of each resilience dimension/sub-dimension that emerged during the interviews, divided by the interviewee’s role and the hospital. The evidence clearly shows some differences between Hospital A and Hospital B. For instance, the codes, clinical knowledge and multi-skilled workforce, are more frequent in Hospital A, while patient-related knowledge ACAP and horizontal collaboration are more frequent in Hospital B. The results of this qualitative comparison will be used in the next section on the cross-case analysis.

With regard to DH, most of our data collection was in regard to three specific technologies, namely, the EHR, telepathology and the optical head-mounted display (OHMD), the latter in the beta-testing phase. Unlike EHR and telepathology, the widespread diffusion and potential adoption of OHMDs as a regular technology in hospitals is still futuristic. However, we also selected Hospital B in our sampling because it is one of the “best of the class” of Italian hospitals in terms of digital technology adoption. Hence, we also decided to consider this technology in our research in order to reinforce and/or expand findings that surfaced as a result of looking at the other two technologies, which are far more common and widespread among healthcare organizations. We found a close link between the use of all of these technologies and some of the resilience capabilities.

4.1 Healthcare knowledge
While the medical and organizational knowledge of physicians and nurses cannot be considered a capability, during the coding process, this concept arose as fundamental in order to overcome operational failures. In fact, nurses and physicians implement actions as a result of and supported by different forms of healthcare knowledge. This may come from their experience and years of work in healthcare or from their clinical studies and educational background. Furthermore, we observed that resilient capabilities were not only strongly influenced by physicians and nurses’ clinical knowledge but also by their knowledge of the dynamics and organizational aspects of the ward and, in some cases, of the whole hospital. In sum, three forms of healthcare knowledge emerged from our coding analysis.

We used the term experience to code the form of knowledge of the clinical/care processes and medicine that had been acquired during years of work. A number of papers have
already examined the positive effects of professional experience in healthcare (Ding, 2014). In the interviews, we found many references to professional experience as something that was crucial to avoiding an operational failure. Almost all of the interviewees stressed the role that experience plays in dealing with a failure. One physician from Hospital A told us that he/she had once had to execute an urgent computed tomography (CT) on a critical patient and that the CT machine had suddenly stopped working: “So I did another exam, an explorative laparoscopy […]. I can do it because I have done that exam in the past: while a CT is relatively harmless, exploratory laparoscopy is an invasive procedure that can endanger the patient, can lead to death. But I can do it because I have enough experience to do it safely.”

Unlike the concept of experience, in managing an operational failure, we found little evidence of operators acknowledging the importance of the clinical knowledge learned during university studies, master programs and other educational courses. Our findings confirm that this kind of knowledge can be codified in terms of both know-what and know-how (Edmondson et al., 2003). A physician from Hospital A said that if the suture stapler breaks down the solution is easy and consists of “Doing everything manually, as we used to do in the past. It’s acceptable, but it’s clear that it’s better with the stapler.” This physician knew how to suture the patient manually because, he says, “Maybe I belong to a transitional generation, which has learned both old and new techniques; whoever learned surgery before, only knows how to employ manual techniques, while those who learned surgery later, only know modern techniques. I am among the minority who knows how to do both.” We were told of a second interesting case regarded a very urgent surgical operation in which, due to the fact that the radiology tests were missing, a physician from Hospital A operated on “a broken spleen with only one hand in the stomach, which they used to do a long time ago. This was a technique I studied.”

Furthermore, we found a third dimension of knowledge that seems to play a crucial role in providing counter-measures for operational failures within the ward: knowledge of organizational dynamics. This includes not only being aware of the standard routines and processes but also of tacit knowledge, comprising the non-written practices and peculiarities typical of the hospital and also of colleagues’ personal traits and interpersonal ties. Tucker et al. (2007) and Berta and Baker (2004) already recognized that in healthcare, lots of practices contain a tacit knowledge component. For instance, a physician from Hospital A said: “If I realize that I have carried out a strenuous exam and I think it is appropriate to keep the patient under observation […] I know that we have a room in the ward where we have three beds, which are not counted in the fourteen official beds of our ward. We use them for special situations, for example when a patient under observation may cause you problems after six, eight hours.” We also found evidence that knowledge of organizational aspects and practices related to non-written agreements between wards was very important for resolving operational failures. For example, a ward may occasionally borrow materials from other wards (“I asked for [missing suture] from other wards,” said a physician from Hospital B) or may allow a change in the scheduling of a resource (“I verified by calling the radiology ward and asked whether the CT exam could be postponed for one hour. In this way, instead of processing our patient, radiology can process a patient from another ward and solve our departmental problem,” said a physician from Hospital B).

4.2 Collaboration
The concept of collaboration already exists in Chowdhury and Quaddus’ (2017) model of resilience capabilities, even if it is present only as a variable of the dimension, “integration.” In contrast, we upgraded this concept and considered it a capability category rather than a single item. Treating “collaboration” as a complex and multi-dimensional construct is quite
common in the field of operations and supply chain management (e.g. Stank et al., 2001; Vachon and Klassen, 2008; Senot et al., 2016).

During the interviews, we observed several different ways of implementing collaboration when engaging in resilience practices, revealing the complexity of this dimension.

Vertical collaboration arises when two or more employees belonging to different organizational levels (e.g. head nurse and nurse) collaborate in order to overcome an operational failure. Vertical collaboration may follow two different directions: top-down and bottom-up. The first arises when an employee belonging to an organizational level that needs help from employees from a lower organizational level, e.g. when the head physician from Hospital A “must call a nurse as a ‘third hand’ during a surgical operation.” Vice versa, the second direction consists of an employee requesting help in order to tackle an operational failure, e.g. when a nurse from the Hospital B “immediately called the anaesthetist in order to manage the allergy as soon as possible.” We also observed a very unexpected case of vertical collaboration that occurs between the nurse and the patient’s relatives. For instance, we found a situation in which, because a particular type of bed was missing (this bed allows the nurse to move obese patients without the help of others), a nurse from Hospital A was forced to “look for help from the patient’s relatives to move the patient from the bed to the wheelchair because it is absolutely impossible to do it alone.”

Horizontal collaboration occurs when teamwork is established between employees or, more generally, when organizational entities, such as wards, belong to the same organizational level. Horizontal collaboration can take place inside the ward, for example, between two nurses in Hospital B: “A few days ago I had to draw some blood from an obese patient. I tried once but the blood was not coming out; I tried the second time and even in this case I wasn’t able to access the blood vessel, so I decided not to try anymore […] it was painful for the patient […] and I asked my colleague for help.” It can also take place between wards, as in Hospital A: “If an antibiotic goes out of stock during the weekend, my colleagues borrow it from another ward, such as orthopaedics or intensive care. On Monday morning, as soon as I’m told that this occurred, I activate the procedure to restore the drug to the other ward. Anyway, it’s something that happens inside the hospital, among all wards” (head physician).

As expected, we also found direct links between DH technologies and the capability to collaborate, both vertically and horizontally, due mainly to the boosting of information sharing. We found that telepathology was a powerful tool for supporting horizontal collaboration between the researchers and the consultants of different hospitals when one wants to obtain help in cases of care process complications. As described by a physician from Hospital B: “We use this technology a lot in collaboration with an American university in the case of resolving particular complications.” In this case, the technology is implemented in order to resolve a complication (operational failure) by increasing the knowledge of the phenomenon through collaboration with another entity outside of the organization. On the other hand, the EHR enables an effective collaboration between nurses and/or physicians in Hospital B during patient care: they can exchange information about patients even if they are not in the same hospital at the same time: “If I’ve got to do an urgent transplant and I’m at home, I can start seeing and studying the patient’s radiological images.”

4.3 Readiness
Employees quite regularly seem to implement practices aimed at quickly noticing if an operational failure has occurred. The failure detection capability is not new in the literature on supply chain resilience and can be associated with the “disruption detection” variable of Chowdhury and Quaddus’ (2017) model. Interestingly, there are cases in which the readiness capability is obtained as a consequence of personal mechanisms. For example, one of the physicians from Hospital B said “[…] I always like to follow my own routine of work activities; this is so standardized in my mind that, with the activities always being the same,
even if I’m distracted by something else, I will always get back to the previous point and check the results to ensure everything is alright.” There are other cases in which readiness is achieved by collaborating with a colleague. “[…] there is a problem that is decontextualized by your routine, maybe the patient has a bronchitis that causes the fever, but you think it’s because he has a perforated colon. I see a colleague who didn’t start my own ‘mental path’ who tells me ‘did you check his chest?’ By being redundant we try to optimize,” said one of the physicians from Hospital A.

While both of the above-mentioned examples provide clear evidence of the readiness dimension of resilience (we framed them under the code operational failure detection capability), the latter can definitively also be coded under the horizontal collaboration capability. When analyzing this evidence in more detail, we saw that collaborating with a colleague allowed the physician to put some level of readiness into action. In this case, we conclude that the horizontal collaboration capability can enable the operational failure detection capability.

We also found evidence of other readiness capability dimensions, which had already been coded in the model of Chowdhury and Quaddus (2017): readiness resource, forecasting and readiness training. We observed that readiness training is not something that is implemented voluntarily. Constantly working under critical conditions and pressure is the main school for training employees about readiness: “[…] We’re working continuously because we have enormous problems regarding the logistics, the infrastructure, the turnaround, the relationship with colleagues […] managing the exception and dealing with the urgency is our real work; thanks to this we have now created alternative guidelines in our minds,” explained a nurse from Hospital A.

In conclusion, we found that the readiness capability in healthcare, implemented by means of operational failure detection, readiness resource, readiness training and forecasting, is an enabler (directly and indirectly) of healthcare resilience. Readiness resource and forecasting lead to the implementation of other variables in order to improve healthcare resilience, while operational failure detection either does not have links with other variables or, alternatively, it is only caused by them, in particular, by variables belonging to the collaboration dimension.

4.4 Flexibility

A flexible supply chain is more likely to be resilient than a rigid one and “flexibility” is one of the resilience dimensions in the already-cited model of Chowdhury and Quaddus (2017). This tight relationship – flexibility and resilience – is also confirmed in the healthcare setting and the flexibility capability was the resilience dimension that surfaced most in the interviews. The interviewees described a number of different situations in which they had faced different forms of failure and in which they highlighted how important it is that the employees are multi-skilled or that the service delivery is flexible. Thanks to a multi-skilled workforce, it is possible to implement a quick response, which is crucial for managing an operational failure when it occurs. However, in some cases, a multi-skilled workforce has to be juxtaposed with a readiness resource to implement a quick response, e.g. when “[…] the patient had to be monitored immediately, but there is only one crash cart, […] so (the nurse) had to use something different, such as a sphygmomanometer or an oximeter that we found at the time” (said a physician from Hospital A) or from collaboration, e.g. when the head nurse of Hospital A knows that “To make it work (the pulse oximeter) I need a quantity of sensors. If the sensors are missing, I am supposed to ask the head physician ‘can I order the sensors?’ In fact, the head physician trusts me, and there is a tacit agreement among us that I can order the sensors autonomously […] it’s not reasonable that, every time, I have to ask.”

The capability coded as service delivery flexibility always seems to play a crucial role in terms of healthcare resilience. We found a situation, namely, insulin administration via an
alternative syringe, in which a nurse from Hospital B told us that “Today, however, you cannot use one syringe instead of another because you can cause even more severe failures.” Using one kind of syringe “instead of another” represents a flexible practice that even if it could be useful in cases of emergency, it may cause an error. In fact, it is possible to administer the wrong dose to the patient because of the different graduation marks on the different kinds of syringes. Hence, even if being flexible is a way to be resilient, employees know that it is not always the “best response” when an operational failure occurs: the potentially bad consequences overcome the benefits.

We found that OHMD technology makes an important contribution to facilitating the process of “multi-tasking.” In healthcare literature, multi-tasking was found to be an integral skill developed by personnel working in the emergency department, as also in other healthcare workplaces (Laxmisan et al., 2007). Multi-tasking seems to be a necessary skill for the execution of daily activities in a dynamic and overcrowding environment such as the healthcare one, but may fail to be an effective mechanism because the interruption of work which occur during the switch between two tasks has been largely demonstrated to be potential cause of delays in task execution but also of errors till compromising patient safety. In other words, multi-tasking is ubiquitous in healthcare and poses a risk to patient safety (Douglas et al., 2017). In case of interleaved multi-tasking, defined as “the management of multiple tasks in which there is switching between tasks that are progressing in parallel” (Douglas et al., 2017, p. 46), facilitation of the process of multi-tasking may limit the number of errors that occur. When a physician from Hospital B was asked to say what improvements were obtained by using a particular set of goggles, he said “They help me because, for example, when something regarding the operation goes wrong and I need to know something about the patient, I can access it immediately just by asking my OHMD.” In other words, the surgeon was forced by the circumstance to interrupt the task in order to get some important information. Then he went back to the operation. The glasses facilitated the switch, made it easier and faster, by allowing an easy access to the needed information. The surgeon neither had to move from his position nor took off his gloves, as if the interruption had not occurred.

In conclusion, we found that the flexibility capability in healthcare is directly connected to healthcare resilience by means of service delivery flexibility. On the other hand, a multi-skilled workforce, which is often associated with other variables, such as readiness resource or vertical collaboration, enables a quick response to operational failures. Furthermore, service delivery flexibility does not always have a positive impact in terms of healthcare resilience; in some cases, it may lead to an operational failure.

4.5 Patient-related knowledge ACAP

We were told about many situations in which the capacity to acquire patient-related knowledge was fundamental to achieving a quick response. For example, a physician from Hospital B said, “Thanks to the OHMD, I can immediately retrieve it [patient information] and choose the best strategy,” while one of her colleagues from the same Hospital said “The transplant is an activity we mainly execute with urgency, it means the hospital calls us when we’re at home, so on my personal computer I can see whatever I need to be ready by accessing the EHR. If I’ve got to do an urgent transplant, and I’m at home, I can start seeing and studying the patient’s radiological images.” We also encountered some cases in which the capacity to exploit the knowledge that had just been acquired about the patient was critical to effectively avoid patient harm. For instance, a physician from Hospital B asserted, “[telepathology] allows us to have a new opinion on histological samples which often are in line with our initial belief. This, for sure, makes us more confident and fast in making the final decision,” thus facilitating and improving the necessary critical decision-making process when a failure occurs.
4.6 Response

All of the three variables associated with the response capability in the Chowdhury and Quaddus’ (2017) model were also observed in our empirical analysis, namely, response team, quick response and effective/adequate response. They all have a direct impact on healthcare resilience and the quick response is executed as a consequence of other variables, such as multi-skilled workforce. For example, when a physician from Hospital A had a failure with a suture stapler and was forced to “do everything manually, as they used to do in the past. It's acceptable, but it’s clear that it’s better with the stapler.”

The response capability is supported by DH technologies in different ways. For example, when there are rare and difficult cases for which there is a need for further diagnostic advice, telepathology ensures that the physicians can get a quick response from other colleagues located remotely. In particular, this technology allows clinicians to reduce the amount of time needed to exchange the huge amount of patient data: “[we use] a system through which we’re able to make a medical report with images remotely, in fact, we have a place in Italy where we do particular kinds of tests and, rather than exchanging information through a CD, we use the Internet. We implement a very sophisticated system in order to be sure that no frame will be lost during the data transmission,” said a physician from Hospital B.

Furthermore, thanks to EHR data, the physician from Hospital B, wherever he/she is, can receive fundamental information about the patient to be able to immediately decide what to do when it is time to operate: “The transplant is an activity we mainly execute in urgency, it means the hospital calls us when we’re at home, so thanks to my personal computer I can see whatever I need to be ready by accessing the EHR.” Finally, OHMD technology increases responsiveness because the physician from Hospital B does not need to halt the workflow, even while he/she is trying to resolve an unexpected event related to the patient: “[with these glasses] I don’t need to stop the workflow because I don’t need my hand to obtain the information, I only have to ask.”

5. Discussion

Operational failures in the healthcare domain are very common and hospitals and wards are used to countering them by employing resilient behavior, which allows them to continue to work and to preserve patient safety (Fairbanks et al., 2014). In this paper, we have tried to understand this behavior in depth by analyzing the findings of our case research through the lens of dynamic capabilities, in line with the approach of Chowdhury and Quaddus (2017). More specifically, by extending the findings of Tucker (2004), who identified two different categories of practices (workarounds and error-handling) for solving operational failures (problems and errors), by encompassing the conceptualization of Alter (2014), who defined workaround practices in detail, and by inheriting/incorporating the work of Kontogiannis (2011), who provided a conceptual model for analyzing error-handling processes, we have classified the different possible capabilities that are required when deploying resilient behavior. These capabilities are similar to those identified by Chowdhury and Quaddus (2017), although a few differences can be highlighted because of the intrinsic differences between a supply chain and healthcare domains.

Within-case analysis has allowed us to identify the dynamic capabilities in the healthcare domain and also to find different cases in which resilience practices and the behavior of the organization are fostered by a combination of two or more capabilities. In both of the analyzed cases, we found capabilities that influence each other, and the combination of which enables resilience behavior. For the sake of clarity, Table II presents a summary of the emerged linkages, together with some examples of interviewees’ quotations from which the linkages have been coded.

The identified capabilities and the network of relationships we found are schematically depicted in Figure 1. The figure includes all the dimensions and linkages that emerged in
<table>
<thead>
<tr>
<th>Quotation</th>
<th>Dimension 1</th>
<th>Dimension 2</th>
<th>Coded linkages</th>
</tr>
</thead>
<tbody>
<tr>
<td>“While the head physician was struggling to get the equipment, my co-worker started making room [within the injury] and with my hand I took the gauze and put it on, but no one told us how to react, we just relied on our familiarity with similar situations”</td>
<td>Healthcare knowledge (experience)</td>
<td>Collaboration (vertical)</td>
<td>Healthcare knowledge→collaboration</td>
</tr>
<tr>
<td>“So, I did another exam, an explorative laparoscopy […] I can do it because I have done that exam in the past: while a CT is relatively harmless, exploratory laparoscopy is an invasive procedure that can endanger the patient, can lead to death. But I can do it because I have enough experience to do it safely”</td>
<td>Healthcare knowledge (experience)</td>
<td>Flexibility (multi-skilled workforce)</td>
<td>Healthcare knowledge→flexibility</td>
</tr>
<tr>
<td>“If I realize that I have carried out a strenuous exam and I think it is appropriate to keep the patient under observation […] I know that we have a room in the ward where we have three beds, which are not counted in the 14 official beds of our ward. We use them for special situations, for example when a patient under observation may cause you problems after six, eight hours”</td>
<td>Healthcare knowledge (organizational dynamics)</td>
<td>Readiness (forecasting)</td>
<td>Healthcare knowledge→readiness</td>
</tr>
<tr>
<td>“I immediately called the anaesthetist in order to manage the allergy as soon as possible”</td>
<td>Collaboration (vertical)</td>
<td>Response (quick response)</td>
<td>Collaboration→response</td>
</tr>
<tr>
<td>“If an antibiotic goes out of stock during the weekend, my colleagues borrow it from another ward, such orthopaedics or intensive care; on Monday morning, as soon as I’m told that this occurred, I activate the procedure to restore the drug to the other ward. Anyway, it’s something that happens inside the hospital, among all wards”</td>
<td>Collaboration (horizontal)</td>
<td>Flexibility (service delivery flexibility)</td>
<td>Collaboration→flexibility</td>
</tr>
<tr>
<td>“There is a problem that is decontextualized by your routine, maybe the patient has a bronchitis that causes the fever, but you think it’s because he has a perforated colon. I see a colleague who didn’t start my own ‘mental path’ who tells me ‘did you check his chest?’ By being redundant we try to optimize”</td>
<td>Collaboration (horizontal)</td>
<td>Readiness (operational failure detection)</td>
<td>Collaboration→readiness</td>
</tr>
<tr>
<td>“We use this technology in collaboration with an American university in case we have to solve particular complications”</td>
<td>Collaboration (horizontal)</td>
<td>Patient-related knowledge ACAP</td>
<td>Collaboration→patient-related knowledge ACAP</td>
</tr>
<tr>
<td>“The patient had to be monitored immediately, but there is only one crash cart, […] so, [the nurse] had to use something different, such as a sphygmanometer or an oximeter that we found at the time”</td>
<td>Readiness (readiness resource)</td>
<td>Flexibility (multi-skilled workforce)</td>
<td>Readiness→flexibility</td>
</tr>
<tr>
<td>“Thanks to the OHMD I can immediately retrieve it [patient information] and choose the best strategy. [with these glasses] I don’t need to stop the workflow because I don’t need my hand to obtain the information, I only have to ask”</td>
<td>Flexibility (multi-skilled workforce)</td>
<td>Patient-related knowledge ACAP</td>
<td>Flexibility→patient-related knowledge ACAP</td>
</tr>
<tr>
<td>“Do everything manually, as they used to do in the past. It’s acceptable, but it’s clear that it’s better with the stapler”</td>
<td>Flexibility (multi-skilled workforce)</td>
<td>Response (quick response)</td>
<td>Flexibility→response</td>
</tr>
<tr>
<td>“The transplant is an activity we mainly execute in an emergency, it means the hospital calls us when we’re at home, so thanks to my personal computer I can see whatever I need to be ready by accessing the EHR. If I’ve got to do an urgent transplant, and I’m at home, I can start seeing and studying the patient’s radiological images”</td>
<td>Patient-related knowledge ACAP</td>
<td>Response (quick response)</td>
<td>Patient-related knowledge ACAP→response</td>
</tr>
</tbody>
</table>

Table II. Summary of linkages between resilience dimensions

Note: “It was possible to obtain more than one linkage from the same quotation/evidence
Hospital A, Hospital B or in both. The thickness of the arrows qualitatively indicates the occasions on which we found evidence of the relationship, thus indicating its strength. Furthermore, the direction of the arrows indicates that we were often told that one capability leads to another capability. Figure 1 also shows the crucial role that nurses and physicians’ medical and organizational knowledge played in enhancing resilience capabilities. This is in line with the idea of Cepeda and Vera (2007) that capabilities can be considered as “processes” based on knowledge.

The following discussion is separated into two parts. The first includes our arguments related to the findings from the within-case analysis, without distinguishing between the two cases (P1–P3), and the second presents our discussion of the findings from the cross-case analysis (P4–P5).

5.1 Clinical knowledge and knowledge of organizational dynamics sustains the implementation of dynamic capabilities for resilient behavior in healthcare settings

In the within-case analysis of the two hospitals, our line of reasoning for explaining the role of knowledge in healthcare resilience is related to the distinctive roles of different types of knowledge content (medical or organizational) and the different types of knowledge sources (university/education/studies or practice/experience). We found that workers’ knowledge of their hospital (and ward) operations and colleagues, including the facilities, dynamics, habits and routines, personal traits and interpersonal ties, has the potential to foster the exploitation of dynamic capabilities, allowing the organization itself to be resilient. Most of the time, this type of knowledge is not written down and there are no official guidelines defining and explaining the dynamics and the practices implemented inside the hospital, in particular, inside a single ward. One of our most robust findings is that the physicians and nurses’ knowledge about the extent to which the employees belonging to different wards can interact with each other by making different requests, from borrowing equipment to postponing an exam, fosters the flexibility and, consequently, the organizational resilience in a significant way. The linkage between knowledge and collaboration in the healthcare domain has already been explored by Senot et al. (2016). They found that a collaboration between physicians and nurses is enabled by formal and informal mechanisms, such as informal hallway conversations or meetings, which increase the level of knowledge of the employees. Moreover, the relationship between the level of knowledge and flexibility was analyzed by Laxmisan et al. (2007), who found that tacit knowledge enables physicians and nurses to implement the process...
of multi-tasking. We define the first proposition (which is also graphically represented in Figure 2) using an extract from Figure 1:

\[ P1. \] Individuals’ knowledge of the hospital organization, operations and colleagues fosters horizontal collaboration between wards, which may increase the resilience through flexibility.

Knowledge of the ward and of the hospital dynamics, in general, is not the only possible type of knowledge that can assist in being resilient. The medical and clinical knowledge acquired from the individual’s past studies and work experience represents an important antecedent to resilient behavior. In some cases, as a result of what they had learned from university courses, some physicians are able to find different and alternative ways to deal with a failure, e.g. by retrieving some dated or out-of-practice techniques from their memory when, for some reason, the most advanced ones cannot be used because of a failure. In some cases, the university studies may allow the physician (or nurse) to be multi-skilled and, consequently, may help her/him to respond quickly to the failure. This is in line with the results of Nair et al. (2013), who found that clinical flexibility allows healthcare organizations to deliver faster services. Our second proposition (shown in Figure 3) is:

\[ P2. \] Individuals’ clinical knowledge, acquired during university studies, increases an organization’s resilience by enhancing flexibility through a multi-skilled workforce, which, in turn, increases the quick response capability.

Zollo and Winter (2002) state that the experience accumulation process represents a fundamental basis for developing dynamic capabilities and Eisenhardt and Martin (2000) specify that dynamic capabilities in high-velocity markets are experiential processes. To confirm the importance of previous work experience for resilience, we found a number of cases in which this had helped physicians and nurses to find solutions or had helped them to be determined and confident about doing something that was differed from the norm. We perceived the scale and the scope of its positive effects in nearly all the dynamic capabilities that determine the resilience behavior of the healthcare system. Our third proposition (Figure 4) is:

\[ P3. \] Workers’ (nurses and physicians) past work experience is a critical antecedent to most healthcare capabilities, which foster resilient behavior even in the absence of collaboration.

5.2 DH technologies support resilience capabilities through stimulating patient-related knowledge ACAP

When comparing the two cases (cross-case analysis) to explain the role of knowledge in healthcare resilience, our findings lead us to follow a line of reasoning that is different to that

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**Figure 2. Dynamic capabilities network for resilient behavior, P1**

**Figure 3. Dynamic capabilities network for resilient behavior, P2**
found in the within-case analysis. In fact, while the within-case analysis was more focused on the roles of different types of knowledge content (medical or organizational) and different types of knowledge sources (university/education/studies or practice/experience), the cross-case analysis allows us to discuss the temporary acquisition of knowledge, assimilation and exploitation in respect of the patient’s conditions/state and her/his medical history, which, thanks to DH technologies, were shown to play fundamental roles in the implementation of resilience capabilities. Indeed, we found a number of instances in which the DH technologies helped physicians and nurses to implement resilient practices. In other words, when comparing the two cases, we first observe that all the quotations/observations related to the dimension of patient-related knowledge ACAP come from professionals in Hospital B (see Table III).

<table>
<thead>
<tr>
<th>Linkage</th>
<th>Nurse</th>
<th>Head nurse</th>
<th>Physician</th>
<th>Head physician</th>
<th>Tot</th>
<th>Hospital A</th>
<th>Hospital B</th>
<th>Tot</th>
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<td>Healthcare</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>knowledge → collaboration</td>
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<td>6</td>
<td>2</td>
<td>10</td>
<td>4</td>
<td>6</td>
<td>10</td>
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<tr>
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<td>2</td>
<td>7</td>
<td>0</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>10</td>
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<tr>
<td>Healthcare knowledge → readiness</td>
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<td>0</td>
<td>3</td>
<td>0</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>6</td>
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<td>2</td>
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<td>5</td>
<td>2</td>
<td>3</td>
<td>5</td>
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<tr>
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<td>2</td>
<td>2</td>
<td>6</td>
<td>3</td>
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<tr>
<td>Collaboration → readiness</td>
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<td>Collaboration → patient-related knowledge ACAP</td>
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</tr>
<tr>
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<td>6</td>
<td>39</td>
<td>9</td>
<td>63</td>
<td>27</td>
<td>36</td>
<td>63</td>
</tr>
</tbody>
</table>

Table III. Frequencies of evidence of linkages between resilience dimensions.
More specifically, in line with the argumentations of Raymond et al. (2017), in nearly all of the observed workaround and error-handling practices in which DH was used, this seemed to boost the role of nurses and physicians’ knowledge in managing the failure. More specifically, we observed that the knowledge that was enhanced by DH technologies was not knowledge of the hospital (or the ward) routines and dynamics, nor the medical know-how acquired during studies or through work experience, it was knowledge of the patient’s medical conditions and history. Figure 5 sketches the linkages among the emergent dimensions, where the gray-colored dimensions come from Hospital B only.

As shown in Figure 5, there is a fundamental difference between the employees use of the two types of knowledge. While clinical and organizational knowledge are the starting points that allow physicians and nurses to acquire dynamic capabilities, such as collaboration or flexibility, in contrast, knowledge of the patient’s medical conditions is obtainable as a result of collaboration and flexibility. These, in turn, are enabled by DH: technology enables the collaboration (between the physician and another physician in a different hospital) that enables the acquisition and exploitation of the knowledge about the patient. In sum, we pose the following proposition:

P4. In order to implement a resilient practice, the clinical and organizational knowledge act as starting points for the acquisition of different dynamic capabilities; conversely, by increasing physicians and nurses’ ACAP, dynamic capabilities are crucial for acquiring and exploiting knowledge of patients’ conditions.

In greater detail, we observed that this ACAP fosters the response capability and is fostered by other dynamic capabilities, namely, flexibility and collaboration. The first association is between EHR and telepathology technologies with the collaboration capability (Figure 6). In fact, every time these two technologies were used to deal with an operational failure, they allowed physicians and nurses to acquire knowledge by collaborating with other colleagues, as a result of which they were able to implement a quick response. Our next proposition (Figure 6) is:

P4a. The EHR and telepathology technologies enable the collaboration among physicians and nurses. This increases their patient-related knowledge ACAP, which, in turn, supports the quick response capability when an operational failure occurs.

![Figure 5. Dynamic capabilities and DH network for resilience behavior in the healthcare domain](image_url)
In an even more direct and decisive way, we found that the OHMD supports the flexibility of the physician, who, for instance, is able to execute different activities at the same time. Although in some situations multi-tasking should be avoided, there are circumstances where this is not possible, for example, when it relates to “those activities that cannot be eliminated nor delegated but have to be handled by people” (Laxmisan et al., 2007, p. 809). We found evidence of the use of OHMD in contexts where there was no possibility of eliminating or delegating activities: for example, during surgery, the surgeon’s responsibility often forces him to acquire first-hand patient-related information in order to continue the operation. In these cases, the OHMD can be considered as a cognitive artifact. “Cognitive artifacts, defined as physical objects made by humans for the purpose of aiding, enhancing, or improving cognition, can play an important role in helping the clinicians” (Laxmisan et al., 2007, p. 809). In sum, by facilitating multi-tasking, DH promotes resilience behavior and this is not only because of its positive influence on collaboration. Thus, our next proposition (Figure 7) is:

**P4b.** The OHMD technology supports the flexibility of physicians. This increases their patient-related knowledge ACAP, which, in turn, supports the quick response capability when an operational failure occurs.

The role that DH plays in enhancing resilience through knowledge of the patient’s medical conditions can, indeed, be interpreted through the lens of the ACAP theory, which expresses the capacity of an organization to acquire and exploit knowledge in order to obtain a competitive advantage (Cohen and Levinthal, 1990; Zahra and George, 2002). More specifically, we found cases in which DH technologies allow employees to acquire knowledge, others in which they support its assimilation and others in which it is useful for exploitation. This is in line with the findings of Raymond et al. (2017), who, in the field of
healthcare management, contextualize ACAP in IT-based clinical knowledge management and find that in primary healthcare, e-learning and EHR capabilities allow clinicians to acquire and exploit clinical knowledge. We found, for example, that by allowing immediate access to the patient’s file, EHR enables the fast acquisition of knowledge related to her/his medical state and history, which—as already noted—is crucially important when an operational failure occurs. Further, the OHMD supports the acquisition of knowledge and its exploitation: we were told by physicians that they can implement in real time what they are learning about the patient from the OHMD, with no need to stop the workflow. We, therefore, state:

P5. DH technologies promote the implementation of resilient practices by enabling, supporting and speeding up the acquisition, assimilation and exploitation of patient-related knowledge during the management of an operational failure.

6. Conclusion
This paper investigates the concept of resilience behavior in healthcare systems through the analysis of related capabilities and practices. The RE literature examines the concept of resilience in the healthcare domain, in both practical and theoretical terms. We found a dearth of research that explores resilience in the healthcare OM domain, even though there are many practical examples related to it that are observable by just spending one day in a hospital ward. These practices, commonly referred to as workaround or error-handling, are often triggered by operational failures, both problems and errors. For this reason, the starting point of our study consisted in exploring how healthcare organizations respond to occurrences of operational failures, an issue that has already been studied and classified by Tucker et al. (2008).

The absence of previous studies in the field of healthcare OM that are related to resilience encouraged us to ground the research in a case study methodology in order to gather as much information as possible that was inherent in the application of resilient practices. Furthermore, from the literature on supply chain resilience and operational failures in healthcare, it was possible to establish a starting point from which to build our conceptual model, to sketch the interview questions and to critically analyze the answers. By using open, axial and selective coding, and from the subsequent within-case and cross-case analyses, we found five different dynamic capabilities that allow the ward to be resilient against operational failures and we highlighted the crucial role of physicians and nurses’ knowledge in conferring resilience. Finally, in relation to DH technologies, we were able to develop different propositions that mainly focused on the most common and most powerful relations between the different dynamic capabilities involved in the resilient practices.

6.1 Theoretical contribution
From a theoretical point of view, this paper provides contributions and insights into the dynamic capabilities theory in different ways. First, we discovered that in order to avoid operational failures employees implement resilient practices alone or in collaboration with other employees: in both cases, the resilient practice is not executed by following organizational routines or managerial processes. This observation is important because the focus of the dynamic capabilities theory is on these kinds of routines or processes (Teece et al., 1997; Eisenhardt and Martin, 2000; Peteraf et al., 2013); thus, our research suggests that practices implemented by single (or small groups of) workers may be the direct expression of a dynamic capability, without being a representation of an organizational routine or a managerial process.

Second, in the vast majority of the observed cases, there is more than one dynamic capability behind a resilient work practice; hence, these different capabilities turn out to be
highly interrelated. Salvato and Vassolo (2018), who studied dynamic capabilities as a multi-level concept, recently examined the relationship between different kinds of capabilities in which the different levels are connected to each other following a vertical pattern – from the level of the individual to that of the organization. In contrast, the relationships that emerged in our study have to be considered horizontal, where, because of their different nature, the differences among capabilities are not quantitative but qualitative. These kinds of relationships have not been studied in the dynamic capabilities theory and we suggest this issue should be investigated in the future.

Third, ACAP, seen as a dynamic capability, can surely help to explain the role of knowledge in implementing resilient practices but, most of all, in understanding the role of DH in operational failure management. We used the theory of ACAP in an original way, i.e. by applying its underlying concepts of knowledge acquisition, assimilation and exploitation in the very short term. We see operational failures as activation triggers (Zahra and George, 2002) that require the acquisition, assimilation, transformation and exploitation of useful knowledge in order to manage them within a few seconds or minutes (in any event, before they become adverse events). Thus, when carrying out some resilient practices, the requested ACAP has to be fast and needs to be related to knowledge about the patient’s medical state and history. This is quite different from the classical interpretation of ACAP found in the strategy literature where it is usually used to explain a company’s innovation and adaptation processes that result from its capacity to acquire and exploit knowledge from the external environment. While, in fact, R&D processes gain advantage from external knowledge acquisition and exploitation, in operational contexts, it is not just external knowledge that matters. In process improvements, in error handling, in problem solving and in operational failures management, the internal transfer of knowledge is very important in leveraging (Johnston and Leenders, 1990). In fact, many of the reported behaviors from our case studies that reflect ACAP’s impact on resilience relates to the ability to acquire patient specific data from internal sources (both information systems and colleagues) and to the line professionals’ sharing of details and ideas about their practice in real time to solve operational failures.

Fourth, DH technologies can enable hospital ACAP. The knowledge acquired, assimilated or exploited through DH is mostly patient-centered and related to the patient’s clinical condition, diagnosis and cure issues, which, in turn, will boost resilient behavior. Other studies have focused on the role of ACAP in supporting digital technology implementation, as in Raymond et al. (2017); we focused on the opposite effect. We think that this different perspective is due to the time factor: the short period of time that is available for the employees to manage operational failure pushes them to use DH technologies in order to quickly deal with their occurrence. This different perspective allows us to contribute to the much-discussed topic of the consequences of DH for patient safety. As already mentioned in the previous sections, there is nothing in the literature that provides a unique answer to this question. Although it is fair to argue that IT in healthcare will reduce medical error (the third leading cause of patient death in the USA), evidence of IT-related patient harm is mounting (Kim et al., 2017). The reasons for this may be highly diverse and may originate in system designs, implementation or use. Furthermore, some communication technologies may increase the risk of physicians and nurses becoming distracted (Froehle and White, 2014) and IT incidents can lead to large-scale adverse events (Chen et al., 2017). Even in relation to the operator’s capability to be resilient, we found new kind of results with respect to the existing literature. For instance, Smith et al. (2014) found that EHR may, in some way, reduce resilient behavior because physicians are conscious that their actions will be fully monitored and evaluated and, thus, they tend to avoid working around a problem or handling an error if the necessary procedure has not previously been prescribed or approved.
6.2 Managerial implications
Aside from offering a few contributions to the theory of dynamic capabilities and the literature on patient safety, operational failures and DH, we think that the presented conceptual model and propositions, which explain resilience capabilities in healthcare and their relations with DH technologies, may also have implications for healthcare managers who continually look for improvements in terms of patient safety, the latter now considered to be a national priority (McFadden et al., 2009). Other than engaging in building complex clinical risk management techniques, when trying to promote a culture of patient safety, we suggest that healthcare managers should focus on promoting and enhancing the dynamic capabilities that we have shown are the basic elements for implementing resilient practices. Other researchers in the field of healthcare OM have already provided suggestions on how to obtain improvements in dynamic capabilities. For example, Senot et al. (2016) found that in order to improve collaboration among physicians and nurses, it is necessary to encourage both formal (weekly safety rounds) and informal (hallway talks between nursing staff and physicians) mechanisms that complement each other.

We found that DH technologies play an important role in supporting or even enabling dynamic capabilities. In a healthcare organization, promoting the use of technologies that are enablers of dynamic capabilities, such as the ones we have considered in this study, may be the key to increase resilience to operational failures. When selecting DH technologies, healthcare managers should take this aspect into account. Furthermore, our cross-case analysis clearly shows that in the absence of a high level of digital technology adoption (Hospital A), hospital’s resilience may be more dependent on human resource policies and structures and a collaborative culture and climate. For example, the evidence shown in Table III suggests that Hospital A gets resiliency from the link healthcare knowledge→flexibility→response, while Hospital B gets resilience mainly from collaboration→patient-related knowledge ACAP→response. Also, looking over to Table AIII, we see that flexibility is attributed in Hospital A to the multi-skilled workforce vs the service delivery system in Hospital B.

6.3 Limitations and future research directions
This study has a number of limitations. We would like to cite a few of them here.

The first limitation is related to the sampling and the number of cases studied. As already explained, we decided to choose only two cases in order to deeply analyze the healthcare context. It is, therefore, necessary to extend the study into other healthcare contexts in order to verify whether the dynamic capabilities (particularly those appearing in the final propositions) are again present or whether there are others that we did not notice, i.e. for the purpose of generalizability. Moreover, we used a hybrid theoretical-convenience sampling approach. It is theoretical in that the choice of sample was driven by the degree of adoption of digital technologies. On the other hand, it cannot be considered theoretical in terms of resilience. The newness of the subject in the OM field (resilience in healthcare) and concerns about the impossibility of a preliminary assessment of the “level of resilience” of a healthcare organization did not allow us to critically choose the cases with regard to this dimension. Because we recognize that pure theoretical or pure random sampling has the potential to provide more robust outcomes, we suggest that further studies consider using larger samples and different sampling approaches.

The second limitation is due to the optimistic approach we had toward resilient practices, when, in fact, Tucker (2004) and Halbesleben et al. (2008) stressed the potential negative impact that practices such as workarounds may have in a healthcare setting, both in terms of economics and patient safety. Consequently, we suggest further studies with the goal of testing if and how dynamic capabilities that foster the implementation of resilient practices may also have a negative impact or if there is the possibility of applying some kind of effective “constraints/controls” to these capabilities in order to obtain only positive effects.
Third, our model explains resilient behavior via dynamic capabilities and considers DH as a way to increase resilience. We do not consider other “non-digital” methods that can be used to promote, foster and enable resilience. Further studies should incorporate and assess the combined effect of DH and proper managerial techniques for increasing resilient behavior and patient safety. For example, the model should include well-structured practices for managing care-process interruptions (such as in Froehle and White, 2014) and lean methods, such as marking “the points in the medication preparation they have reached” or by using visible artifacts (such as in Patterson and Wears, 2015, p. 46). Moreover, this study applies the dynamic capabilities theory to employees’ practices and further studies should analyze whether the practices of hospital managers or organizational routines have the potential to increase the resilience of a hospital or a ward in a complementary manner.

Fourth, in this study, the unit of analysis consists of a hospital ward and we subsequently managed data and information from the employees without distinguishing between the roles they played. Nevertheless, if we consider the types and number of pieces of evidence related to different professional roles we can observe some dissimilarity. To cite the most manifest, we only found evidence related to patient-related knowledge ACAP in interviews with physicians and head physicians, while evidence related to the readiness capability was only found in interviews with line professionals. In sum, our preliminary findings suggest there may be differences in the interviewees’ responses dependent on their role in the workplace. As mentioned in this research, we deliberately did not analyze our results from this perspective, but we strongly believe future research should explore this issue further. Investigating if and how management vs line professional and nurse vs doctor may contribute to the ward resilience capabilities would be extremely interesting and surely deserves to be deepened in further studies.

Fifth, in this study, we intentionally focused on resilience capabilities with respect to operational failures and on the role of digital technology in supporting resilience. We did not focus on if and how specific resilience capabilities and specific digital technologies might be more useful and effective for specific types of operational failures (see Table AII). We strongly support further research to investigate this issue.

Finally, we think it would be interesting to explore resilience behavior through the lens of dynamic capabilities in professional service settings other than healthcare. As already discussed, professional services share particular features that do not easily allow them to prevent all the possible “failures” that may occur while carrying out the operations. Consequently, resilient capabilities are much needed when managing operational failures in these sectors and, thus, for improving their quality performance.

References


Appendix 1. Protocol A – physicians, nurses, head physicians, head nurses
[Questions for Head Physicians and Head Nurses in square brackets]

PATIENT SAFETY

(1) What do you do to ensure “patient safety” during your work? [What do you do to ensure “patient safety” in light of your role?]

(2) Do you think that the ability to handle an “operational failure” when it happens is important in a hospital? Why? Have you ever found yourself in a situation like this? Give me an example
[Do you think that the ability of your subordinates to manage a “failure” when it happens is important in a hospital? Why?]

(3) Have you ever been able to handle an “operational failure” when it happened? What enabled you to manage it? Did you use an IT system when you were handling the failure?
[NOT ASKED TO HEADS]

(4) Have you ever been unable to manage a “failure,” even if you were capable of doing it? What stopped you? [NOT ASKED TO HEADS]

(5) In terms of patient safety improvement, do you feel that you are using all your knowledge, experience and skills to achieve positive results? If not, why not? [NOT ASKED TO HEADS]

RESILIENCE (Problems and Errors)
The researcher shows the slide containing the categories of operational failures (Table AII).
For each category, the researcher asks the following questions:

(6) When a problem that can have an impact on patient safety occurs, how do you behave? Give me an example [When one of your subordinates has a problem (and as a consequence the workflow is blocked) that can have an impact on patient safety, how would you like the subordinate to act? Why? Give me an example.]

(7) What are the factors (responsibility, fear, fear of being seen, times to be respected, etc.) that influence your behaviour? [What are the factors that affect your wishes?]

(8) If, in order to solve the problem you need to break guidelines, protocols, etc [...], would you do it? Why? Would you give me an example of when you had to do it? [If, in order to solve the problem (in order to overcome the block to the workflow) the subordinate breaks guidelines, protocols, etc., [...] how would you react? Give me an example.]

(9) When trying to solve the problem, did you use any digital technology? Give me an example? Do you think that, in general, digital technology may help physicians and nurses to solve problems in healthcare? Why? [Do you think the digital technologies used in your ward will inhibit or will help physicians and nurses to solve problems? Why? Give me an example.]
(10) When you realize that you made an error that could have an impact on the patient safety, how do you behave? Give me an example. [When a subordinate realizes that he/she has made an error that could have an impact on patient safety, how would you like the subordinate to act? Why? Give me an example.]

(11) What are the factors (responsibility, fear, fear of being seen, times to be respected, etc.) that influence your choice? [What are the factors that affect your wishes?]

(12) If, in order to correct the error you need to break guidelines, protocols, etc., […] would you do it? If so, why? If not why not? [If, in order to solve the error the subordinate breaks guidelines, protocols, etc., […] how would you react? Give me an example.]

(13) Would you give me an example of when you had to do this? [NOT ASKED TO HEADS]

(14) When trying to correct the error, did you use any digital technology? Give me an example. Do you think that, in general, digital technology may help physicians and nurses to correct errors in healthcare? Why? [Do you think the digital technologies used in your ward will inhibit or will help physicians and nurses to solve problems? Why? Give me an example.]
### Appendix 2

<table>
<thead>
<tr>
<th>Operating room (surgery)</th>
<th>An OR application that provides clinical documentation/management of relevant real-time surgery procedure, both from an OR nurses and Anesthesiologists perspective.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating room (surgery) post-operative</td>
<td>An OR application that provides clinical documentation/management of relevant follow-up procedures, transfers to step down units, ICUs, etc., both from an OR nurses and Anesthesiologists perspective.</td>
</tr>
<tr>
<td>Operating room (surgery) pre-operative</td>
<td>An OR application that provides clinical documentation/management of relevant pre-surgery information and patient preparation for surgery. It also provides for the management of relevant pre-surgery availability/scheduling/reservation/preparation of room, OR supplies/meds, and staff.</td>
</tr>
<tr>
<td>Clinical data repository</td>
<td>A centralized database that allows organizations to collect, store, access and report on clinical, administrative, and financial information collected from various applications within or across the healthcare organization that provides healthcare organizations an open environment for accessing/viewing, managing, and reporting enterprise information.</td>
</tr>
<tr>
<td>Order entry (includes order communications)</td>
<td>A legacy HIS application that allows for entry of orders from multiple sites including nursing stations, selected ancillary departments, and other service areas, and allows viewing of single and composite results for each patient order. This function creates billing records as a by-product of the order entry function.</td>
</tr>
<tr>
<td>Blood bank</td>
<td>An application specifically designed to support the management and operations of a hospital blood bank. These systems require FDA certification.</td>
</tr>
<tr>
<td>Anatomical</td>
<td>An application that is used to manage the operations of histology and cytology departments within the pathology laboratory.</td>
</tr>
<tr>
<td>In-house transcription</td>
<td>Transcription functions are performed within the healthcare organization using internal resources and applications.</td>
</tr>
<tr>
<td>Clinical decision support</td>
<td>An application that uses pre-established rules and guidelines, which can be created and edited by the healthcare organization, and integrates clinical data from several sources to generate alerts and treatment suggestions.</td>
</tr>
<tr>
<td>Nursing documentation</td>
<td>This software documents nursing notes that describe the care or service to that client. Health records may be paper documents or electronic documents, such as electronic medical records, faxes, emails, audio or video tapes and images. Through documentation, nurses communicate their observations, decisions, actions and outcomes of these actions for clients. Documentation software tracks what occurred and when it occurred.</td>
</tr>
<tr>
<td>Computerized practitioner order entry (CPOE)</td>
<td>An order entry application specifically designed to assist practitioners in creating and managing medical orders for patient services or medications. This application has special electronic signature, workflow and rules engine functions that reduce or eliminate medical errors associated with physician ordering processes.</td>
</tr>
<tr>
<td>Physician documentation</td>
<td>The use of structured template documentation by physicians to capture any of their patient findings that are part of the electronic medical record (e.g., history and physicals, diagnostic findings, discharge notes, etc.). The structured template documentation captures discreet data that is used for interaction with the clinical decision support system relative to evidence-based medicine guidelines and/or protocols. Dictation and transcription applications do not qualify as a physician documentation application for the purpose of this study.</td>
</tr>
<tr>
<td>Nurse staffing/scheduling</td>
<td>An application that automates decisions about staffing, nursing stations, and scheduling nurses’ time. May include functions that enable a hospital to quickly review and generate its nurse scheduling; adjust staffing and scheduling based on patient volume, acuity, and staff ability; keep records for budgeting; produce management reports on productivity and census; and maintain records on personnel qualifications.</td>
</tr>
<tr>
<td>Electronic medication administration record (EMAR)</td>
<td>An electronic record keeping system that documents when medications are given to a patient during a hospital stay. This application supports the five rights of medication administration (right patient, right medication, right dose, right time and the right route of administration).</td>
</tr>
</tbody>
</table>

**Source:** Adapted from Sharma et al. (2016)
## Appendix 3

<table>
<thead>
<tr>
<th>Category</th>
<th>Explanation</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment/supply</td>
<td>Damaged or missing equipment and/or inventory</td>
<td>Pulse oximeters are missing because they are under maintenance and have not been replaced. There is an obese patient and his bed is not suitable</td>
</tr>
<tr>
<td>Facility</td>
<td>Layout not conducive to patient care</td>
<td>The arrangement of the equipment inside a room does not allow patients to be kept under observation. Storage of equipment in unsuitable places as the designated space was not sufficient.</td>
</tr>
<tr>
<td>Communication/documentation</td>
<td>Poor information transfer between providers</td>
<td>Doctors receive inconsistent communications from nurses about the condition of patients. Nurses find it difficult to contact doctors to communicate. General lack of information about the status of patients (e.g. the need for oxygen), with the consequence that the departments are unprepared for the arrival of the patient.</td>
</tr>
<tr>
<td>Staffing/staff development</td>
<td>Insufficient staff/scheduling issues</td>
<td>Not knowing if the pharmacy has received the order from the unit. Automated drug dispensing (ADD) terminate drugs. Increased waiting times due to lack of laboratory results. Rough hand wash. Switch suddenly from one patient to another. Use of non-sterile surfaces because the sterile surfaces are occupied.</td>
</tr>
<tr>
<td>Medication</td>
<td>Communication</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Staffing/staff development</td>
<td></td>
</tr>
</tbody>
</table>

### Table AII.

**Categories of operational failures**

*Source:* Adapted from Tucker *et al.* (2008)
Table AIII. Frequencies of evidence of resilience dimensions

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Tot</th>
<th>Hospital A</th>
<th>Hospital B</th>
<th>Tot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare knowledge</td>
<td>5</td>
<td>4</td>
<td>18</td>
<td>29</td>
</tr>
<tr>
<td>Experience</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Clinical knowledge</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Organizational dynamics</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Readiness</td>
<td>3</td>
<td>0</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Operational failure detection</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Readiness training</td>
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<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Readiness resource</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Forecasting</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Collaboration</td>
<td>3</td>
<td>3</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Vertical collaboration</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Horizontal collaboration</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Flexibility</td>
<td>4</td>
<td>3</td>
<td>11</td>
<td>19</td>
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<tr>
<td>Multi-skilled workforce</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Service delivery flexibility</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>8</td>
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<tr>
<td>Patient-related knowledge ACAP</td>
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<td>0</td>
<td>7</td>
<td>7</td>
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<tr>
<td>Response</td>
<td>3</td>
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<td>9</td>
</tr>
<tr>
<td>Quick response</td>
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<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Response team</td>
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<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>10</td>
<td>59</td>
<td>101</td>
</tr>
</tbody>
</table>

Appendix 4

Digital health technology

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Resilience of medium-sized firms to supply chain disruptions: the role of internal social capital

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Department of Marketing and Logistics, Fisher College of Business, Ohio State University, Columbus, Ohio, USA

Abstract

Purpose – The purpose of this paper is to explore resources or capabilities that enable medium-sized firms to be resilient, namely, to avoid and recover from supply chain disruptions.

Design/methodology/approach – A case-study method is employed with four medium-sized manufacturing firms headquartered in the USA that have global supply chains. Data are collected from semi-structured interviews with key informants from diverse functions and managerial levels, archival documents, observation and a resilience assessment.

Findings – Internal social capital emerged as a resilience-enhancing resource, comprising: structural capital grounded in small network size, geographical proximity among decision makers and low hierarchy; relational capital grounded in close relationships, commitment and respect; and cognitive capital grounded in long employee tenure.

Originality/value – This is the first paper in the supply chain management literature to examine the resilience of medium-sized firms, an under-researched context. It is also the first paper to introduce internal social capital as a resilience-enhancing resource. Hence, this is among the few papers to propose a resilience-enhancing resource rooted not in a firm’s supply chain operations but its human resources. This paper, moreover, identifies several facets of internal social capital within medium-sized firms. Finally, the paper makes several managerial contributions.

Keywords Multiple-case study, Supply chain disruptions, Resilience, Medium-sized firms, Internal social capital

Paper type Research paper

1. Introduction

Supply chain disruptions are a significant managerial concern (World Economic Forum, 2013) given their high frequency (Resilinc, 2018) and severe consequences for firms and supply chains (Hendricks and Singhal, 2003). Firms, therefore, seek to avoid or accelerate recovery from disruptions by developing resilience (Melnyk et al., 2014). Indeed, the supply chain management (SCM) literature proposes several capabilities that improve resilience to disruptions (e.g. Christopher and Peck, 2004; Sheffi and Rice, 2005). This literature, however, has limitations that constrain our holistic understanding of resilience. First, little is known about what constitutes resilience in smaller firms (Scholten et al., 2017). The SCM literature primarily examines large firms and proposes capabilities prevalent in these firms (e.g. Blackhurst et al., 2011; Pettit et al., 2013). For example, redundancy, sourcing and manufacturing flexibility, visibility or collaboration (Christopher and Peck, 2004; Sheffi and Rice, 2005; Pettit et al., 2013) necessitate abundant resources, large scale and power in the supply chain – typical attributes of large firms (Rothwell, 1989; Vossen, 1998). Second, little
is known about what engenders resilience beyond common supply chain strategies (Scholten et al., 2017). The SCM literature principally identifies resilience-boosting capabilities rooted in a firm’s supply chain operations (i.e., sourcing, logistics and production) and overlooks those rooted, for example, in its human resources. The latter may be more pertinent to smaller firms and may enhance our understanding of resilience in these firms (Gunasekaran et al., 2011).

In this paper, we examine the resilience of medium-sized firms, an under-researched context. These are firms with annual revenue between US$10m and US$1bn (NCMM, 2011). Medium-sized firms are a relevant context to examine resilience for theoretical reasons. First, these firms have fewer tangible resources, such as financial, infrastructural or technological (Hendricks and Singhal, 2003). These resources enable firms to overcome problems threatening their survival (Brüderl and Schüssler, 1990) and improve their resilience (Pettit et al., 2013). Medium-sized firms, therefore, likely rely on other resources to develop resilience. Moreover, these firms are more liquidity-constrained and face higher barriers to attracting new capital and resources than both small and large firms do (Brüderl and Schüssler, 1990; Audretsch and Elston, 2002). Attracting new capital and resources reduces susceptibility to disruptions, helps finance operations during disruptions and provides buffers to mitigate disruption effects (Pettit et al., 2013). Additionally, medium-sized firms may face more severe disruptions (Hendricks and Singhal, 2003), as they do not enjoy reputation effects to the extent that large firms do, which protect a firm’s market position post disruption (Sleuwaegen and Goedhuys, 2002). Finally, medium-sized firms face a more challenging policy environment than small and large firms do. They tend to be overlooked by policy makers, whose initiatives are often designed to assist small or large firms (Grant Thornton, 2014). They are considered too small to compete with large firms and be influential government stakeholders but too big to benefit from small-business set-asides, incentives and support (HSBC, 2015; Chabot, 2017). Such concessions create a more favorable business climate and reduce environmental risks for small and large firms but not medium-sized firms.

Medium-sized firms are also a relevant context for practical reasons. They represent an important market for several global economies: they are the “market that moves America” (NCMM, 2011) and the backbone of major European economies (Blackstone and Fuhrmans, 2011; Grant Thornton, 2014). Furthermore, they are critical links in the supply chains of large firms (NCMM, 2017a). As supply chain resilience is determined by the weakest link (Rice, 2011), it is essential to understand how medium-sized firms can become a reliable link so that they and their larger partners design and operate resilient supply chains.

In this paper, therefore, we address the following research question:

**RQ1.** What resources or capabilities do medium-sized firms have that enhance their resilience to supply chain disruptions?

A capability refers to “a firm’s capacity to deploy resources, usually in combination, using organizational processes, to effect a desired end” (Amit and Shoemaker, 1993, p. 35). We examined this question by conducting case studies with four medium-sized manufacturing firms headquartered in the USA that operate global supply chains. We collected data from several sources, including 23 semi-structured interviews with key informants from diverse functions and managerial levels, archival sources, observation and a resilience assessment. Our analyses reveal internal social capital as a resilience-enhancing resource. It refers to links or relations among individuals or groups within an organization that create cohesion and “facilitate the pursuit of collective goals” (Adler and Kwon, 2002, p. 21). Internal social capital emerged as: structural capital grounded in small network size, geographical proximity among decision makers and low hierarchy; relational capital grounded in close relationships, commitment and respect; and cognitive capital grounded in long employee tenure.
Our paper makes theoretical and managerial contributions. Theoretically, this is the first paper in the SCM literature to examine the resilience of medium-sized firms, an under-researched context. Although these firms exhibit resilience (NCMM, 2011), little is known why. Our paper thus sheds some light on the “why.” Moreover, our paper introduces internal social capital as a resilience-enhancing resource. It is thus among the few papers in the SCM literature to go beyond the generic supply chain capabilities and examine internal factors that improve resilience. In this way, our paper also contributes to the broader SCM literature on social capital, which mainly focuses on external social capital, by examining internal social capital, an under-researched aspect. Finally, our paper identifies facets of internal social capital within medium-sized firms (e.g. small network size, geographical proximity among decision makers, low hierarchy; employee relationships characterized by closeness, commitment and respect; and long employee tenure). Practically, our paper suggests that medium-sized firms should retain or enhance these facets generating internal social capital. These firms should also be cognizant of how they can continue developing this resilience-enhancing resource as they grow into larger firms. Finally, large firms seeking to develop resilience through internal social capital may learn from their medium-sized counterparts by emulating the simpler and nimble internal structures of these firms.

2. Literature review and theoretical background
Firm resilience to supply chain disruptions is the firm’s ability to “[...] resist disruptions and recover operational capability after disruptions occur” (Melnyk et al., 2014, p. 36). Firm resilience, therefore, comprises the proactive component of resistance – the ability to avoid a disruption – and the reactive component of recovery – the ability to restore operations post disruption (Melnyk et al., 2014). Tukamuhabwa et al. (2015), based on Ponomarov and Holcomb (2009), extend the concept of firm resilience to supply chain resilience and define it as the supply chain’s “adaptive capability [...] to prepare for and/or respond to disruptions, to make a timely and cost-effective recovery, and therefore progress to a post-disruption state of operations [...]” (p. 5599).

SCM research proposes several capabilities that improve firm resilience to supply chain disruptions (see Tukamuhabwa et al., 2015; Kamalahmadi and Parast, 2016 for literature reviews). A prominent resilience-enhancing capability is redundancy. It involves maintaining excess resources (e.g. safety stock or low capacity utilization) that serve as a buffer when disruptions occur (Sheffi and Rice, 2005; Pettit et al., 2013). Redundancy helps firms gain time during disruptions (Zsidisin and Wagner, 2010) but is costly (Sheffi and Rice, 2005).

Another prominent capability is flexibility, the ability to adapt to unforeseen changes (Golden and Powell, 2000). Flexibility involves designing systems with built-in capabilities used not only during disruptions but also in daily operations (Sheffi and Rice, 2005), and it has multiple facets: sourcing flexibility (e.g. sourcing from multiple suppliers); manufacturing flexibility (e.g. maintaining standard processes across plants, multiple plants with built-in interoperability or several capabilities at each plant); transportation flexibility (e.g. using multiple modes, carriers or routes); and distribution flexibility (e.g. using postponement) (Sheffi and Rice, 2005; Tang, 2006; Tang and Tomlin, 2008).

Collaboration with supply chain partners is another resilience-enhancing capability (Christopher and Peck, 2004; Wieland and Wallenburg, 2013; Scholten et al., 2014). It involves working with partners to identify and mitigate supply chain risks through collaborative planning and information sharing (Christopher and Peck, 2004). Collaboration improves end-to-end visibility and velocity (Scholten et al., 2014; Scholten and Schilder, 2015), enabling firms to respond quickly to demand and supply changes (Christopher and Peck, 2004).

Finally, developing a risk-focused culture is another important aspect to building resilience. Such culture may be developed by incorporating risk factors and risk-management techniques in the decision-making process (Sheffi and Rice, 2005) and developing business
continuity plans (Christopher and Peck, 2004). Similarly, Bode et al. (2011) suggest that firms
develop a disruption-management orientation, namely, a “general awareness and
consciousness of, concern about, seriousness toward, and recognition of opportunity to
learn from supply chain disruptions” (p. 837).

2.1 Why might the resilience of medium-sized firms differ?
Large firms typically possess abundant tangible resources, large scale and strong influence in
the supply chain. Thus, they are generally better-suited to develop the capabilities mentioned
above. Conversely, medium-sized firms may find it challenging to develop redundancy, given
their limited financial resources (Rothwell, 1989). Medium-sized firms may also find it
challenging to develop sourcing, manufacturing and distribution flexibility. Their small
volumes prevent them from sourcing from multiple suppliers, operating multiple plants and
distributing their goods through multiple carriers. Additionally, medium-sized firms, due to
their small size, volume and scale have less power to collaborate with or influence the behavior
of other supply chain partners to improve visibility or velocity and, subsequently, supply
chain resilience. Finally, medium-sized firms typically lack business continuity plans
(Herbane, 2010) and either do not focus on developing a risk-oriented culture or do so in an
undisciplined fashion (Vargo and Seville, 2011). Generally, medium-sized firms lack the
resources to dedicate to resilience (Sullivan-Taylor and Branicki, 2011).

Medium-sized firms also have specific attributes that may increase their susceptibility to
disruptions. For example, they typically have concentrated and highly-customized product
offerings that focus on niche markets (Terziowski, 2010). Their profitability, therefore,
depends on flawless SCM for this limited set of products (Thakkar et al., 2008). This focus
may reduce their flexibility during demand fluctuations and increase the economic impact of
disruptions. Moreover, medium-sized firms typically lack other capabilities that help avoid
or recover quickly from disruptions. They may have less-developed information-technology
systems (Thakkar et al., 2008), limiting their ability to detect disruptions and quickly recover
from them. Furthermore, these firms tend to evaluate suppliers based on price and quality
rather than risk-related metrics (Thakkar et al., 2008), limiting their ability to assess supply
risk and increasing their susceptibility to supply disruptions.

In summary, medium-sized firms may be more susceptible to disruptions and lack the
resilience-enhancing capabilities proposed in the SCM literature to recover from disruptions.
Nonetheless, medium-sized firms exhibit resilience (NCMM, 2011) but little is known why.
We suggest it is essential to augment resilience research by exploring what other internal
resources or capabilities are pertinent to smaller firms (Gunasekaran et al., 2011) and
enhance their resilience to disruptions (Fiksel et al., 2015). Our investigation of medium-sized
firms reveals a novel resilience-enhancing resource: internal social capital. Hence, we first
review this literature before discussing our findings.

2.2 Social capital
Social capital regards “the sum of the actual and potential resources embedded within, available
through, and derived from the network of relationships possessed by an individual or social unit
concept comprising three dimensions: structural, relational and cognitive (Nahapiet and
Ghoshal, 1998). These dimensions take many forms but each of these forms has two common
characteristics: “they constitute some aspect of the social structure” and “facilitate the actions of
individuals within the structure” (Nahapiet and Ghoshal, 1998, p. 244).

Structural capital regards the links among a network’s actors and the pattern of
those links (Nahapiet and Ghoshal, 1998); that is, whom the actors reach and how
they reach them (Burt, 1992). It thus describes the impersonal attributes of relationships
Nahapiet and Ghoshal, 1998). Structural-capital facets include the presence/absence of ties among a network’s actors (Scott, 1991) and network configuration (Krackhardt, 1994) described based on size, density, connectivity and hierarchy (Nahapiet and Ghoshal, 1998).

Relational capital regards the assets gained through or rooted in interpersonal relationships (Nahapiet and Ghoshal, 1998). It describes the quality of interpersonal relationships and how they develop and strengthen over time (Whipple et al., 2015). Relational-capital facets include interpersonal relationships characterized by close interaction, friendship, trust, respect, reciprocity and identification with and commitment to the collective (Nahapiet and Ghoshal, 1998; Kale et al., 2000; Wasko and Faraj, 2005).

Relational capital regards “the resources providing shared representations, interpretations, and systems of meaning” among a network’s actors (Nahapiet and Ghoshal, 1998, p. 244). Cognitive capital is created as network actors interact with each other over time, learn network-specific skills and knowledge, and develop a common understanding of goals, norms and ways of acting in the collective (Tsai and Ghoshal, 1998; Wasko and Faraj, 2005). Cognitive capital results from either first-hand experience or shared narratives that provide information about how other individuals have acted in the past (Wasko and Faraj, 2005). Cognitive-capital facets include shared codes, language, goals, vision and long tenure in the shared practice (Nahapiet and Ghoshal, 1998; Tsai and Ghoshal, 1998; Wasko and Faraj, 2005).

Social capital is a valuable, rare, inimitable and unsubstitutable resource (Nahapiet and Ghoshal, 1998; Bolino et al., 2002). According to the resource-based view of the firm, resources possessing these attributes provide the firm with capabilities that lead to superior performance and long-term competitive advantage (Barney, 1991). Therefore, firms with higher social capital are more successful (Nahapiet and Ghoshal, 1998). Social capital enhances success and competitive advantage through assets deriving from relationships developed among a firm’s employees (i.e. internal social capital) or employees of different firms (i.e. external social capital) (Adler and Kwon, 2002). Internal social capital improves information exchange and knowledge creation and accumulation within a firm (Nahapiet and Ghoshal, 1998). External social capital reduces interfirm transaction costs (Nahapiet and Ghoshal, 1998) and improves firm performance (Krause et al., 2007; Carey et al., 2011).

3. Method
We examined our research question using the multiple-case study method. In our study, the unit of analysis is the firm; thus, each case represents a firm. The case-study method is appropriate for our investigation for several reasons. There is limited scientific knowledge of resilience in medium-sized firms (Eisenhardt, 1989; Edmondson and McManus, 2007; Yin, 2009). Our study thus reflects an early, exploratory investigation regarding why medium-sized firms exhibit resilience (Voss et al., 2002; Yin, 2009). Through our open-ended inquiry, we seek to identify whether new constructs, not previously proposed in the resilience literature, emerge in the middle-market context (Edmondson and McManus, 2007). Moreover, our research purpose is to understand and empirically observe the phenomenon in its actual context (Barratt et al., 2011; Yin, 2009) and develop insights by comparing observations within and across cases (Eisenhardt and Graebner, 2007). Ultimately, we seek to develop propositions that link new constructs with resilience to supply chain disruptions (Yin, 2009).

3.1 Research setting: US medium-sized firms
US medium-sized firms have annual revenue between US$10m and US$1bn (NCMM, 2011). They operate in several industries including manufacturing, wholesale and retail trade, finance, and other services (NCMM, 2017a). They are a crucial market for the US economy:
they employ approximately 45m people representing a third of US jobs, generate more than ten trillion USD in annual revenue, and produce 33 percent of the private-sector GDP (NCMM, 2016). These firms are labeled “the mighty middle market” (The Economist, 2012) and “America’s engine of growth” (NCMM, 2016). Their importance, moreover, extends beyond the USA, as they represent the world’s third largest economy (NCMM, 2016).

US medium-sized firms are also critical links in the supply chains of large firms, operating as first-, second- and third-tier suppliers (NCMM, 2017a). Importantly, more than one-third of US medium-sized firms are the exclusive provider for the particular products/services they offer to their customers, making them a critical player in global supply chains (NCMM, 2017a). Medium-sized firms, however, generally lack the resources, know-how and business continuity plans to mitigate supply chain risks (Herbane, 2010). Meanwhile, most of these firms rank operational risk as their top risk area (NCMM, 2017a). Consequently, both these and large firms may be exposed to higher risk that compromises supply chain resilience.

3.2 Case selection
US medium-sized firms are an appropriate setting for our research, as the USA has the largest concentration of medium-sized firms globally (HSBC, 2015). We identified cases using purposeful sampling (Patton, 1990; Corley and Gioia, 2004) and employed specific criteria to identify information-rich cases that elucidate the issues of interest (Patton, 1990). First, we focused on the manufacturing sector, as it is a primary and well-performing middle-market sector (American Express and Dun and Bradstreet, 2016). We selected firms that operate across various manufacturing sectors to ensure our findings are not constrained to a specific product/industry sector and allow alternative explanations to emerge (Eisenhardt and Graebner, 2007). Second, we studied firms with annual revenue between US$100m and US$500m. Firms in this segment use several SCM best practices and are the best-performing and most effective middle-market suppliers among all middle-market firms (NCMM, 2017a). Also, firms in this segment likely have started thinking about supply chain risk but have not yet developed the expertise to manage it (NCMM, 2017b). Hence, studying these firms allowed us to identify cases that “will most likely illuminate” our research question (Yin, 2009, p. 26). We assumed that firms with revenue over US$500m start behaving and exhibit similar resilience-enhancing resources and capabilities as large firms do. Finally, we selected firms that have global supply chains through sourcing, manufacturing, or selling globally. Global presence increases supply chain complexity (Choi and Krause, 2006), which increases disruption occurrence (Bode and Wagner, 2015) and severity (Craighead et al., 2007).

We identified firms by first deliberating our existing contacts with industry professionals and then consulting the NCMM to find firms matching our criteria. Next, we emailed our primary contact at a given firm to determine whether the firm was appropriate for and interested in participating in our study. The email included a description of the research objectives, information about the research team and approximate time commitment by the firm’s employees. Our contact discussed the research proposal with a senior manager to gain permission for and commitment to participation. Upon participation agreement, we worked with our primary contact to identify a set of key informants from diverse functions and managerial levels that could answer our questions and to schedule a site visit. We continued adding firms to our sample by identifying new cases using the criteria above that could further illuminate the concepts emerging from our analyses (Strauss and Corbin, 1990).

3.3 Data collection
We conducted the case studies following guidelines proposed in the literature to ensure the reliability and validity of our findings (Eisenhardt, 1989; Voss et al., 2002; Yin, 2009).
Our data collection was guided by a research protocol (Voss et al., 2002; Yin, 2009), which specified the opening and closing script of the interview, the request to audio-record the interview, the interview questions and their sequence, and the request to collect supplemental data. We also emailed a one-page research overview and the interview guideline to each key informant for preparation purposes (Voss et al., 2002; Yin, 2009).

We collected data using semi-structured interviews, archival documents, observation and resilience assessment. Table I provides information about the four case firms, key informants and data collected. To protect the identities of the firms, we refer to them as Firm A, B, C and D.

Our primary data source included in-depth, semi-structured interviews with 23 key informants. In each firm, we interviewed between four and eight functional managers (e.g. sourcing, operations, logistics, finance and sales) from diverse managerial levels to ensure that distinct perspectives and a holistic representation of the firm’s resources and capabilities emerged during the interviews (Voss et al., 2002; Corley and Gioia, 2004). Each interview lasted between 40 and 70 min. During each interview, at least two research team members were present and took notes to ensure different perspectives emerged (Eisenhardt, 1989). After each site visit, we discussed what we had heard from the informants and transcribed the interviews within 24 h (Eisenhardt, 1989). We stopped collecting additional data (by adding either a case or informants) when we reached the point of theoretical saturation at which interviews did not help identify new or expand the emerging concepts (Eisenhardt, 1989).

We collected additional data to check the statements from the interviews, complete any missing information and triangulate our findings (Jick, 1979; Scholten and Schilder, 2015). We collected archival information about each firm before and after the site visits, including materials from the firms’ websites to familiarize ourselves with the firms before each visit; press releases about the disruptions encountered by the firms; articles from newspapers and ABI/Inform; and analyses about the firms from Capital IQ. At Firm A, we also collected observational and resilience-assessment data. We participated in two business continuity meetings to observe interpersonal interactions and gather data about the firm’s plans to improve resilience. We also administered the Supply Chain Resilience Assessment and Measurement (SCRAM) survey (Pettit et al., 2013) to key informants to gather additional insights about the firm’s vulnerabilities and capabilities. We analyzed and presented our findings to the firm’s executive team and case participants to gather feedback on our conclusions and additional information not captured by the SCRAM survey instrument. At Firm B, we gathered internal risk-assessment data, such as survey data and presentation materials about supply chain risks collected by the firm.

### 3.4 Data analysis

We began analyzing the data as we collected it (Eisenhardt, 1989) and organized our analyses in a database using the software package MAXQDA 2007 (VERBI GmbH, Berlin, Germany). Data analyses included within-case and cross-case analyses (Eisenhardt, 1989; Miles and Huberman, 1994). In this stage, we took several actions to ensure the reliability and validity of our findings (Yin, 2009).

We began the within-case analyses by reading the transcribed interview data multiple times and writing summary reports for each interview (Miles and Huberman, 1994). We began the first-order analysis (i.e. open coding) by reducing the data to words, sentences and short paragraphs deemed relevant to answer our research question (Scholten and Schilder, 2015). We used the sub-factors of vulnerabilities and capabilities (e.g. multiple sources, reserve capacity, liquidity) (cf. Pettit et al., 2013) as a starting guide to coding. Hence, we could deduce second-order categories and overarching dimensions grounded in the resilience literature. As we coded the sub-factors of capabilities, we realized that the key...
<table>
<thead>
<tr>
<th>Case</th>
<th>Manufacturing sector and product examples</th>
<th>Annual revenue (US$)¹</th>
<th>Employees²</th>
<th>Ownership</th>
<th>Key informants (Interview length in minutes³)</th>
<th>Data sources</th>
<th>Collected data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm A</td>
<td>Protective apparel and equipment (e.g. helmets, gloves and uniforms) High-mix and low-volume manufacturer</td>
<td>100–300m</td>
<td>600–800</td>
<td>Privately-owned</td>
<td>Chief Executive Officer (50)</td>
<td>Eight in-depth semi-structured interviews</td>
<td>130 double-spaced pages</td>
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<td>Chief Financial Officer (55)</td>
<td>Archival documents (news articles, press releases, firm website, and information from ABI/Inform and Capital IQ)</td>
<td>About 55 press releases, 100 news articles and reports, and 20 analysis pages (Capital IQ)</td>
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<td>Chief Information Officer (50)</td>
<td>Direct observation of two business continuity meetings</td>
<td>About 50 pages and slides</td>
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<td>Chief Procurement Officer (50)</td>
<td>Supply chain resilience assessment and management survey (Pettit et al., 2013)</td>
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<td>Director of Information Technology (50)</td>
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<td>Director of Operations (60)</td>
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<td>Transportation Officer A (55)</td>
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<td>Transportation Officer B (55)</td>
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<td>Firm B</td>
<td>Cabling and connectivity equipment (e.g. A/V cables and wall plates, PC cables, fiber-optic cables and hardware) High-mix and low-volume manufacturer</td>
<td>100–300m</td>
<td>200–400</td>
<td>Privately-owned</td>
<td>Chief Executive Officer (55)</td>
<td>Six in-depth semi-structured interviews</td>
<td>140 double-spaced pages</td>
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<td>Chief Operations Officer (60)</td>
<td>Archival documents (news articles, firm website, and information from ABI/Inform and Capital IQ)</td>
<td>About 90 news articles and reports, and 20 analysis pages (Capital IQ)</td>
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<td>Director of Marketing (60)</td>
<td>Survey data and presentation materials on supply chain risks collected by Firm B for internal use</td>
<td>About 40 pages and slides</td>
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<td>Director of Purchasing (45)</td>
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<td>Senior VP of Finance (50)</td>
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<td>Treasurer (55)</td>
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Table I. Case firms

Supply chain disruptions (continued)
<table>
<thead>
<tr>
<th>Case</th>
<th>Manufacturing sector and product examples</th>
<th>Annual revenue (US$)</th>
<th>Employees</th>
<th>Ownership</th>
<th>Key informants (Interview length in minutes)</th>
<th>Data sources</th>
<th>Collected data</th>
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</thead>
<tbody>
<tr>
<td>Firm C</td>
<td>Medical equipment and supplies (e.g. ambulance cots, stretchers and trauma bags) High-mix and low-volume manufacturer</td>
<td>100–300m</td>
<td>400–600</td>
<td>Privately-owned</td>
<td>Chief Financial Officer (55) Logistics Manager (70) Sourcing and Operations Manager (55) VP of Operations (55) VP of Sales (40)</td>
<td>Five in-depth semi-structured interviews Archival documents (news articles, firm website and information from ABI/Inform and Capital IQ)</td>
<td>120 double-spaced pages About 100 news articles and reports, and 20 analysis pages (Capital IQ)</td>
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<td>Firm D</td>
<td>Plastics materials and resins (e.g. acrylic sheets, polymer and coatings) High-mix and low-volume manufacturer</td>
<td>300–500m</td>
<td>500–700</td>
<td>Privately-owned</td>
<td>Chief Operations Officer (65) Controller (50) Director of Purchasing (40) VP of Sales (50)</td>
<td>Four in-depth semi-structured interviews Archival documents (news articles, press releases, firm website and information from ABI/Inform and Capital IQ)</td>
<td>124 double-spaced pages About ten press releases, 100 news articles and reports, and 30 analysis pages (Capital IQ)</td>
</tr>
</tbody>
</table>

**Notes:**

- Annual revenue and number of employees are provided in ranges to protect firm anonymity;
- Rounded up to nearest 5 min
informants discussed their firms’ lack of those capability sub-factors (cf. Pettit et al., 2013). Instead, they mentioned new terms not previously identified in the resilience literature. Hence, we added these emerging terms to our coding scheme by remaining close to informants’ language whenever possible (Strauss and Corbin, 1990; Gioia et al., 2013). Next, we began searching for similarities and differences among the first-order categories and assembled those into second-order themes (i.e. axial coding) (Strauss and Corbin, 1990; Gioia et al., 2013). Finally, we combined similar second-order themes into broader overarching dimensions (Gioia et al., 2013). During coding, we iterated between our codes and the resilience and social-capital literature streams to compare the emerging concepts with and ground them in the literature (Eisenhardt, 1989). The results of the within-case analyses are four case profiles (available upon request).

Once we completed the within-case analyses, we began the cross-case analysis to compare and contrast the findings deriving from each case, identify patterns of resilience-enhancing resourcesCapabilities and determine how those enhance the resilience components of avoidance and recovery. We constructed meta-matrices to juxtapose the findings from each case (Miles and Huberman, 1994), assembled the evidence for the emerging concepts, and ensured replication across cases. The cross-case analysis revealed internal social capital, an overlooked perspective of social capital (Adler and Kwon, 2002; Bolino et al., 2002), as a resilience-enhancing resource in medium-sized firms.

4. Findings and discussion

Figure 1 shows the structural, relational and cognitive dimensions of internal social capital and their respective facets. From our analyses, structural capital emerged through small network size (Bourdieu, 1986), geographical proximity among decision makers (Inkpen and
Tsang, 2005; Whittington et al., 2009) and low hierarchy (Youndt and Snell, 2004; Inkpen and Tsang, 2005). Relational capital emerged through close relationships (Kale et al., 2000), commitment (Wasko and Faraj, 2005) and respect (Nahapiet and Ghoshal, 1998; Kale et al., 2000). Finally, cognitive capital emerged through long employee tenure (Fischer and Pollock, 2004; Wasko and Faraj, 2005). Table II and the following subsections offer and discuss evidence for these facets in the case firms.

4.1 Structural capital

4.1.1 Network size. Network size regards the number of individuals represented by a collective and is an attribute of network configuration (Bourdieu, 1986; Bolino et al., 2002). In our case firms, it regards the number of decision makers within the firm. All case firms have small management teams, enabling firms to avoid and recover quickly from supply chain disruptions and improve their resilience.

A small network size facilitates collective action (Wasko and Faraj, 2005). It thus helps case firms organize and respond swiftly to changing environmental conditions, enabling them to avoid disruptions. For example, the VP of Sales (Firm C) described changing market requirements that would have interrupted the firm’s business unless the firm adjusted its product portfolio to match the new requirements. Senior managers at Firm C quickly gathered and developed a plan to shift the firm’s market direction and update its product portfolio, resulting in new product introductions. This swiftness, which the VP attributed to the firm’s small management team, helped the firm mitigate market risk and remain competitive: “For a lot of companies to do that in that short period of time would be unheard of. Now could they do it? Sure, but it would take a while. [In our case], five of us met. This is what we want to do. You find out the pricing; you find out how long; you find out this; you find out that, and we are done. It will be done by this Friday, and it took not even a week to have everything done. I think that's phenomenal about this company.”

Similarly, a small network size eases coordination among decision makers post disruption, as we observed at Firm B, enabling firms to respond swiftly. The Treasurer (Firm B) mentioned: “I think it [being smaller] can be helpful. We can get the right people in the room. It's not such a big room. When we get the key people together, we probably have 10-12 people.”

4.1.2 Geographical proximity among decision makers. Geographical proximity refers to the physical distance among the firm’s decision makers (Whittington et al., 2009), and is a structural characteristic of networks (Inkpen and Tsang, 2005). Medium-sized firms, due to their smaller size and scale, tend to have geographically-concentrated management teams. In our case firms, for example, senior decision makers are in the same physical location. Our findings suggest that a short distance among decision makers improves resilience by enabling firms to avoid and recover from supply chain disruptions.

Geographical proximity facilitates face-to-face meetings and interactions through which individuals learn about and become comfortable with each other. By doing so, they form and maintain ties over time (Inkpen and Tsang, 2005), improving their future access to resources (Borgatti and Cross, 2003). The VP of Operations (Firm C), for example, mentioned that senior managers were willing to support investments to mitigate supply chain risks (e.g. new capital-equipment investments to increase production capacity) because they were physically close to the functions. Proximity allowed senior managers to understand functional needs. Specifically, he stated: “[The request] would more than likely be accepted. Most people can see it, right? It's not like you have to go to some capital-equipment committee in [another state] to get a new building or something. Everything's right here, and the people can it see every day, what it's doing to the company.”

At the same time, face-to-face interactions enable decision makers to gather quickly post disruption to develop and implement disruption-recovery plans. For example, the CEO (Firm A)
Aggregate dimension: structural capital

First-order quote (representative interview data)

“We don’t have to go to many people to take action” (Firm A, CEO)

“[Cross-functional collaboration] is easier because you’re smaller […] you have less people that you need to know” (Firm C, VP of Operations)

“When you got 20 engineers, those guys are going to be able to go on the floor and see the people. When you got 500 engineers [such as in a large company], the engineers that really interact with people outside the Engineering Department are a lot less. I think a smaller company is probably more apt to have the cross-functional” (Firm C, VP of Operations)

“Sometimes you get lost in the big, corporate world where you’re just specifically [doing] accounting. You don’t really deal with too many people outside the department. But here, it’s for sure across the board; I have access to everything” (Firm D, Controller)

“The CFO is sitting here. I think we are pretty capable on the resilience side for our size” (Firm A, Director of Operations)

“When you are a $50 M company you can look over the cubicle and talk” (Firm B, Senior VP of Finance)

 “[The owners] are down the hall from me” (Firm B, CEO)

“There’s more communication in our organization amongst our purchasing group and our sales group and our operations group[…] Some of the companies that we buy from might have a sales manager that lives in [the Midwestern U.S.], the plant might be in [the southern U.S.] and might have a rep that lives in [the central U.S.]. They are more scattered […] We don’t have a lot of people scattered all over the place” (Firm D, Director of Purchasing)

“I think smaller firms are more nimble. There’s less bureaucracy […]” (Firm A, CFO)

“When getting larger and the distance between the frontline and the management is getting longer, you got to have more processes” (Firm B, Senior VP of Finance)

“We are not very layered […] each of those factories reports up to somebody here, who has a pretty good understanding of what’s going on in those areas” (Firm B, Treasurer)

 “[I came from very large companies] and you don’t have as many layers in the [smaller] organizations to get things done. So you are definitely far more flexible” (Firm C, Sourcing and Operations Manager)

“There are fewer hoops to jump through in this company, such as in getting money, than at [name of large company] or some of the other companies. Most people can see it, right?” (Firm C, VP of Operations)

“There’s definitely less bureaucracy here. That’s part of our strength […] There isn’t a lot of red tape that we have to go through. If we need to make a decision, or if we need to make a change, it really doesn’t take that long” (Firm D, Controller)

Aggregate dimension: relational capital

First-order quote (representative interview data)

“I know most of the managing directors, I have been to their plants, I have been to their homes […]” (Firm C, VP of Operations)

“I think the executives have done a fantastic job of […] having those relationships built. [The executives] are very active, as far as communicating and trying to build those relationships with people throughout the company. You’ll notice that when you go out on the production floor. A lot of the people on the production floor know the executives, know who the various managers are on a first name basis and vice versa” (Firm D, Controller)

“I think there’s a family atmosphere here […] the company tries to engender that and I think that helps” (Firm C, VP of Operations)

“This really is more like a family type atmosphere” (Firm D, Director of Purchasing)

Second-order category

Network size

Geographical proximity among decision makers

Organizational hierarchy

Relationship closeness

Supply chain disruptions
described how a tornado wrecked the town where the firm’s factory was located. The tornado spared the factory but “leveled” the town. Hence, the supply of electricity, gas and water to the firm’s factory was disrupted, halting production. Nonetheless, the CEO stated that the firm reacted swiftly to the disruption because the senior management team gathered quickly due to the geographical proximity among the managers: “The decision-making power is right here [...]. We had to immediately mobilize a plan of action on how to find out where people were, how quickly we could get back up, who in government we could talk to about what their plan was [...].” Geographical proximity among decision makers is particularly crucial for medium-sized firms, given that these firms are resource-constrained and likely find it difficult to gather a crisis team from diverse geographical locations to develop disruption-recovery plans, as is more typical in large firms.

Moreover, face-to-face interactions enable communication and knowledge exchange (Inkpen and Tsang, 2005), accelerating information sharing post disruption. Hence, face-to-face interactions are particularly important when functional employees need to work and coordinate cross-functionally post disruption (Olcott and Oliver, 2014). For example, the Director of Purchasing (Firm D) emphasized that managers, who are geographically close, know first-hand the urgency of a given situation and tend to respond positively to any requests for implementing disruption-recovery plans: “Your flexibility in walking down the hallway and communicating face-to-face as opposed to calling somebody 400 miles away that doesn’t understand the issue or the urgency of the issue is certainly an advantage.”
4.1.3 Organizational hierarchy. Organizational hierarchy refers to the number of levels in the chain of command within an organization (Huang et al., 2010), and is an attribute of structural configuration (Krackhardt, 1994). It is a source of structural capital, reflecting the extent and ease of connectivity with and accessibility to other network members (Inkpen and Tsang, 2005). Our case firms, for example, tend to have flatter organizational structures characterized by shorter chains of command and lower decision-making complexity. These attributes improve their resilience by enabling them to avoid and recover from disruptions.

A low hierarchy allows increased interpersonal contact and accessibility to other network actors, facilitating the flexible exchange of knowledge and best practices within the network (Youndt and Snell, 2004; Inkpen and Tsang, 2005). In our study, low hierarchies enabled case firms to be proactive and avoid disruptions. For instance, Firm A’s information technology (IT) department developed a business continuity plan for IT operations. The successful implementation of this plan, combined with Firm A’s increasing interest in mitigating supply chain risks, motivated the firm to augment the business continuity plan by incorporating other aspects and functions of the business. The CIO (Firm A) noted that the IT department initiated the business continuity process, which diffused to other departments effectively and efficiently. He asserted that best-practice diffusion across functions is easier at medium-sized than large firms: “We put [the business continuity plan] in place, it worked well. The more it worked, the more people wanted it, and now it’s just become the standard. I think that’s true with almost everything. As things work in other elements of the company, which is again very different from a larger company, when we see things work well in sales, we may implement them in IT […] A smaller company is much more agile. [In] large companies, it’s hard to get institutionalized change.”

Medium-sized firms are better positioned to induce change because of lower hierarchies. Additionally, a low hierarchy helps firms react to disruptions. It facilitates quicker reactions to changing market and environmental conditions and swifter decision-making post disruption (Rothwell, 1989). For instance, the Director of Purchasing (Firm D) mentioned: “Compared to other large-sized companies that I deal with, it seems they have many more layers of management and people at their organization […] Here, if a situation pops up, there are enough people that can get together on the phone and come up with a game plan, and boom, it’s in motion.”

Furthermore, a low hierarchy allows firms to adapt to external changes by enabling employees to make decisions more quickly or receive approval to implement necessary changes without delays from multiple management layers. The social-capital literature suggests that firms decentralize decision-making authority to network members because members can assess how to apply their knowledge to a specific situation, and do so promptly (Inkpen and Tsang, 2005), which is beneficial for resilience (Sheffi and Rice, 2005). For example, the Sourcing and Operations Manager (Firm C) mentioned that the firm did not remain trapped in its old ways of doing business but adapted to market changes swiftly because the short command chain enabled swift decision making: “The fact that we are a small company, it makes it a lot easier to change […] Once you decide to do something, you don’t have to go through a lot of red tape that you might have to go through at a large organization with different layers […]”

Based on our case findings and insights from the literature on structural capital and supply chain resilience, we propose that structural capital is a resilience-enhancing resource in medium-sized firms:

P1. Structural-capital facets, such as small network size, geographical proximity among decision makers and low hierarchy, facilitate face-to-face interactions, access to other network members and resources, information- and knowledge-sharing, and swift coordination and decision making before and after supply chain disruptions. These facets, therefore, enhance the resilience of medium-sized firms by enabling them to avoid and recover from disruptions.
4.2 Relational capital

4.2.1 Relationship closeness, commitment and respect. Interpersonal relationships characterized by closeness, commitment and respect are primary facets of relational capital (Nahapiet and Ghoshal, 1998; Kale et al., 2000). These are beneficial for firms, as they facilitate the acquisition of tacit knowledge, access to resources, and willingness to exchange information and collaborate (Kale et al., 2000).

We discuss the three relational-capital facets together because they regard the quality of interpersonal relationships observed in our case firms, and our key informants discussed these facets together when describing interpersonal relationships and resilience. For example, the CPO (Firm A) described the tornado that disrupted the supply of utilities and subsequently the factory’s production, and he attributed the firm’s success in managing and recovering from the disruption to the following: “The good relations we have [help us be resilient], that we have a lot of dedicated people […] that creates resilience because when things happen, [the people] are more willing to be loyal.” Therefore, although these represent different facets, they seem to influence a firm’s ability to avoid or recover from disruptions in the same way.

Our case findings reveal that close and respectful relationships increase the willingness of individuals to work cross-functionally to mitigate risks or recover from disruptions. For example, the VP of Operations (Firm C) mentioned: “We have a very close relationship with sales and marketing. We have some very close relationships with our group companies.” He continued saying: “You respect them […] that’s driven by the company. I think it helps quite a bit here.”

Moreover, employee commitment is another facet that improves resilience in our case firms. Employee commitment reflects “an individual’s identification with and involvement in an organization” (Shepherd et al., 2011, p. 1,233) and willingness to “give energy and loyalty to the organization” (Kanter, 1968, p. 499). Our analyses show that employees are willing to provide to their colleagues or the firm. They also have a sense of obligation to participate in the firm’s activities and responsibility to help their colleagues (Coleman, 1988; Wasko and Faraj, 2005). For example, the Senior VP of Finance (Firm B) described a disruption at the firm’s headquarters triggered by a storm. The storm damaged several electricity lines used to power the firm’s headquarters, including the server room that housed the data center. Only one power line remained that was used to keep the server running. Nonetheless, the power was insufficient to maintain the room’s air-conditioning system, which was also important to keep the server running. Hence, the IT department’s employees brought a portable air conditioner to cool the server room, and they took turns monitoring it: “I think our capabilities are really good and it’s just because of the people, because at the end of the day if something hits the fan, you are going to have all hands on deck […] I call the culture here the superman culture. If something happens, the employees get charged. During the power outage, I’ve never seen the IT guys happier. It was as if they were babysitting something. The room was getting too hot, so they brought this little air-conditioner, and they had to drain the water out of it, so somebody had to be here every hour because the bucket was getting full. The IT guys loved it. That is the culture. I think we could get through a lot of adversity just because of the culture of the people here.”

Based on our case findings and insights from the literature on relational capital and supply chain resilience, we propose that relational capital is a resilience-enhancing resource in medium-sized firms:

**P2.** Relational-capital facets, such as relationship closeness, commitment and respect, facilitate tacit knowledge sharing, increase the willingness of employees to work together, and strengthen the sense of obligation and responsibility of employees to their colleagues and the firm before and after supply chain disruptions. These facets, therefore, enhance the resilience of medium-sized firms by enabling them to avoid and recover from disruptions.
4.3 Cognitive capital

4.3.1 Employee tenure. Employee tenure refers to the number of years an employee works at a firm (Fischer and Pollock, 2004). Long tenure is a source of cognitive capital, as it enables the development of shared knowledge and understanding about how things work at a firm (Bantel and Jackson, 1989; Fischer and Pollock, 2004). Our findings suggest that long employee tenure enhances the resilience of the case firms by enabling them to avoid and recover from supply chain disruptions.

Longer employee tenure suggests that employees have accumulated knowledge, experience and expertise on their tasks, allowing them to learn from and avoid past mistakes that could trigger disruptions (Jiang et al., 2009). Hence, long employee tenure enables the proactive component of resilience by improving a firm’s ability to avoid disruptions. For example, the Sourcing and Operations Manager (Firm C) emphasized the importance of mixed teams comprising long-tenured and newer employees. Having worked for a long time, long-tenured employees have made mistakes and learned from them, ensuring they do not repeat those mistakes in the future. He also emphasized that long-tenured employees used their experience to warn others about potential disruptions: “The experience of the employees around here is invaluable. You don’t want to repeat mistakes of the past, and a lot of the experience helps you in doing that, at least to warn you.”

Similarly, the Director of Purchasing (Firm D) mentioned that his prior experience with disruptions allowed him to apply his knowledge to new situations and proactively avoid future disruptions. He described an event that caused a critical material – “the bloodline of the business” – to become unavailable. Based on his prior experience with that material, he proactively communicated with other functional managers to develop a strategy to mitigate that risk in the future: “In my seat, we don’t see the production schedule. We get the forecasts from the sales guys. We’re trying to pull those numbers together. We don’t have a crystal ball. Through experience, I think, and the number of transactions you make when something does go awry and you fix it, you remember that, and you seem to put something in place. Maybe you notify a scheduler and say: ‘hey, you guys had customer XYZ that went through all the [product name]. You didn’t notify us. In the future, if you get an abnormal order for something, let purchasing know so that they can react accordingly.’”

At the same time, long employee tenure improves a firm’s ability to react to disruptions. Long tenure implies that employees have worked together for a long time, enabling them to develop shared knowledge, work patterns and routines, and perform their daily tasks more effectively (Bantel and Jackson, 1989; Fischer and Pollock, 2004). These shared resources help firms become more effective at handling discontinuities (Fischer and Pollock, 2004), as exemplified by the statements of the Director of Purchasing (Firm D): “The experience of the workers we have here […] I’ve been in my job for 20 years. Our quality manager has been here for 35 years. [The CEO] has been here for 35 years. Plant managers have been here for over 25 years. Schedulers have been here for 30 or so years.” He further emphasized that long tenure is invaluable, as it generates accumulated experience that may be applied when responding to disruptions: “I think we react better to some curveballs than some other companies that are more transient and have people that shift from place to place, job to job, or going to other companies.”

This latter quote illustrates that employee tenure relates to employee turnover. High turnover poses significant risks for a firm: it creates frictions and instability of skills within the firm (Jiang et al., 2009); lowers product quality, productivity and customer service (Jiang et al., 2009); hinders a firm’s ability to complete critical processes and achieve its objectives (Chapman, 2006); and disrupts interpersonal relationships within and between firms (Tangpong et al., 2010; Kahn et al., 2013). Hence, long employee tenure mitigates these risks.
Long employee tenure also improves the reactive component of resilience through the sharing of past knowledge that can be applied to new situations. As knowledge is rooted in experience and expertise, those employees with more experience possess greater abilities, skills and expertise, and are more likely to contribute knowledge when disruptions arise (Wasko and Faraj, 2005). Additionally, employees working together for a long time share that knowledge among them and with new employees (Wasko and Faraj, 2005). For example, the Director of Purchasing (Firm D) used his knowledge and experience with prior disruptions to react to new disruptions: “I’ve been doing this 25 years and have a pretty good feel for our supply chain. If a situation does arise, I think we’re able to react, minimize any major damages […] There are some other products that I think we can adapt on the fly and react.”

Based on our case findings and insights from the literature on cognitive capital and supply chain resilience, we suggest that cognitive capital is a resilience-enhancing resource in medium-sized firms:

**P3.** Cognitive-capital facets, such as long employee tenure, enable learning, facilitate the avoidance of past mistakes, and enhance the exchange of knowledge and expertise that can be applied before and after supply chain disruptions. These facets, therefore, enhance the resilience of medium-sized firms by enabling them to avoid and recover from disruptions.

Figure 2 illustrates our proposed conceptual model that relates internal social capital to firm resilience to supply chain disruptions. Internal social capital is conceptualized as a complex construct comprising structural, relational and cognitive capital.

### 5. Conclusion

Supply chain disruptions are frequent and detrimental for firm and supply chain performance. Therefore, firms of all sizes are concerned with avoiding or recovering quickly from disruptions. SCM researchers have responded to this emerging concern and developed frameworks and tools that advance theory and practice in the area of supply chain resilience. Prior research, however, primarily examines large firms that have the resources, scale, and influence to develop several resilience-enhancing capabilities, such as redundancy, flexibility or collaboration. The prior focus on large firms and the theoretical and practical importance
of the middle-market sector have led us to ask what resources or capabilities medium-sized firms have that enhance their resilience to disruptions, given their limited resources, scale and influence. Findings from four case studies with US medium-sized manufacturing firms reveal that these firms excel in their ability to generate internal social capital through structural, relational and cognitive components. These components improve a firm’s ability to avoid and recover from disruptions and thus be resilient. Our findings contribute to theory and practice by expanding resilience thinking into including internal social capital, a resource rooted in interpersonal relationships. Hence, our findings suggest that examining smaller firms can shed light on nuances to the concepts underlying resilience, which can advance theory and practice.

5.1 Research contributions
This is the first study in the SCM literature to study the resilience of medium-sized firms, an under-researched context. These firms are important for several global economies and supply chains. SCM research, however, has conspicuously overlooked these firms and their uniqueness as the middle child in supply chains. Our findings suggest these firms are resilient but more likely to utilize resources embedded not in their supply chain operations but their human resources. One such resource, per our findings, is internal social capital. Moreover, this is the first paper in the SCM literature to propose internal social capital as a resilience-enhancing resource. While organizational and SCM researchers have examined external social capital and its effects on firm performance and interfirm relationships, they have overlooked internal social capital (Adler and Kwon, 2002). To our knowledge, our study is the first to offer empirical evidence to show that internal social capital enhances resilience by helping firms avoid and recover from supply chain disruptions. Therefore, our paper supports research calls to extend resilience inquiries beyond common supply chain strategies (Scholten et al., 2017) and prior research arguing for the importance of identifying organizational factors that improve supply chain resilience (Gunasekaran et al., 2011; Fiksel et al., 2015). Our paper also complements recent research, which demonstrates that interpersonal relationships across firms improve firm resilience (Durach and Machuca, 2018).

Finally, our paper conceptualizes internal social capital as a complex resource manifesting through structural, relational, and cognitive components. By doing so, the paper proposes several facets generating internal social capital. These facets are rooted in the structure (e.g. small network size, geographical proximity among decision makers and low hierarchy), quality (e.g. close relationships, commitment and respect) and length (e.g. long employee tenure) of employee relationships within a given firm. Hence, our findings contribute to the broader social-capital literature by identifying under-researched facets of social capital, such as network size, network hierarchy and tenure.

5.2 Managerial contributions
Our paper has implications for medium-sized and large firms. We encourage medium-sized firms to engage in practices to develop or enhance internal social capital, as such practices do not necessarily involve large tangible investments (La Due Lake and Huckfeldt, 1998). Medium-sized firms should retain small management teams, whose members are geographically close to each other, and prevent bureaucracy from creeping into firm operations and decision making. These aspects help firms sense impending disruptions, gather information and knowledge, coordinate decision makers, mobilize resources and swiftly execute disruption-recovery plans. Nonetheless, as medium-sized firms continue to grow, they should be cognizant of how these structural-capital aspects change (e.g. larger teams, longer physical distance among decision makers and higher hierarchies).
Furthermore, medium-sized firms should take actions to improve relational capital by increasing face-to-face interactions among employees. Such interactions enable the development of respect and commitment among colleagues and toward the firm. These aspects enhance firm resilience, as they facilitate information- and knowledge-sharing and increase the willingness of employees to assist their firms during and after disruptions.

Additionally, medium-sized firms should take measures to retain a stable and skillful workforce in the long term, as that helps avoid past mistakes, apply past knowledge to new situations and reduce employee turnover. Insights from organizational behavior suggest that high-performance human-resource practices, such as cross-functional work assignments, teamwork, socialization, use of employee suggestions, empowerment and open communication, are effective mechanisms to retain employees and enhance resilience (Lengnick-Hall et al., 2011).

Finally, we encourage large firms, which seek to develop resilience through internal social capital, to emulate the simpler and nimbler internal structures of their medium-sized counterparts. Large firms could establish smaller teams, decentralize decision-making authority during disruptions, and empower those employees possessing the knowledge and expertise to act irrespective of their position in the organizational hierarchy. In smaller teams, close interpersonal relationships are also likely to develop. Finally, large firms could also invest in the human-resource practices mentioned above to improve employee retention in the long term.

5.3 Limitations and future research
Our study involves some limitations. We have not conducted a formal comparison of resources or capabilities across firms of varying sizes but base our comparisons on learnings from the small and medium enterprise and SCM literature streams. Future research could conduct case studies to formally compare the resilience-enhancing resources or capabilities of firms of varying sizes. Findings from comparative studies could be insightful for assessing the resilience of supply chain networks that likely comprise firms of varying sizes. Moreover, we focus on a specific middle-market sector. While these firms are an ideal context to examine resilience, it is plausible that smaller medium-sized firms exhibit other resilience-enhancing resources or capabilities. Future research could study the entire spectrum of the middle-market sector.

Note
1. Medium-sized firms are defined on a country-by-country basis (GE Capital, 2014). The definition offered here regards US medium-sized firms, the focus of our study. In the four largest European economies, medium-sized firms are defined as firms with annual revenue between €20m and €1bn (Germany), 15m and 800m British Pounds (UK), €10m and €500m (France), and €5m and €250m (Italy) (GE Capital, 2014).

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Supply chain resilience: the whole is not the sum of the parts

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Abstract
Purpose – The purpose of this paper is to investigate how resilience at different nodes in the supply chain influences overall supply chain resilience (SCRES) during an extreme weather event.
Design/methodology/approach – Based on 41 in-depth interviews, this qualitative study examines two Brazilian agri-food supply chains (AFSC). The interviews explored the impacts, preparedness, response and adaptation strategies adopted by farmers, processors and manufacturers during Brazil’s extreme drought of 2014–2015.
Findings – SCRES does not depend on all organizations in the supply chain but rather on the company able to reconfigure the resources to control for the disruption. In a supply chain with low interdependence among players, individual firm resilience elements might be preferable to interorganizational ones.
Research limitations/implications – This study is based on the context of AFSCs with low interdependence among players and during the experience of a climatic event. The results might not be generalizable to other sectors and phenomena.
Practical implications – Firms must evaluate their positions in supply chains and their interfirm relationships to determine which resilience strategy to invest in and rely on. Moreover, to leverage resilience at the supply chain level, firms must intensify information sharing and improve proactive resilience strategies upstream as well as downstream in the supply chain.
Originality/value – This study presents a broader perspective of resilience by comparing resilience elements at both the node and supply chain levels and by discussing their interactions and trade-offs.

Keywords Resilience, Case study, Agri-food supply chain

1. Introduction

The increasing frequency and impact of unexpected adverse events have led researchers and practitioners to shift from a traditional risk management approach to the resilience approach (Jüttner and Maklan, 2011; Pettit et al., 2013). Resilience enables systems to cope with the unexpected (van der Vegt et al., 2015) and to ensure continuity of operations and delivery to final customers (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009; Stone and Rahimifard, 2018). Although resilience seems to engage all organizations in a system, rarely has it been investigated how each part contributes to the overall process, such as in the context of supply chains.

Since organizations are interconnected, their interdependencies can magnify the consequences of local events and cause disruptions across the whole supply chain (Jüttner et al., 2003; van der Vegt et al., 2015; Stone and Rahimifard, 2018). Building resilience is strategic and helps organizations anticipate disruptions and adapt to new post-event states (Ponomarov and Holcomb, 2009; Ali et al., 2017). However, resilience strategies implemented at individual nodes can be detrimental to upstream or downstream
stages and may not contribute to the creation of a stronger supply chain (Tukamuhabwa et al., 2015; Stone and Rahimifard, 2018). Despite that, the literature on supply chain resilience (SCRES) has focused on the organizational level (Jüttner, 2005), particularly on focal companies, which are usually in a position to structurally influence the supply chain (Christopher and Peck, 2004; Wieland and Wallenburg, 2013; Brandon-Jones et al., 2014; Tukamuhabwa et al., 2017). Thus, while investigating the effects from the perspective of focal firms, the study of SCRES might overlook consequences for the overall supply chain.

Another gap relates to the development of resilience elements at the different phases of preparedness, response, recovery and adaptation (Hohenstein et al., 2015; Tukamuhabwa et al., 2015; Kamalahmadi and Parast, 2016; Ali et al., 2017). Resilience elements are management practices that support SCRES capabilities, such as flexibility, redundancy, collaboration, visibility and velocity (Ponis and Koronis, 2012; Hohenstein et al., 2015; Tukamuhabwa et al., 2015). Each phase requires the development of different elements that can be implemented by firms individually or at the supply chain level. To date, there is no empirical evidence that all resilience elements are relevant in all different supply chains (Stone and Rahimifard, 2018). Additionally, little is known about how interfirm relationships influence the development of resilience elements at each phase of a disruption.

This study addresses these gaps by investigating SCRES from the perspective of different supply chain nodes, instead of addressing the singular point of view of a focal firm. Hence, this study poses the following research question:

*RQ1.* How does resilience, built at different nodes of a supply chain, influence SCRES?

For that purpose, we conducted a qualitative, inductive study regarding the process of resilience building in the sugarcane and orange supply chains during an extreme drought in the Southeast region of Brazil. Climatic events are associated with high levels of uncertainty. The agri-food supply chains (AFSC) is particularly sensitive to these uncertainties, which requires building resilience. Thus, based on 41 in-depth interviews with farmers, processors, manufacturers and relevant stakeholders, our research analyzed the resilience at each node of the supply chain as well as the SCRES and compared the resilience elements adopted by each node at each resilience phase.

The contribution of our study is twofold. First, this study brings a broader system-wide perspective of SCRES that addresses the implications for all firms in upstream and downstream nodes, rather than a focal firm perspective. By investigating three different nodes in two AFSC, the research reveals the interaction between firm and SCRES and the contribution of each node to the overall process, providing a more holistic understanding of SCRES. Our findings highlight the role of different nodes for SCRES, even when upstream organizations are not resilient. SCRES does not necessarily mean that every organization in the supply chain is resilient; rather, it is more dependent on one company’s ability to reconfigure resources and players to control for the disruption.

Second, driven by the AFSC context, this study empirically explores the influence of interfirm relationships on the development of certain resilience elements at each resilience phase. SCRES literature has focused primarily on the most cited resilience elements, without adapting it to different contexts (Stone and Rahimifard, 2018). By comparing resilience elements at both the node and supply chain level as well as at each phase of a disruption, our results provide evidence about the importance of considering supply chain context specificities when making investment decisions for building resilience.

This paper is organized as follows. The first section presents a literature review on SCRES. Next, data collection and data analysis are described in the Methods section. The Findings section describes the concept that emerged from the data, and in the Discussion section, propositions are formulated. Finally, in the Conclusions section, academic and managerial implications, limitations, and possibilities for future research are presented.
2. Literature review

2.1 Firm and supply chain resilience

Resilience is widely defined as the ability of organizations and supply chains to plan for, respond to, and recover from disruptions in a timely and cost-effective manner; it is the ability to take actions that should return them to an original or perhaps better state than before the disruption (Ponomarov and Holcomb, 2009; Wieland and Wallenburg, 2013; Tukamuhabwa et al., 2015). This definition covers the moments before, during and after the disruption (Sheffi and Rice, 2005; Ali et al., 2017) and encompasses different phases of resilience: preparedness, response, recovery and growth or adaptation (Hohenstein et al., 2015; Ali et al., 2017; Stone and Rahimifard, 2018).

The concept of resilience addresses different units of analysis: the firm and the supply chain (Kamalahmadi and Parast, 2016; Ali et al., 2017). Firm resilience refers to an organization’s capacity to anticipate, prepare for, quickly respond to, and then recover from a crisis by learning from the experience and adapting to the new scenario (Hohenstein et al., 2015; Ali et al., 2017; Stone and Rahimifard, 2018). Resilient firms are less vulnerable to disturbances and better able to manage internal resources, such as routines and systems, to cope with unexpected disturbances (Ponomarov and Holcomb, 2009; Ambulkar et al., 2015). Firms depend on individuals, processes and organizational culture to build resilience (Bhamra et al., 2011; Kamalahmadi and Parast, 2016).

SCRES, in turn, refers to how supply chain stakeholders contain and control a disturbance from spreading to other organizations within the system. In particular, SCRES focuses on maintaining the core function of supplying goods to end consumers by anticipating disruptions and developing strategies to decrease a disturbance’s impact, thus providing immediate response and recovery (Kamalahmadi and Parast, 2016; Ali et al., 2017). Despite the acknowledged interdependence between the firm and SCRES, the SCRES literature has not thoroughly investigated the interaction between these two levels.

Supply chains are dynamic systems that connect different organizations, which means SCRES is impacted by these interfirm relationships, the compatibility amongst firms, the number of players and the length of the supply chain (Tukamuhabwa et al., 2015; Kamalahmadi and Parast, 2016; Kaufmann et al., 2018). In this sense, the supply chain context may influence firm-level decision-making during the crisis, which affects the SCRES level (Burnard et al., 2018; Stone and Rahimifard, 2018).

For example, transactional and arm’s length relationships do not encourage information sharing or the development of cooperative and cohesive endeavors among partners, which are important features of SCRES (Liu et al., 2009; Kaufmann et al., 2018). On the other hand, interfirm efforts increase supply chain response capacity (Christopher and Peck, 2004; Revilla and Saenz, 2017). Consequently, it is important to investigate the development of resilience elements under different contexts of interfirm relationships.

2.2 Resilience elements

Current SCRES research has analyzed what management and operational elements a firm can adopt to build resilience capabilities (Hohenstein et al., 2015; Ali et al., 2017; Stone and Rahimifard, 2018). The most cited resilience elements in the literature are flexibility, redundancy, collaboration, velocity and visibility (Ponis and Koronis, 2012; Hohenstein et al., 2015; Tukamuhabwa et al., 2015). Flexibility refers to how easy it is for a supply chain to change based on its range of options (Stevenson and Spring, 2007; Ali et al., 2017). Flexibility can be achieved by using multiple suppliers’ strategies, flexible supply bases and flexible processes for operations, transportation and order fulfillment (Kamalahmadi and Parast, 2016; Ali et al., 2017). Redundancy involves maintaining an idle response capacity to access in case of disruptions. This is done primarily through investments in capital and capacity, such as safety stocks and backup suppliers or storage (Rice and Caniato, 2003;
Kamalahmadi and Parast, 2016). Collaboration refers to the level and degree of shared information, knowledge and decisions between two or more members of the supply chain (Christopher and Peck, 2004; Wieland and Wallenburg, 2013; Scholten and Schilder, 2015). Both vertical and horizontal forms of collaboration are based on trust and synergies (Cao and Zhang, 2011; Leat and Revoredo-Giha, 2013; Ali et al., 2017). Velocity encompasses the ability to react rapidly to changes (Christopher and Peck, 2004; Brandon-Jones et al., 2014), while visibility addresses the extent to which supply chain participants have access to or share information regarding their operations during the crisis (Barratt and Oke, 2007; Wieland and Wallenburg, 2013).

Each phase of a disruption requires different elements. Ali et al. (2017) have proposed a framework that organizes these elements and the supporting managerial practices into different resilience phases. During the preparedness phase, companies should anticipate the situation by evaluating and interpreting possible risks, while simultaneously building redundancy to develop robustness and a security plan. Firms should also increase visibility by monitoring structures, processes and information at all nodes in the supply chain. During disruptions, companies must use their flexibility, redundancy and velocity capacities, as well as use collaboration with other players to respond to an event. After the disruption, organizations should review and learn from the event and then prepare new contingency plans for future occurrences.

Resilience elements also differ in scope. Some elements are adopted to manage disruptions at the organizational level, like firm flexibility and redundancy. Others address collective efforts to prevent supply chain disruptions, such as collaboration and visibility (Stone and Rahimifard, 2018). According to Stone and Rahimifard (2018), it is important to optimize solutions at each resilience phase; however, solutions at each level need to consider the entire system.

Given the lack of empirical validation, there is poor consensus regarding how these elements interact to build SCRES. The individual firm’s response to any event depends on the context in which the organization is embedded, its own resource configurations, as well as the interactions among organizations and with the natural environment (Tukamuhabwa et al., 2015; Burnard et al., 2018; Stone and Rahimifard, 2018). Thus, SCRES research should go beyond simply identifying constructs and begin to explore their interactions. This means considering how they might complement, reinforce, or conflict with each other (Tukamuhabwa et al., 2015; Kamalahmadi and Parast, 2016; Stone and Rahimifard, 2018).

In summary, our research aims to fill two gaps identified in the literature:

1. Investigate resilience at the node and the supply chain level to explore the role of different organizations in the SCRES; and

2. Analyze the influence of interfirm relationships on the resilience elements adopted by each node at each resilience phase.

3. Methods

This study applies a multiple-case method to investigate how firms at each node of the AFSC built resilience during a major drought and its overall impact on SCRES. Given the specificity of the phenomenon investigated in the AFSC, the case study is the most suitable method (Eisenhardt, 1989; Barratt et al., 2011). Moreover, the inductive approach is appropriate for building and refining theory regarding specific research questions and settings such as this one (Eisenhardt, 1989).

The central phenomenon of this study, the extreme drought, took place during the summer of 2014–2015. One of the most impacted industries was agriculture, particularly the orange and sugarcane plantations located in the southeast region of Brazil. Given the extensive
impact on agricultural activities, this study investigates the effects of the extreme drought through all nodes of the AFSCs, starting upstream with the farmers.

A generic AFSC includes farmers, processors, manufacturers and distributors of food (Roth et al., 2008; Stone and Rahimifard, 2018). Unlike a traditional linear supply chain, it can include thousands of firms, especially upstream in the supply chain (Stone and Rahimifard, 2018). In contrast to most supply chain studies, AFSCs are not based on downstream focal firms, but rather on upstream firms, as each supply chain has its own characteristics depending on the product (Maloni and Brown, 2006; Roth et al., 2008).

The AFSC provides a unique context in which to study the interactions of different resilience elements since it involves organizations which are vulnerable to different, yet interconnected risks and must constantly adapt to a changing environment (Roth et al., 2008; Stone and Rahimifard, 2018). Each node in the supply chain introduces different vulnerabilities that could impact the overall SCRES, such as a product’s shelf life or specific climatic and environmental risks (Leat and Revoredo-Giha, 2013; Stone and Rahimifard, 2018). Therefore, we have adopted an embedded, multiple-case design in which the firms become part of a larger unit, the supply chain node, which is our unit of analysis (Yin, 1989). Figure 1 illustrates the two supply chains analyzed and their respective nodes.

### 3.1 Sugarcane and orange supply chains

Sugarcane’s economic and sociocultural relevance for Brazil goes back to the fourteenth century. Operations have evolved to produce not only quality sugar but also biofuels, bioenergy and bioplastics, among others. Today, there are approximately 370 sugarcane mills and more than 70,000 independent sugarcane farmers (UNICA, 2015). The development of research centers, industry associations and government agencies has helped to achieve product
flexibility in the processing phase. Typically, farmers sell sugarcane to mills (processors) which sell the sugar either via a cooperative for export or directly to manufacturers. Relationships between farmers and processors are based on formal contracts. Spot market purchases are not a typical alternative, and most processors are vertically integrated (producing up to 80 percent of their own supply).

In 2007, sugarcane farmers and processors in the state of São Paulo signed the Environmental Protocol and committed to mechanizing the harvesting process, in order to avoid the practice of burning sugarcane, and to reduce the use of water in processing (UNICA, 2015). Over the last decade, farmers and processors have adapted their procedures to the new regulation: in farming, new types of seedlings and new ways of planting sugarcane were developed; in processing, sugarcane mills implemented closed-circuit processes to reuse water by treating (regenerating) effluents to reuse either in the mills or on the plantations (Mosqueira-Salazar et al., 2013).

Brazil is the world’s number one producer of frozen concentrated orange juice, and most of it is produced in the state of São Paulo (Neves et al., 2013). Orange farmers sell products to processors (cooperatives) that either resell the products in natura or produce orange juice. In the orange supply chain, contracts between farmers and processors are based on quality and volume requirements, making it more difficult for smaller farmers to compete (Neves et al., 2013). Recently, the orange sector was consolidated into fewer, larger integrated processors.

3.2 Case study data collection
The selected cases studies consist of 28 organizations. A total of 24 firms are grouped into three nodes: farmers (5 firms), processors (15 firms, 10 of them vertically integrated) and manufacturers (4 firms). Additionally, we included sector associations (two organizations) and government entities (two organizations). To determine the theoretical sampling, we selected respondents from the first node (farmers) of the impacted region based on their ability to provide information regarding the event (Eisenhardt, 1989). The first respondents in this node were identified with help from industry associations. As the interviews progressed, they were asked to provide additional names based on their supply chain relationships so that the impacts could be followed along the supply chain.

The selected cases bring diversity in terms of firm size and structure (vertical integration), which are relevant aspects in the capacity to build resilience (Sullivan-Taylor and Branicki, 2011). Table I presents descriptions of the selected firms and their positions in the supply chain as well as the respondents’ profiles.

The interviews took place during two separate periods after the event – July to November 2015 and the same timeframe in 2016. The interviews followed a protocol, involving semi-structured questions (Appendix) regarding broad aspects of the event impacts, the measures undertaken to adapt operations, the involvement of supply chain partners, and the plans and preparations for future events. During the initial data collection, the results were analyzed, and the protocol was adjusted with additional questions to increase our understanding of the phases of SCRES (Ali et al., 2017). In the second round of interviews, the initial cases were revisited to complement and clarify the initial responses. A total of 41 semi-structured interviews were conducted.

Interviewees agreed to have the interviews recorded. The respondents were key informants responsible for operations at the firms and were involved in the supply chain relationships. In some cases, the interviews were conducted with more than one respondent, which allowed us to validate the information. Whenever possible, two researchers conducted the interviews to increase internal validity (Eisenhardt, 1989; Barratt et al., 2011). For triangulation purposes, we collected additional data from documents and web sources (e.g. websites, reports and organization newsletters). Finally, we interviewed industry
<table>
<thead>
<tr>
<th>Supply chain</th>
<th>SC node</th>
<th>Name</th>
<th>Product</th>
<th>Size</th>
<th>Respondents job function (No. of interviews)</th>
<th>Interviews length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane</td>
<td>Farmer</td>
<td>Cachaça_A</td>
<td>Cachaça</td>
<td>Micro</td>
<td>Owner (2)</td>
<td>43/32 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cachaça_C</td>
<td>Cachaça</td>
<td>Micro</td>
<td>Owner (2)</td>
<td>38/45 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cachaça_D</td>
<td>Cachaça</td>
<td>Micro</td>
<td>Owner (1)</td>
<td>25 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SugarFarm</td>
<td>Sugar/</td>
<td>Medium</td>
<td>Owner (1)</td>
<td>27 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ethanol/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bioenergy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Farmer/Processor</td>
<td>Bioenergy</td>
<td>Large</td>
<td>Owner (2)</td>
<td>Managers: Supply Chain (2) and Legal (2)</td>
<td>30/18 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cachaça_Big</td>
<td>Cachaça</td>
<td>Large</td>
<td>Managers: Agriculture (1), Industrial (1) and Sustainability (1)</td>
<td>58/82/20 min</td>
</tr>
<tr>
<td>SugarMill_B</td>
<td>Sugar/</td>
<td>Sugar/</td>
<td>Ethanol/</td>
<td>Large</td>
<td>Operations Director (1)</td>
<td>45 min</td>
</tr>
<tr>
<td></td>
<td>Ethanol/</td>
<td>Ethanol/</td>
<td>Bioenergy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bioenergy</td>
<td>Large</td>
<td>Owner (1)</td>
<td>Operations Director (1)</td>
<td>32 min</td>
<td></td>
</tr>
<tr>
<td>SugarMill_C</td>
<td>Sugar/</td>
<td>Sugar/</td>
<td>Ethanol/</td>
<td>Large</td>
<td>Agricultural Manager (2)</td>
<td>85/25 min</td>
</tr>
<tr>
<td></td>
<td>Ethanol/</td>
<td>Ethanol/</td>
<td>Bioenergy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bioenergy</td>
<td>Large</td>
<td>Manager (1)</td>
<td>Operations Manager (1)</td>
<td>35 min</td>
<td></td>
</tr>
<tr>
<td>SugarMill_D</td>
<td>Sugar/</td>
<td>Sugar/</td>
<td>Ethanol/</td>
<td>Large</td>
<td>Production Manager (1)</td>
<td>37 min</td>
</tr>
<tr>
<td></td>
<td>Ethanol/</td>
<td>Ethanol/</td>
<td>Bioenergy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bioenergy</td>
<td>Large</td>
<td>Manager (1)</td>
<td>Operations Manager (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orange</td>
<td>Farmer/Processor</td>
<td>OrangeFarm</td>
<td>Oranges</td>
<td>Small</td>
<td>Owner (2)</td>
<td>20/21 min</td>
</tr>
<tr>
<td>OrangeProc_A</td>
<td>Orange/</td>
<td>Orange/</td>
<td>Oranges</td>
<td>Large</td>
<td>Operations Manager (3) and Operations Director (3)</td>
<td>25/32/40 min</td>
</tr>
<tr>
<td>Processor</td>
<td></td>
<td>OrangeProc_B</td>
<td>Oranges</td>
<td>Medium</td>
<td>Owner (1)</td>
<td>25 min</td>
</tr>
<tr>
<td>OrangeProc_C</td>
<td>Orange/</td>
<td>Orange/</td>
<td>Oranges</td>
<td>Medium</td>
<td>Operations Manager (1)</td>
<td>21 min</td>
</tr>
<tr>
<td>ConCoop</td>
<td></td>
<td>Orange/</td>
<td>Oranges</td>
<td>Small</td>
<td>Agricultural Manager (1)</td>
<td>32 min</td>
</tr>
<tr>
<td>LocalCoop</td>
<td></td>
<td>Oranges</td>
<td>Small</td>
<td>Large</td>
<td>Agricultural Manager (2)</td>
<td>44/49 min</td>
</tr>
<tr>
<td>LargeCoop</td>
<td></td>
<td>Oranges</td>
<td>Large</td>
<td>Small</td>
<td>Operations Director (1)</td>
<td>30 min</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Manufacturer</td>
<td>F&amp;B_Large</td>
<td>Food</td>
<td>Large</td>
<td>Sustainability Manager (1)</td>
<td>43 min</td>
</tr>
<tr>
<td>and Orange</td>
<td></td>
<td>F&amp;B_MNE</td>
<td>Beverage</td>
<td>Large</td>
<td>Purchasing Manager (1)</td>
<td>36 min</td>
</tr>
<tr>
<td>Sugarcane</td>
<td></td>
<td>F&amp;B_New</td>
<td>Beverage</td>
<td>Large</td>
<td>Quality Manager (1)</td>
<td>27 min</td>
</tr>
<tr>
<td>and Orange</td>
<td></td>
<td>F&amp;B_Small</td>
<td>Beverage</td>
<td>Small</td>
<td>Operations Manager (1)</td>
<td>23 min</td>
</tr>
<tr>
<td></td>
<td>Associations and government</td>
<td>SugarAssoc</td>
<td>n/a</td>
<td>n/a</td>
<td>Water Resources Consultant (1)</td>
<td>39 min</td>
</tr>
<tr>
<td>Sugar Assoc</td>
<td>Government</td>
<td>GovAssist</td>
<td>n/a</td>
<td>n/a</td>
<td>Agricultural Manager (1)</td>
<td>32 min</td>
</tr>
<tr>
<td>Orange Assoc</td>
<td></td>
<td>GovResearch</td>
<td>Research and assistance</td>
<td>n/a</td>
<td>Agricultural consultant</td>
<td>30 min</td>
</tr>
</tbody>
</table>
| Table I. Cases studied
associations and government entities for a better understanding of the AFSCs and to confirm our findings. This study applied several measures to ensure the rigor of data collection and analysis, as well as the credibility of our findings (Table II).

### 3.3 Data analysis

The process of data analysis was iterative throughout the data collection, and the results were constantly compared to the existing literature to determine the categories that should be expanded (Eisenhardt and Graebner, 2007). The data analysis followed the inductive method described by Gioia et al. (2013), and it evolved in three stages, resulting in the data structure presented in Figure 2.

In the first stage, an open coding process (in vivo coding) of the interviews was adopted by each researcher, using the informants’ own expressions and terms. During this process, attention was paid to how firms were impacted by the unexpected event, and how they responded to it using their own resources or those of the supply chain. The researchers’ coding schemes were shared and discussed by the research team to reach a consensus in terms of interpretation. The selection of codes was based on their relevance and predominance during the interviews. For example, “nothing to do” was a typical response to the event. After comparing the interviews, the codes were refined, and we began grouping and categorizing similar ones, resulting in the first-order categories (Gioia et al., 2013). The composition of the first-order categories is demonstrated in the Findings section, with representative quotes for each category.

In the second stage, we compared the first-order categories to the theoretical concepts from the literature to consolidate them into the second-order themes (Gioia et al., 2013). For example, we identified the practices of “multi-sourcing” and “conserving water” in response to the event as evidence of flexibility. In terms of preparation, the attitudes of “surprise”, “climate perception” and “lack of information” configured the state of low risk awareness. “Friction in the supply chain” and “contracts” at different nodes characterized the power asymmetry of the supply chains context.

<table>
<thead>
<tr>
<th>Trustworthiness criteria</th>
<th>Study method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credibility (extent to which the results appear to be acceptable representations of the data)</td>
<td>Used the research protocol and definition of questions identified in the literature Two researchers collected data, and four researchers analyzed the data 3-page summary of initial interpretations was provided to the respondents for feedback Theoretical sampling based on the food supply chain in two distinct industries: sugarcane and orange Sample presented firms from different nodes of the supply chain and different sizes</td>
</tr>
<tr>
<td>Transferability (extent to which the findings from one study in one context will apply to other contexts)</td>
<td>Respondents recounted experiences covering the phenomenon studied (water crisis), as well as historic data from other severe events More than one informant per firm Triangulation with associations and government, as well as with documents</td>
</tr>
<tr>
<td>Dependability (extent is unique to time and place; the stability or consistency of explanations)</td>
<td>All of the interviews and documents were analyzed by four co-researchers Summary of preliminary findings was analyzed by other team members who acted as controllers</td>
</tr>
<tr>
<td>Confirmability (extent to which interpretations are the results of the participants and the phenomenon, as opposed to researcher biases)</td>
<td></td>
</tr>
</tbody>
</table>

**Sources:** Based on Flint et al. (2002), Kaufmann and Denk (2011)
We also compared the codes across nodes during the different phases of the resilience process to investigate their impact at the supply chain level. This analysis provided a better understanding of the differences among nodes (farmers, processors and manufacturers) as well as the differences between supply chains (sugarcane and orange).

The second-order themes were aggregated into six broader theoretical dimensions that served as foundations for our discussion (Strauss and Corbin, 1998; Gioia et al., 2013) and are linked to each phase of resilience and to the supply chain context.

The aggregate dimensions were named: impact of the event, preparedness of the firms, responses of the firms, adaptation for the future, preparedness of the supply chain, response of the supply chain and supply chain context. The impact of the event dimension refers to the direct impact of the event for the different nodes and also reflects how the direct impact at one node affected all other stages in the chain. The preparedness of the firms dimension merges data on how respondents were aware of the risk of drought and their capacity to anticipate the disruption. Responses of the firms relate to the strategies chosen and decisions made by firms to manage and adjust their resources and minimize the negative impact. Adaptation for the future describes the degree to which different nodes learned from the crisis and whether they were willing to adapt for future occurrences. The preparedness of the supply chain dimension refers to collective efforts to exchange information and prepare the supply chain to maintain the flow of goods, while the response of the supply chain relates to how organizations jointly planned and coordinated processes to address the drought. Finally, the supply chain context refers to the structure of the supply chain in terms of the players, the industry and their relationships.

Relationships between the emergent concepts were then summarized in a model that illustrates the phenomenon and became the foundation for the propositions presented in the Discussion section.
4. Findings
This section begins by describing our findings on how the drought impacted each node and the supply chain. It then examines the node findings by providing an overview of how each node managed the unexpected event on three aggregate dimensions: preparedness of the firms, responses of the firms and adaptation for the future. In the supply chain findings section, results were compared to generate an understanding of the three aggregate dimensions – preparedness of the supply chain, response of the supply chain and supply chain context – and the two supply chains are then compared.

4.1 Impact of the event
Analysis of the drought’s impact focused on direct effects (node level) as well as indirect effects (supply chain level) (Table III). The perceived direct effects were decreased productivity and restricted water supply. Farmers suffered major losses as in terms of decreased productivity. Processors suffered from restricted water supplies but recognized that the major impacts were to farming activities. In contrast, manufacturers did not report relevant negative impacts on their operations; instead, the water shortage caused an increase in the sales of soft drinks:

And as a result, we had a large loss in productivity, around 40% [...] (SugarFarm).

What we noticed was that we had no impact [...] in fact, we were favoured because my sales increased [...] (F&B_MNE).

The drought’s indirect impacts were the result of spillover from other nodes. Decreased farming productivity resulted in supply shortages for sugarcane and orange supply chains and increased costs for orange processors. Orange processors also perceived deterioration in fruit quality.

Overall, the drought resulted in farmers suffering major losses. Processors were less affected, and manufacturers were not impacted by the drought. In both the sugarcane and orange supply chains, the upstream impacts did not cause disruptions for end customers, suggesting that the downstream nodes were resilient. The next sections aim to clarify this finding by providing a detailed analysis of each node’s resilient phases.

4.2 Node findings
4.2.1 The preparedness of firms. The findings documented three main first-order categories of low awareness. We have categorized the reactions and attitudes of organizations toward the unexpected drought as follows: surprise, climate perception and lack of information (Table IV). In general, the respondents were not monitoring climatic changes beyond the very short term. They had no knowledge of eminent climate risks and vulnerabilities, which resulted in low awareness and did not help them to anticipate the event.

First, despite the climate sensitive aspects of AFSC, farmers were surprised by the extreme weather event and, therefore, were not prepared for it. Weather is regarded as an “act of God,” and they did not realize how serious the situation was until they were fully impacted. Processors were also surprised by the event. While processors recognized climate as a well-known risk in farming, it was the first time the water restriction impacted the production capacity of the mills in the sugarcane supply chain:

Not in our worst of nightmares could [we] have imagined that the drought would truly be of this size and this proportion. (OrangeProc_A)

The novelty was the impact on processors and not the impact on farming, which is common, though perhaps not at this scale; but we always have droughts and rainy periods. However, processing plants have never suffered it [the impact]. (SugarAssoc)
Second, organizations perceived and understood climate based on historical events, which resulted in implicitly denying upcoming climate changes. Although respondents recognized climate variations had increased in frequency and amplitude, those events were regarded as “an exception.” The respondents had not reconciled historical perceptions of climate with recent events; therefore, most were confident that there was no need to change traditional procedures, such as choosing not to irrigate:

[…] there was a paradigm that, in the south of São Paulo, it was unnecessary to irrigate oranges […] (OrangeProc_A)

[…] in our region the rainfall on average is very good […] (SugarMill_I)

---

Table III. Impact of the event

<table>
<thead>
<tr>
<th>Second-order theme</th>
<th>First-order categories</th>
<th>Position SC</th>
<th>Supply chain</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct impact</td>
<td>Productivity decrease</td>
<td>Farmer</td>
<td>Sugarcane</td>
<td>And as a result, we had a large loss in productivity – around 40% […] (SugarFarm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sugarcane</td>
<td>Was there a decline in productivity? A lot – around 30% or more (Cachaça_D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gov.</td>
<td>[…] some sugar plantations lost 30% of their production of sucrose and alcohol (GovAssist)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Sugarcane</td>
<td>So less sugarcane was grown, and there was less productivity per hectare (SugarMill_B)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sugarcane</td>
<td>We ended 2014 […] with a shortfall (productivity) of 17%, compared with what we planned (Cachaça_Big)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orange</td>
<td>We are producing less than we produced previously […] (less than) our potential (OrangeProc_A)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orange</td>
<td>Yes, there were losses. There was a producer that lost as much as 40% with the drought (ConCoop)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orange</td>
<td>It impacted our business here by more or less R$ 150,000, some 5% [of revenues] (LocalCoop)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orange</td>
<td>In the crop it was productivity [impact] […] around 30% (OrangeProc_C)</td>
<td></td>
</tr>
<tr>
<td>Restricted water supply</td>
<td></td>
<td>Manufacturer</td>
<td>Sugarcane/Orange</td>
<td>We didn’t actually stop the mill, but we rationed [water] a lot. Our supply was very scarce (SugarMill_V)</td>
</tr>
<tr>
<td>No significant impact</td>
<td></td>
<td>Manufacturer</td>
<td>Sugarcane/Orange</td>
<td>We started to use […] to treat water and reuse for washing containers (CachaçaBig)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manufacturer</td>
<td>Sugarcane/Orange</td>
<td>We had very little impact […] from this water crisis (Bioenergy)</td>
</tr>
<tr>
<td>Indirect impact</td>
<td>Lower quality</td>
<td>Processor</td>
<td>Orange</td>
<td>What happened was a reduction in fruit size (LargeCoop)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Orange</td>
<td>When the fruit came with production, the quality was worse […] (OrangeProc_B)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Orange</td>
<td>Therefore, the processor also had productivity problems and price problems for the product (LargeCoop)</td>
</tr>
<tr>
<td>Increased product cost</td>
<td></td>
<td>Manufacturer</td>
<td>Sugarcane/Orange</td>
<td>[…] the price was absurd. The price of oranges increased by 70% […] (F&amp;B_Small)</td>
</tr>
</tbody>
</table>

Table III.
Impact of the event
<table>
<thead>
<tr>
<th>Second-order theme</th>
<th>First-order categories</th>
<th>Position SC</th>
<th>Supply chain</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparedness</td>
<td>Low awareness</td>
<td>Farmer</td>
<td>Orange</td>
<td>No. It was all very surprising (OrangeFarm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Sugarcane</td>
<td>It was very frightening […] we’d never experienced a period as critical as that one (SugarFarm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Orange</td>
<td>Therefore, we started to become desperate […] “and now what’s the plan?” (SugarMill_B)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Farmer</td>
<td>Sugarcane</td>
<td>[…] we were caught by surprise, and we were unable to prepare (OrangeProc_A)</td>
</tr>
<tr>
<td>Climate perception</td>
<td>Farmer</td>
<td>Gov.</td>
<td>Sugarcane</td>
<td>You don’t irrigate sugarcane (GovAssist)</td>
</tr>
<tr>
<td></td>
<td>Processor</td>
<td>Orange</td>
<td>Sugarcane</td>
<td>I think there’s a belief that this drought was an exception […] (Cachaça_C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Farmer</td>
<td>Sugarcane</td>
<td>[…] there was a paradigm that, south of São Paulo, it was unnecessary to irrigate oranges […] (OrangeProc_A)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Orange</td>
<td>We get very little information […] (OrangeProc_A)</td>
</tr>
<tr>
<td>Lack of information</td>
<td>Farmer</td>
<td>Orange</td>
<td>Sugarcane</td>
<td>We get weekly bulletins, and things don’t materialize […] (SugarMill_C)</td>
</tr>
<tr>
<td></td>
<td>Processor</td>
<td>Sugarcane</td>
<td>Orange</td>
<td>The producers’ access to information is a chronic problem we have in agriculture (LargeCoop)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sugarcane</td>
<td>This is a weakness we have because we truly need more information (SugarCoop)</td>
<td></td>
</tr>
<tr>
<td>Response</td>
<td>No response</td>
<td>Farmer</td>
<td>Sugarcane</td>
<td>There was nothing we could do (SugarFarm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orange</td>
<td>Because in fact we didn’t see many measures being taken (OrangeFarm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Sugarcane</td>
<td>Therefore, you abort [production], and it’s no use. You have to live with it (SugarMill_E)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orange</td>
<td>[…] there’s not much you can do. We just prayed to God to send rain (OrangeProc_C)</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>Conserve water</td>
<td>Processor</td>
<td>Orange</td>
<td>In fact, we have too much water. We reuse it in some processes, and in others, there’s not an opportunity to reuse it […] (Cachaça_Big)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sugarcane</td>
<td>In fact, we have too much water. We reuse it in some processes, and in others, there’s not an opportunity to reuse it […] (Cachaça_Big)</td>
<td></td>
</tr>
<tr>
<td>Redundancy</td>
<td>Multi-sourcing</td>
<td>Manufacturer</td>
<td>Sugar/Orange</td>
<td>As we have a lot of equipment with a closed circuit, we had no major problems (SugarMill_V)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Orange</td>
<td>I detailed internal projects to reduce waste (F&amp;B_Large)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sugarcane</td>
<td>Because we went after groves that had been irrigated (OrangeProc_B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orange</td>
<td>There are 11 mills in 5 different states, and so, it’s unlikely you’re going to have a catastrophe (SugarMill_B)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manufacturer</td>
<td>Sugar/Orange</td>
<td>They normally buy from a wide region (LargeCoop)</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Second-order theme</th>
<th>First-order categories</th>
<th>Position SC</th>
<th>Supply chain</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adaptation</strong></td>
<td>No adaptation</td>
<td>Farmer/</td>
<td>Sugarcane</td>
<td>[...] if tomorrow we get another very severe crisis, I think we're going to have problems (SugarMill_C)</td>
</tr>
<tr>
<td></td>
<td>prevention</td>
<td>Processor</td>
<td>Orange</td>
<td>At least from our side, we haven't done anything effective yet (LargeCoop)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gov.</td>
<td>Sugarcane</td>
<td>Regarding the sugarcane, we truly do depend on the rain (GovAssist)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Association</td>
<td>Sugarcane</td>
<td>[...] the irrigated area has not been increasing as it should (Oranges Assoc)</td>
</tr>
<tr>
<td><strong>Negative cost/benefit</strong></td>
<td>Farmer</td>
<td>Sugarcane</td>
<td>Sugarcane</td>
<td>What could be done is you irrigate the sugarcane, but it was not economically feasible (Cachaça_A)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>In our case, there's not much to be done [...] It's not economically feasible to irrigate sugarcane (Cachaça_D)</td>
</tr>
<tr>
<td><strong>Willingness to adapt</strong></td>
<td>New investments</td>
<td>Processor</td>
<td>Sugarcane</td>
<td>[...] Irrigation of sugarcane is very expensive (SugarFarm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orange</td>
<td></td>
<td>You're not going to irrigate; you're not going to invest R$ 10,000 or R$ 12,000 per hectare to wait for a weather event like this that might occur every 10 to 15 or 20 years (OrangeProc_A)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sugarcane</td>
<td></td>
<td>I think that [the problems are] the available technology and the cost, the investment (Cachaça_Big)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>We decided in 2014 that we weren't going to fail to make these investments [crop management] (SugarMill_B)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[...] we sought out these technical alternatives [water conservation] (SugarMill_Z)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sugarcane We gradually increased our closed-circuit system (SugarMill_V)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sugarcane Some decisions about varieties [in crops] were made because of their water resistance (SugarMill_I)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manufacturer</td>
<td>Sugar/ Orange</td>
<td>We have plans to dig a new well to have a backup (F&amp;B_New)</td>
</tr>
</tbody>
</table>
Finally, these climate perceptions were corroborated by a lack of information regarding climate change and extreme events. The main available weather sources provided, on average, a 30-day forecast and did not anticipate long-term climate variance. Even manufacturers acknowledged that there was a lack of awareness regarding the impacts of climate change:

Look, we get very little information [climate]. (OrangeFarm)

4.2.2 The responses of firms. The way organizations responded to the event was grouped into three different first-order categories: nothing to do, conserving water, and multi-sourcing. Basically, reactions corresponded either to a no-response strategy or the use of existent flexibility and redundancy to cope with the unexpected event (Table IV). Given the agricultural production cycle, farmers had no capacity to develop an immediate response to the drought and lamented their losses. Most claimed that there was nothing to be done regarding the drought:

The strategy was to pray a lot to see if it rains. (Cachaça_D)

Processors and manufacturers, in contrast, were able to react and respond to the drought due to existing flexible processes. To manage the water shortage in the sugarcane mills and the orange processing plants, processors accelerated the implementation of closed-circuit and water conservation processes. Originally designed to comply with the Environmental Protocol, the closed-circuit projects provided flexibility to processors in the reuse of water. Manufacturers also analyzed how to reduce water consumption during their manufacturing process and how to avoid wastewater in their facilities.

In addition to this flexibility, processors and manufacturers also responded to the event by using multi-sourcing strategies to prevent indirect impacts. Integrated processors accessed proprietary farms, which were geographically diversified. Non-integrated processors and manufacturers searched for alternative providers in other regions to ensure supply, given that the drought only affected the southeast region. In this sense, both groups managed to mitigate the impact of the event with supply diversification and low dependence on suppliers.

4.2.3 The adaptation for the future. During the interviews, firms were still in the process of making sense of the past event, and recovery projects were not fully implemented. Nevertheless, evidence of their intended adaptive strategies could be organized as follows: no prevention, negative cost/benefit of projects and plans of new investments (Table IV). Some firms demonstrated no ability to adapt – mainly farmers and processors. A few processors and manufacturers were willing to adapt, however, changing was not a priority for most firms.

Regarding farming activities, respondents continued to view extreme events as rare and not justifying an investment in adaptation measures. Some respondents recognized the need to be prepared for future events, but they assessed the trade-off between costs and benefits as negative and therefore preferred not to act. In both AFSCs, irrigation technologies were considered too expensive and perceived as not economically viable, considering the uncertainty of climatic events:

At least from our side, we have not done anything effective yet. (LargeCoop)

Therefore, even though it was a disaster, we thought that it was not worth investing because of the cost [of the investment] and the return. (SugarMill_I)

Nevertheless, we could identify processors and manufacturers willing to invest in new processes and strategies to mitigate the future occurrence of extreme weather events, such as drilling new wells, crop management and water conservation projects. In the case of
manufacturers, aggravation of the crisis in major cities (including São Paulo) generated a
sense of responsibility and public accountability in terms of water management. Concerned
with their public image, manufacturers accelerated the development and the implementation
of eco-efficiency and water reuse projects; for them, the event was a catalyst for adaptation:

Some decisions about varieties [in crops] were made because of their water resistance. (SugarMill_I)

In summary, our data provided evidence that the nodes in the supply chain were affected in
distinct ways by the same event, resulting in a disturbance that had a limited effect on the
firms positioned downstream in the supply chain (Table V). The vulnerability of farmers to
weather events confined them to a higher risk position in the supply chain. Farmers were
less prepared for the drought. With rigid configurations of processes and resources, they
were not able to respond to the event. Despite this fact, farmers continued to neglect the
climate risk and were reluctant to undertake any future action. Processors also
demonstrated low risk awareness but were able to respond to the event with flexible
processes and multi-sourcing strategies. The event also served as a catalyst for some
projects. Their investments in technologies and processes, however, depended greatly on the
cost-benefit ratio, which, for most processors, was still perceived as negative. Finally,
manufacturers were less impacted by the event but developed prompt responses to manage
supply risks. They also demonstrated a better understanding of the implications of climate
change and were willing to invest in new adaptation projects.

4.3 Supply chain findings
4.3.1 The supply chain’s preparedness. Our interviews provided evidence that there was no
dialogue among nodes and players in both supply chains. In fact, there was a general
perception of lack of information sharing among partners about the crisis, especially from
farmers and processors’ perspective (Table VI). Farmers and processors did not appear to
have a clear picture of the downstream supply chain and instead were mainly focused on
their own businesses. At the same time, the interviews did not provide any evidence
regarding a formal governance mechanism to promote the exchange of information about
the event in the supply chain. Even though information sharing and connectivity

<table>
<thead>
<tr>
<th>Event impact on productivity</th>
<th>Direct impact on farming units and restricted water supply (processing)</th>
<th>Quality issues and price increases due to impact to farmers</th>
<th>Direct impact on the supply chain</th>
<th>No significant direct impact; some impact on the supply chain</th>
<th>No impact to final consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparedness</td>
<td>Low awareness</td>
<td>Low awareness</td>
<td>Low awareness</td>
<td>Low awareness</td>
<td>No visibility</td>
</tr>
<tr>
<td>Response</td>
<td>No response capability</td>
<td>Used flexibility and redundancy to avoid major impacts</td>
<td>Used flexibility and redundancy to avoid impacts</td>
<td>Few collaboration initiatives in the supply chain</td>
<td></td>
</tr>
<tr>
<td>Adaptation</td>
<td>Reluctance to undertake preventive measures</td>
<td>Reactive learning from the event. Some reluctance in undertaking preventive measures and some willingness to act</td>
<td>Willingness to adapt with new investments and environmental climate analysis</td>
<td>No evidence</td>
<td></td>
</tr>
<tr>
<td>Resilience</td>
<td>No</td>
<td>Some</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

Table V. Summary
<table>
<thead>
<tr>
<th>Second-order theme</th>
<th>First-order categories</th>
<th>Position SC</th>
<th>Supply chain</th>
<th>Quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparedness</td>
<td>No visibility</td>
<td>Farmer</td>
<td>Sugarcane</td>
<td>No, I haven’t noticed anything like that [dialog and collaboration] (Cachaça_C)</td>
</tr>
<tr>
<td></td>
<td>No collaboration</td>
<td>Processor</td>
<td>Sugarcane</td>
<td>No. It’s very difficult [dialog and collaboration] (SugarMill_E)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manufacturer</td>
<td>Sugar/Orange</td>
<td>There was no specific action [with suppliers] because of a water shortage (F&amp;B_New)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td>Association</td>
<td>There was no direct support […] except in terms of news/information [about the drought] (SugarAssoc)</td>
</tr>
<tr>
<td>Response</td>
<td>Collaboration</td>
<td>Processor</td>
<td>Orange</td>
<td>This irrigation department is specifically for helping the cooperative members to overcome this water shortage situation (LargeCoop)</td>
</tr>
<tr>
<td></td>
<td>Support</td>
<td>Processor</td>
<td>Orange</td>
<td>We’re training the cooperative members to carry out some projects using irrigation and changing crop management to prevent this (ConCoop)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manufacturer</td>
<td>Sugar/Orange</td>
<td>We took part in some meetings and assessments with partners and suppliers, [analyzing] what this might also mean in terms of losses (F&amp;B_Large)</td>
</tr>
<tr>
<td>Context</td>
<td>Lack of cohesion</td>
<td>Farmer</td>
<td>Sugarcane</td>
<td>Because the SugarAssoc is the industry union […] we’re midgets compared to them […] (Sugar Farm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Sugarcane</td>
<td>We’re a very fragmented industry (Cachaça_Big)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gov/Association</td>
<td>Gov.</td>
<td>Everyone pulls in their own direction, even the government bodies. No one works together (GovAssist)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gov/Association</td>
<td>Association</td>
<td>[…] producers already know how to manage their groves (Orange Assoc)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Orange</td>
<td>Of the 17,000 citrus growers that existed 3 years ago, there are only 7,000 left (Orange Proc_A)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td>Orange</td>
<td>Before, there were 15,000 citrus growers, and today, there are fewer than 2,000 (Orange Assoc)</td>
</tr>
<tr>
<td>Power asymmetry</td>
<td>Friction in SC</td>
<td>Farmer</td>
<td>Sugarcane</td>
<td>The first thing is that the industry has to be more united (Sugar Farm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Sugarcane</td>
<td>[…] we should get these big companies together and develop technologies (Sugar Mill_I)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Processor</td>
<td>Orange</td>
<td>This is very complicated in the industry. You’d have to make contracts like the big firms, but we’re small (Orange Proc_C)</td>
</tr>
<tr>
<td></td>
<td>Contracts</td>
<td>Manufacturer</td>
<td>Sugar/Orange</td>
<td>The small producers were affected, particularly those that had no contracts or short contracts (F&amp;B_MNE)</td>
</tr>
</tbody>
</table>

Table VI. Preparedness, response and context – supply chain level
throughout the supply chain are key to preparing the whole supply chain for any unexpected event, we found no evidence of visibility in the studied supply chains.

4.3.2 The supply chain’s response. The supply chain responses depend on the collective efforts of more than one node. Our findings revealed three different types of attitudes: no support, cooperative support and vertical collaboration (Table VI). Most firms reported there was no collaboration and that they were working in isolation with no joint action or support from others. The interviews suggest only a few collective initiatives among the nodes to manage the unexpected event, mainly restricted to orange cooperatives and occasional initiatives:

The mills have that salvage irrigation because they work with the vinasse [a sugarcane by-product] and we do not have access to that vinasse [...] They say “but the vinasse is at your disposal”, but then, we have to have the trucks, and we have to have everything, and all [collaboration] ends. (SugarFarm)

In the orange supply chain, vertical collaboration was mainly identifiable in the support of cooperatives for farmers. Cooperatives searched for partnerships with irrigation experts and acted as important coordinators of farmers’ activities by helping farmers in terms of information and training. Apart from those, coordinated initiatives in the two analyzed supply chains were scarce, and two manufacturers and two processors promoted discussion only with first-tier suppliers and partners to evaluate losses in the supply chain:

This irrigation department is specifically for helping cooperative members overcome this water shortage situation. (LargeCoop)

Thus, our findings revealed that there was no collaboration among nodes, except for a few cases downstream in the studied AFSCs and the vertical collaboration between farmers and cooperatives in the orange supply chain.

4.3.3 The supply chain context. In terms of sector structure and relationship interdependencies, four aspects of supply chain context emerged from our data analysis. Specifically, both the fragmented nature of sectors and the process of sector consolidation culminated in a lack of cohesion amongst the firms. Additionally, relationship friction and governance based on (formal) contracts demonstrated the power asymmetry in the two analyzed supply chains (Table VI).

Both AFSCs have a larger number of players upstream than downstream – with only a few manufacturing companies. Given the abundance of alternative players upstream, both supply chains were regarded as highly fragmented. This structural aspect did not favor the commitment of players to join forces; therefore, there was a lack of cohesion in the supply chains:

Everyone pulls in their own direction, even the government bodies. No one works together. (GovAssist)

The non-cohesive context in both supply chains is related to a secondary contextual aspect: the nature of the relationships. Relationship frictions demonstrated the conflict of interest among players in orange and sugarcane supply chains. Additionally, the asymmetry in the contractual relationships and the reliance on formal contracts configured the power asymmetric context. Companies of both supply chains tended to manage their businesses independently and have more formal governance mechanisms based on contracts:

If tomorrow for some reason […] you cannot produce, you will not be able to meet your contracts, and this would be very damaging. (SugarMill_C)

In summary, our data analysis provides no evidence of some of the most cited elements in the literature, such as velocity or adaptation, at the supply chain level. Similarly, the findings at the supply chain level do not provide much evidence of visibility and collaboration,
suggesting that resilience was primarily developed at the firm level. In terms of supply chain context, both supply chains can be regarded as highly fragmented and with few interactions among actors within and across nodes. In the next section, we discuss our findings vis-à-vis the literature based on the emergent model proposed in Figure 3 by comparing the resilience built at each node within the overall SCRES.

5. Discussion
In this section, we explain the relational dynamic among the aggregate dimensions that emerged from our findings to answer our research question:

RQ1. How does resilience, built at different nodes of a supply chain, influence SCRES?

Literature suggests that to cope with and recover from the impacts of unexpected events, organizations need to build different resilience elements at the individual and supply chain level, and at each phase of the disruption (Hohenstein et al., 2015; Ali et al., 2017; Stone and Rahimifard, 2018).

Figure 3 illustrates the elements found in our study at each resilience phase and the interaction with the contextual aspects of those supply chains. While lack of awareness, responsiveness and adaptation capability were traits identified at upstream nodes, SCRES was mainly supported by the flexibility and redundancy of processors and manufacturers, instead of visibility and collaboration in the supply chain. The occasional collaborative initiatives were related to adaptation plans; however, not all adaptation plans were based on collaboration. Therefore, our study evidences that resilience elements were primarily built at the node level, not at the supply chain level. In the investigated supply chains, firms sought isolated solutions rather than using common strategies to cope with the risk for the whole supply chain.

Our research suggests that the preference for individual strategies, rather than supply chain solutions, is related to a lack of cohesion and asymmetry in the supply chains. Thus, the interfirm relationship context is important to the development of resilience at firms and the supply chain levels, as explained herein.
5.1 Resilience at the node level and SCRES

We found no evidence of significant impact or disruption at the end of the supply chain. Considering that SCRES is the capacity of the supply chain to maintain operational continuity and satisfy the end consumer (Ponomarov and Holcomb, 2009; Kamalahmadi and Parast, 2016; Stone and Rahimifard, 2018), our findings reveal that both supply chains were resilient, despite the evidence of no resilience at farmers’ node.

However, the compared analysis demonstrates different levels of impact as well as different degrees of preparedness, response and adaptation among the three nodes (Table V). Farmers, the most vulnerable node to the climatic events, were the least resilient, with no evidence of elements to anticipate, respond, or even to learn from the event. As we moved downstream in the AFSC, we identified different resilience elements adopted by processors and manufacturers, such as flexibility and redundancy, that were developed in advance, and allowed them to respond and control the disturbance and fulfill the demands of end consumers. Our findings highlighted that their resilience strategies were not dependent on the development of resilience at previous stages in the supply chain. Instead, SCRES depended on the capacity of downstream organizations to manage unexpected events. Our study demonstrates that SCRES is not dependent on the resilience of each node, as suggested in the literature (Leat and Revoredo-Giha, 2013; Stone and Rahimifard, 2018) and that different levels of resilience in a supply chain may not jeopardize SCRES. Thus:

P1. SCRES is not dependent on the resilience of all firms in the SC.

This proposition also suggests that SCRES may not require resilience in the overall system but rather specifically from some key players. Most studies emphasize the perspective of a focal company in the analysis of supply chain and thus overlook the impacts, response and recovery at some nodes (Leat and Revoredo-Giha, 2013; Tukamuhabwa et al., 2015; Birkie et al., 2017). Our approach allows the observation of the role of different nodes in the continuity of the supply chain operations and reveals that SCRES can be achieved even when upstream organizations are not resilient. In this sense, it is important to understand that the concept of SCRES does not apply to all organizations in the supply chain but is primarily associated with the company that is able to reconfigure the resources and players to control the disruption. Therefore, the analysis of the nodes offered a different perspective of SCRES.

5.2 Resilience elements

SCRES depends on both firm and SCRES elements that should be developed prior to, during and after the disruption (Hohenstein et al., 2015; Ali et al., 2017; Stone and Rahimifard, 2018). Organizations may adopt different resilience strategies depending on the risk source (Tukamuhabwa et al., 2015) and the supply chain context and environment (Birkie et al., 2017; Stone and Rahimifard, 2018). Nevertheless, the empirical studies on SCRES still have to analyze the relationship among the resilience elements (Tukamuhabwa et al., 2015; Stone and Rahimifard, 2018). By investigating different nodes in the supply chain, our research brings new insights into how the supply chain context influences the adoption of different elements to cope with vulnerabilities.

The data analysis revealed a context of low connectivity and contractual relationships among firms that did not foster cohesion and joint efforts to manage the disruption (Lawler and Yoon, 1996; Fiksel, 2003). In the environment of relative independence and asymmetric relationships between buyer–suppliers, companies focus on their own interests rather than on common goals, and there is no great need for coordination of activities between partners. Consequently, firms make individual decisions in response to any changes in their environments (Pathak et al., 2007). Therefore, when facing unexpected events, stronger firms will hedge their risks through redundant capacity and independent...
resources (Caniels and Gelderman, 2007; Jüttner and Maklan, 2011). In this sense, the lack of cohesion in both supply chains investigated and the power asymmetry among the nodes seemed to drive the resilience strategies towards firm-level elements, such as flexibility and redundancy, rather than supply chain elements, such as collaboration. Our results corroborate with those of Stone and Rahimifard (2018) in that resilience elements are enabled by different variables at the node and the supply chain level. Therefore:

\[ P2. \text{In a supply chain context of low interdependence, resilience elements at the node level will be preferred to those at the supply chain level.} \]

This proposition highlights the importance for managers to understand their specific supply chain context in order to better allocate resources and invest in the most appropriate resilience elements to reduce vulnerabilities (Fiksel et al., 2015). Nevertheless, the choice of node level solutions might not result in the best overall performance for the supply chain. For example, although the multi-sourcing strategy was successful for processors and manufacturers, it did not provide support for the development of the farming stage. Consequently, farmers – with no information, no visibility and no support – were not willing to adapt to the new climatic scenario. The current process forces downstream nodes to search for individual solutions to assure the continuity of their operations and might have a negative effect on SCRES. Alternatively, if the whole supply chain is involved in building resilience elements for each phase, results in terms of time and cost might be optimized.

System solutions, rather than end-user focus, are crucial in networks such as AFSC (Stone and Rahimifard, 2018). Interfirm ties are important for adaptation and learning; therefore, a lack of collaboration in a supply chain does not promote the development of adaptation capabilities (Zollo et al., 2016) and represents a high risk to AFSC due to the cyclical and cumulative nature of the resilience building process (Stone and Rahimifard, 2018).

6. Conclusions
This research investigated how resilience, built at different nodes of a supply chain, influences overall SCRES, bringing a new perspective to the literature that normally focuses on the analysis of a focal company (Wieland and Wallenburg, 2013; Brandon-Jones et al., 2014; Tukamuhabwa et al., 2015). In this sense, this research contributes to knowledge about SCRES in two ways.

First, it provides a broader perspective of resilience in the supply chain by analyzing and comparing the impact, preparedness, response and adaptation at each supply chain node. The analysis of different perspectives (farmers, processors and manufacturers) demonstrates an independence of firms in the supply chain and the different relevance of firms when securing SCRES. Moreover, it suggests that SCRES can be primarily associated with a resilient organization downstream in the supply chain.

Second, this study compares node and SCRES elements in a supply chain context with low interdependence among firms. In this case, node resilience elements are preferred to those at the supply chain level. Therefore, this study also sheds light on the influence of the supply chain context (interfirm relationships) in the process of developing resilience strategy.

6.1 Managerial and social implications
This study highlights the interdependence of firms’ resilience and SCRES, and the importance of individual resilience elements in certain supply chain contexts. For managers, our findings suggest the need to evaluate vulnerabilities and alternative resilience elements at different supply chain nodes to assure SCRES.
For more vulnerable nodes, the findings suggest that exchange of information and collaboration in the supply chain have to be built prior to disruptive events. Specifically, in AFSC, there is a need to intensify the dissemination of climate information, particularly among farmers, to increase their risk awareness and willingness to adapt. As suggested in this study, associations, cooperatives and government organizations are relevant in fostering the knowledge and training in upstream AFSC. They may also promote knowledge exchange and collaboration in the supply chain. This aspect is key to increasing the overall SCRES.

The research indicates that, for firms located downstream in the supply chain, current choices of resilience strategy have been able to assure continuity of operations but fail to address future uncertainties. In scenarios with an increasing frequency of climate extremes, current solutions may not be sufficient. Particularly in AFSC, downstream companies could help upstream companies build resilience in order to prepare for climatic events, such as slow-onset droughts that are cumulative and difficult to perceive immediately. Developing SCRES elements rather than organizational ones might improve the SCRES.

6.2 Limitations and further research

Our study has some limitations. The first limitation refers to the case studies. Although our research contained firms from two different AFSC, the agribusiness has peculiarities in terms of climate dependence and market environment that are not present in all industries. Our study was performed in a single institutional context of an emerging economy, with implications for the dynamics of interfirm relationships. The second limitation relates to the case study method and the difficulty in establishing the external validity of the study findings (Eisenhardt, 1989). Triangulation with other documents and interviews with associations and influential stakeholders were intended to reduce this problem, but the findings of this study should be tested in different institutional and supply chain contexts to validate the findings. Further research should also explore the difference between slow-onset and sudden-onset events.

References


Further reading


Appendix – Interviews Protocol

1. Before this extreme drought, have you ever faced a similar event? How often do these severe droughts affect the company?

2. Considering your experience in agri-food supply chain and climate. Was this event different from others? In what way?

3. How did this extreme drought affect your company? Can you give us some examples?

4. How did you know that something new was going on?

5. From the moment you perceived this was an extreme event, what measures were adopted by the organization related to your processes? Were there changes adopted by the organization in terms of resources? Can you explain which measures were more effective?

6. During the drought, did you work with buyers/suppliers to better respond to it? Can you give us any example?

7. How did the actions taken by buyers/suppliers affect your reaction to the drought?

8. Can you give us any example of how do you monitor such climate events? How reliable is the information available today? Can you tell us about your source of information about weather conditions?

9. Can you tell us if you have plans for future events like this one? Do you have plans for new investments to avoid losses in future events?

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