Supply chains' sustainability trajectories and resilience: a learning perspective in turbulent environments

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Supply Chains' Sustainability Trajectories and Resilience: A Learning Perspective in Turbulent Environments

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Abstract

Purpose: While various supply chain (SC) sustainability investigations exist, their connection to supply chain resilience (SCRes) remains largely unexplored. To fill this gap, we answer the question: "*How do firms' sustainability actions affect their SCs' resilience and sustainability trajectories in turbulent environments?"* by exploring the context of the COVID-19 pandemic.
Design/methodology/approach: We conducted 10 case studies in five industries located in six European countries. A total of 19 semi-structured interviews and relevant secondary data were collected and analyzed in reference to SC sustainability learning and the literature on SCRes approaches (i.e., engineering, ecological, and social-ecological).
Findings: 31 SC actions referring to different sustainability dimensions were identified to map SCRes learning through a temporal, spatial, and functional scale analysis. While five cases are related to an engineering approach focused on "bouncing back" to pre-pandemic goals, three cases were focused on "bouncing forward" as part of an ecological approach. Moreover, we identified the existence of two social-ecological resilience cases which developed long-term actions, updating functional set-ups transcending the SC level. The results furthermore illustrate an influence of the SCRes approaches on SC sustainability learning, generating three different paths: flat, flat ascending, and ascending SC sustainability trajectories.
Research limitations/implications: The study develops an overview of the adoption of SCRes approaches due to temporal, spatial and functional scales, and their effect on SC sustainability trajectories through exploitation and exploration capabilities. Future research should elaborate on potential moderators in the proposed relationships.
Practical implications: A better understanding of the link between SC sustainability actions and SCRes will help practitioners to make better informed decisions in turbulent environments.
Originality: Unlike previous research, this paper provides empirical evidence on engineering, ecological, and social-ecological SCRes approaches, as well as SC sustainability trajectories.
Keywords: Supply chain resilience, sustainability trajectories, ecological resilience, engineering resilience, social-ecological resilience, COVID-19 pandemic.
Article classification: Research Paper

1. Introduction

Since more than two years now, the various waves of the COVID-19 pandemic create highly unstable and turbulent environments and thus significant challenges for governments, public institutions, organizations, firms, and people alike (Bryce *et al.*, 2020). This impacted and disrupted supply chain (SC) production and demand patterns and therefore provides a continuous stress test for organizational and supply chain resilience (SCRes) (Linton and Vakil, 2020; Van Hoek, 2020).

However, despite the growing number of studies connecting for example COVID-19 and SCs (e.g., Finkenstadt and Handfield, 2021; Lorentz *et al.*, 2021; Xiong *et al.*, 2021; Nikookar and Yanadori, 2022), only a small fraction of prior studies investigates how SC sustainability actions were affected by turbulent events, such as the pandemic (see Chowdhury *et al.* (2021) for a detailed overview). This gap in the literature is surprising as at least three reasons can be found to extend the existing debates. First, some researchers allude to the potential opportunity to transit towards higher sustainability levels (Trautrims *et al.*, 2020; Sarkis, 2021) and empirical evidence shows that firms' commitment towards SC sustainability actions were not significantly affected by the COVID-19 pandemic; but that in some cases the corporate interest in sustainability even increased (Bateman *et al.*, 2021). Second, it could be assumed that financially struggling firms would predominantly focus on economic survival, thereby (temporarily) neglecting environmental and social SC sustainability actions (Amankwah-Amoah, 2020). Lastly, some scholars postulate a shift of priorities to the social dimension, given that a pandemic is a social and health crisis (Fasan *et al.*, 2021). Consequently, more research is needed on how the pandemic, defined as an example of a turbulent environment, impacts SC sustainability (Sarkis, 2021; Schleper *et al.*, 2021).

Additionally, only few studies research connections between SC sustainability and SCRes in detail (Negri *et al.*, 2021), mainly in the context of COVID-19 pandemic. This gap comes also rather unexpected as sustainability actions and strategies are generally perceived as potential drivers of (SC) resilience (Fahimnia and Jabbarzadeh, 2016; DesJardine *et al.*, 2019; OECD, 2020; Paul *et al.*, 2021; Sarkis, 2021). In this study, we understand SCRes as "the capacity of a SC to persist, adapt, or transform in the face of change" (Wieland and Durach, 2021, p. 316). Traditionally, the resilience aspects of survival and returning to a prior state prevailed, especially in SC research (Wieland, 2021). This so-called "engineering resilience" describes the speed at which a system returns to its previous equilibrium following a shock, also referred to as "bouncing back" (Holling, 1996). Recently, this understanding of SCRes has been challenged in the sense that

companies should be able to develop new capabilities to move forward towards new states of resilience once they experienced shocks (Novak *et al.*, 2021; Wieland, 2021). This "bouncing forward" is defined as "ecological resilience" and further evolved into "social-ecological resilience" (Adobor and McMullen, 2018; Wieland and Durach, 2021). While previous COVID-19 pandemic research has oftentimes been descriptive, we attach our findings to the mentioned SCRes approaches.

Grounded in the interest to fill these mentioned research gaps, we apply a SC learning perspective to better identify nuances of how firms coped with the pandemic. Following Pereira *et al.* (2021) who explored SC sustainability learning using the supplier perspective to understand such COVID-19 pandemic impacts, we understand that "an entity learns if, through its processing of information, the range of its potential behaviors is changed" (Huber, 1991, p. 89). This learning perspective can be applied to a firm level, but also to inter-organizational networks (Knight, 2002). By focusing on learning within networks, we explore in this study the SC sustainability trajectories that refer to how fast and efficient SCs are able to learn (Silvestre, 2015). Therefore, to understand SC sustainability learning and its connection with SCRes we ask: "*How do firms' sustainability actions affect their SCs' resilience and sustainability trajectories in turbulent environments?*".

To address this question, our research bases on 10 case studies in five industries located in six European countries. A total of 19 semi-structured interviews as well as publicly available and internal data were collected from the relevant years before and during the pandemic. These data are analyzed in three steps. First, we conducted an inductive analysis of the actions taken during the pandemic and the SC scale at which they are exercised. Second, a deductive content analysis is applied to understand which SCRes approaches and capabilities these actions represent what learning can be observed. Finally, we inductively identified the cases' SC sustainability trajectories.

The findings contribute to the literature as follows: (1) We respond to the broader call of theory-building around COVID-19 (Craighead *et al.*, 2020; Chowdhury *et al.*, 2021) by framing the pandemic as a complex multi-scale event (Novak *et al.*, 2021). More precisely, we demonstrate that SC sustainability learning is affected by the particular SCRes approaches mobilized, which rely on spatial, temporal, and functional factors. (2) Although SCRes has been widely discussed and applied in our field, it still demands more empirical evidence (Hendry *et al.*, 2019; Novak *et al.*, 2021). This study is among the first to provide case-based evidence and reasoning on the

adoption of engineering, ecological, and social-ecological resilience in a SC context. (3) We provide practitioners with a better understanding of the link between SCs' sustainability actions and resilience, which is still underdeveloped in the literature (Negri *et al.*, 2021). In doing so, this research inductively identifies SC sustainability trajectories based on existing literature (Silvestre, 2015; Silvestre *et al.*, 2020).

The remainder of this paper is organized as follows. Section 2 provides the theoretical background of this research, including a review of the literature on SC sustainability actions, SC learning, and an overview of SCRes research. The section concludes with a presentation of our analytical framework. The methodology is presented in Section 3, followed by the findings in Section 4. Section 5 discusses the results and provides theoretical and managerial implications. Section 6 concludes with a summary, limitations, and future research avenues.

2. Literature review

This section provides the theoretical background for our study by summarizing how sustainability and SCRes have been linked in previous research. Both concepts are pivotal attributes of contemporary SCs (Fahimnia and Jabbarzadeh, 2016). However, they are rarely studied together and research on their intersection is still nascent (Pettit *et al.*, 2019; Chowdhury *et al.*, 2021; Negri *et al.*, 2021).

In the following, we will first explore SC sustainability actions and then link it to the lens of SC learning, explicitly in turbulent environments. Thereafter, we briefly summarize the discourse around SCRes, and subsequently introduce our analytical framework guiding our research.

2.1 Supply chain sustainability actions

Sustainable development is commonly understood as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8). In many cases and studies, sustainability has been interpreted by firms as the "triple bottom line" (TBL) (Elkington, 1997). From this perspective, firms must include environmental and social issues and extend their focus on purely economic benefits. Although Elkington (1997) highlighted that the TBL dimensions result in complex interrelations and trade-offs, he provided a "management concept recall" on how firms and scholars were using the TBL (Elkington, 2018). Despite the extensive criticism that the TBL has experienced, management scholars have widely applied it in different areas, making it the dominant view in management studies and SC

management (SCM) (Tregidga *et al.*, 2018).

Such a dominant view has followed an instrumental logic in which economic performance is the main goal instead of "true" sustainability itself (Montabon *et al.*, 2016). While SC sustainability is generally understood as the sum of managerial actions taken to make the SC more sustainable (Pagell and Wu, 2009), the TBL perspective shifted the focus back towards a more economic accentuated definition of "activities that organizations can engage in which not only positively affect the natural environment and society, but which also result in long-term economic benefits and competitive advantage for the firm" (Carter and Rogers, 2008, p. 364). However, such ideas of either compatibility among the three TBL dimensions or the priority of the economic dimension have been mentioned as potential barriers to progress towards sustainable SCM (Pagell and Shevchenko, 2014; Gold and Schleper, 2017).

As an alternative to the instrumental logic, Montabon *et al.* (2016) propose the "ecologically dominant logic". According to them, the existing instrumental logic asks "what can existing firms do to reduce their harm while maintaining or increasing their profits" (Montabon *et al.*, 2016, p. 12), which cannot lead to truly sustainable SCs. What is needed is a hierarchical "nested view" of sustainability, in which the social system and its economic subsystem cannot exist without a functioning ecological system as precondition (Tregidga *et al.*, 2018). While the ecologically dominant logic might also create trade-offs among the three TBL dimensions, it clearly and unequivocally advocates a prioritization of the ecologic dimension (Montabon *et al.*, 2016).

While this nested view of subservient systems is certainly correct, previous research started to look at sustainability actions during the COVID-19 pandemic (for a detailed overview beyond the operations and SC field see Ranjbari *et al.*, 2021) and partially found evidence that firms shift their prioritization of the TBL and their SC sustainability trajectory in turbulent environments, such as the COVID-19 pandemic. For instance, Sajko *et al.* (2021) find that turbulent environments can induce myopic behavior which results in a focus on economic outcomes only, thereby neglecting social and environmental issues. This again reflects the instrumental TBL narrative that economic survivability is a pre-condition to ecological and social sustainability. Amankwah-Amoah (2020) finds that firms' environmental initiatives in turbulent times may be suspended to prioritize economic aspects while others assume that COVID-19 might have led to a partial reorientation towards more social issues, away from environmental ones (Fasan *et al.*, 2021; Pereira *et al.*, 2021). However, others did not find such changes. Bateman *et al.* (2021) expected COVID-19 to have a

negative effect on SC sustainability actions while firms had to manage its repercussions. Yet, they found in their survey study that the majority (80%) of firms did not cut down on SC sustainability and 83% reported that the pandemic had increased the awareness for this issue and in some cases even accelerated SC sustainability actions (Bateman *et al.*, 2021).

Interestingly, some scholars see COVID-19's disruptive force as an opportunity. According to this view, the pandemic could overcome some of the negative repercussions of the instrumental logic and potentially change unsustainable production and consumptions patterns (e.g., Trautrims *et al.*, 2020; Sarkis, 2021). However, other scholars are less optimistic (Van Hoek, 2020) or at least point towards unintended negative consequences of sustainability actions taken during the pandemic (Matos *et al.*, 2020).

As a result and despite recent research in this area, details on the development of SC sustainability actions and SC sustainability learning in turbulent environments remains scarce (Cormack *et al.*, 2021). For instance, Klymenko and Lillebrygfjeld Halse (2021) investigate sustainability actions from an institutional perspective in the maritime industry in Norway. They find that the role of the institutional context is ambivalent as it can both trigger and hinder firms' sustainability transition. In the end, they contend that future studies need to investigate how exactly this resilience is built. Silva and Nunes (2022) point out that a sustainability logic should be stronger than a prioritization of TBL dimensions. For these authors, other elements such as event sequencing and institutional entrepreneurship are vital to represent how firms learn and ensure the continuity of SC sustainability actions even during unexpected events, such as the COVID-19 pandemic.

2.2 SC sustainability learning in turbulent environments

While previous research has often explored SC sustainability through the lens of performance and outcomes, even with some priority for economic issues (Beske and Seuring, 2014; Montabon *et al.*, 2016), some colleagues argue that SC sustainability might be more appropriately perceived as a dynamic and evolutionary learning process which shapes the sustainability trajectory of SCs over time (Silvestre, 2015; Gong *et al.*, 2018; Silvestre *et al.*, 2020; Cormack *et al.*, 2021). This learning includes how individuals, groups, organizations, or inter-organizational networks evolve and change over time (Huber, 1991; Knight, 2002; Knight and Pye, 2005). As SCs represent inter-organizational networks, we adopt a perspective of learning within networks (Knight, 2002) which

represents that the firm's learning process relies on the exchange with SC partners (Silvestre, 2015).

To understand how firms learn to shape their SC sustainability trajectories, we understand SC sustainability learning as the "sustainability-related knowledge, behaviours and values resulting from the experiences of supply chain actors in implementing sustainability initiatives [actions]" (Pereira *et al.*, 2021, p. 716). According to Roy (2019), SC sustainability learning relies on knowledge management and how this knowledge is applied, which somehow limits other sources of learning. Accordingly, SC sustainability trajectories refer to how fast and efficient SCs are able to learn (Silvestre, 2015). This perspective can be illustrated as a non-linear journey, in which learning of SC sustainability relies on a sequence of events and structural changes (Roy *et al.*, 2018; Silva and Nunes, 2022). However, SC sustainability trajectories are also influenced by the pre-existing inertia faced by firms or even resistance for change, which hamper their ability to learn (Silvestre *et al.*, 2020; Roy *et al.*, 2018).

An important factor that can influence these learning processes and trajectories is the external environment, especially when it is highly turbulent (Levinthal and March, 1993). Highly turbulent environments induce high uncertainty for SCs and might lead to changes in learning, i.e., how the SC is collecting and processing relevant information to rationalize its behavior, that is the actions taken. Moreover, a turbulence can influence the learning capabilities to be leveraged (Silvestre *et al.*, 2020). Beyond the research on SC sustainability learning, a closer look on which capabilities can emerge is required (Silvestre *et al.*, 2020; Pereira *et al.*, 2021). For learning, exploitation and exploration capabilities need to be mobilized (Huber, 1991). These capabilities can support the emergence of other capabilities, which is the case for SCRes. As little is known on how SC sustainability and SCRes are interconnected, more research is needed. The turbulence may for example cause the need to refine previous behaviors, i.e., leveraging exploitation learning capabilities. Alternatively, turbulences may raise the need to overcome or substantially change previous behavior by relying on exploration learning capabilities. Consequently, turbulent change can also influence the SC sustainability trajectories (March and Olsen, 1975; Silvestre, 2015).

Such an influence can be represented by several stages of learning. Although learning is closely related to knowledge, there is a need to observe which initiative or action companies have used to learn sustainability (Silvestre *et al.*, 2020). In this context, Cormack *et al.* (2021) summarize the existence of four processes of learning for sustainable SCM: set-up, operating, sustaining, and updating. For these authors, these processes represent the learning loops that firms pass through.

While the "set-up" process refers to how a firm approaches its sustainability actions internally or by collaborating with few SC partners, the operating process focus on the SC level. Additionally, "sustaining" refers to learning from experience in the same SC level and with no big changes. Finally, the "updating" process includes the SC level and beyond with a clear growing in the trajectory from previous SC sustainability actions. Cormack *et al.* (2021) claim that environmental turbulence can change the journey of a SC sustainability trajectory.

Prior literature has characterized environmental turbulence as "frequent changes in external factors beyond your control" (Pettit *et al.*, 2010, p. 11) which lead to uncertainty and risk and therefore bear the continuous possibility of disruptive events in SC contexts (Chopra and Sodhi, 2004; Pettit *et al.*, 2010). Although the operations and SCM literature generally assumes a ground level of environmental turbulence, the current COVID-19 pandemic certainly serves as a paradigmatic instance of a turbulent environment as it presents a transboundary crisis which affects a multitude of societal layers and entities around the world (Bryce *et al.*, 2020). Thus, Craighead *et al.* (2020) argue that the pandemic qualitatively differs from other disruptive events in specifically three interrelated dimensions: scope (i.e., the pandemic is a truly global event), spillover (i.e., the pandemic comes in waves which spill over other locations and sectors), and shifts (i.e., demand and supply can be highly volatile and affected at the same time).

2.3 SCRes to encounter turbulence

SCRes "involves change and the corresponding response to that change" and is thus an adaptive phenomenon (Tukamuhabwa *et al.*, 2015, p. 5609). Furthermore, it can be defined as a dynamic capability, since it refers to the ability of responding to threats and opportunities that emerge during a changing environment (Teece *et al.*, 1997). Correspondingly, we understand SCRes in this study as "the capacity of a SC to persist, adapt, or transform in the face of change" (Wieland and Durach, 2021, p. 316). To build SCRes, multiple capabilities need to be developed (Pettit *et al.*, 2019), but the effectiveness of these proactive or reactive capabilities relies on the level of disruption orientation on the firm level and on each firm's distinctive capabilities within a SC (Ambulkar *et al.*, 2015; Chowdhury and Quaddus, 2017).

Prior literature identifies a wide set of capabilities, antecedents, and enablers to improve SCRes, such as SC network design through configuration, flexibility, redundancy, visibility, collaboration, and agility (see Tukamuhabwa *et al.* (2015) for an overview). In their conceptual

and widely cited paper, Pettit *et al.* (2010) link two key SCRes research streams, namely vulnerabilities for disruptions and capabilities to build capacity for overcoming disruptions (Pettit *et al.*, 2019). More precisely, they identify a total of 14 capability factors to foster SCRes: flexibility in sourcing, flexibility in order fulfilment, capacity, efficiency, visibility, adaptability, anticipation, recovery, dispersion, collaboration, organization, market position, security, and financial strength. These capabilities are adapted according to how firms mobilize their resources in changing environments (Pettit *et al.*, 2013), and the emphasis on a specific capability depends on the needs to face a certain disruption (Pettit *et al.*, 2019).

In the context of a global pandemic, vulnerabilities emerge as part of the turbulence defined by Pettit *et al.* (2010) as external changes that are not under firms' control and which might even differ qualitatively from other disruptive events (Craighead *et al.*, 2020). So far, SCRes research during the COVID-19 pandemic has mainly focused on identifying and reporting existing response strategies (Chowdhury *et al.*, 2021). For instance, El Baz and Ruel (2021) investigate how risk management can support SCRes and robustness of companies during the pandemic. In addition, Van Hoek (2020) claims the need for risk management that moves beyond risk mitigation to sustainably de-risk SCs structures in a post-COVID era. Although a plethora of publications exist, most perspectives lack a deeper recognition of the complexity attached to this unexpected event. We thus argue that more than simply being a turbulence (Pettit *et al.*, 2010), the COVID-19 pandemic triggered a set of multiple vulnerabilities simultaneously, affecting supply and demand at the same time (Schleper *et al.*, 2021).

Recent research has highlighted that a large number of contingencies can influence the outcome of SCRes activities and thus need to be taken into account in future empirical investigations (e.g., Novak *et al.*, 2021; Wieland, 2021; Wieland and Durach, 2021). For instance, Novak *et al.* (2021) conceptually raise the importance of investigating a set of contingencies labelled as "scales". They advocate for research to better understand how activities and outcomes are related to scales of space, time, and function, and especially investigating them together. Otherwise, the same actions and events may be understood in different ways due to the distinct focus of the single scales. The spatial scale for instance captures the involved organizations such as firms, NGOs, agencies, or customers, as well as overarching systems of economies, environments, or politics. The temporal scale focuses on the time frames of actions, decisions, or strategies, i.e., short- vs. long-term. Finally, the functional scale covers the firm governance by the

surrounding social or SC system. While the single scales seem almost intuitive, Novak *et al.* (2021) underline their joint value to systematically map and understand the events and dynamics of today's globally interlinked SC networks.

Through the application of these three scales, we characterize COVID-19 as complex multi-scale event. Its turbulence is caused by a) the wave-like development of the pandemic across space, i.e., from Asia to the rest of the world and then differing numbers and magnitudes of infection waves in single continents or countries, b) the wave-like development of the pandemic across time within the single spaces, i.e., depending on spatially proximate infection numbers, spatially bound climate conditions like rising infection numbers in winter, and c) the different functional set-ups to counter the pandemic like the comparatively very strict (and also spatially wide ranging) "zero COVID" approaches in China or Australia vs. relatively industry- and region-specific restrictions in the USA or Europe.

This development of the pandemic then caused turbulence in production and consumption patterns (Sarkis, 2021; Schleper *et al.*, 2021) that were again strongly driven by the developments a) to c), which in themselves were interdependent. We believe that this conceptualization is useful to investigate a wide set of cases that differ in terms of these scales and thus to better understand how firms learn to build SCRes through SC sustainability actions in turbulent environments. Such an investigation of building SCRes is supported by the discussion of three different SCRes approaches, namely "engineering", "ecological", and "social-ecological" (Adobor and McMullen, 2018; Wieland, 2021). Previously, SCRes has foremost been understood as the capacity of a system to quickly return to its previous equilibrium in a post-shock phase, i.e., engineering resilience or "bouncing back" (Holling, 1996). Yet, this understanding of SCRes does not always match reality as some firms have been observed to strengthen after turbulences. Instead of bouncing back to previous states, this approach can be characterized as a "bouncing forward" and "ecological resilience" as it "emphasizes conditions far from any equilibrium steady state, where instabilities can flip a system into another regime of behavior—that is, to another stability domain" (Holling, 1996, p. 33). Lastly, some authors rejected the idea of equilibrium-based definitions of SCRes altogether by replacing the equilibrium aspect with concepts of uncertainty, adaptability, transformation, continuous change, and instability (Adobor and McMullen, 2018). As a consequence, they defined the concept of "social-ecological" or "evolutionary resilience" (Adobor and McMullen, 2018; Wieland and Durach, 2021). This type of resilience can be described as "the

ability of a complex social-ecological system to change, adapt and transform in response to stresses and strains, whether external or internal" (Adobor and McMullen, 2018, p. 1461). In this vein, DesJardine *et al.* (2019) find that investments in strategic social and environmental practices can help firms recover from crises by lessening the severity of the shock and accelerating recovery times. We thus assume that the distinctive nature of the SCRes approaches can affect the SCs' sustainability trajectories.

2.4 Analytical framework

In this paper, we assume that firms and SCs need to learn how to survive, adapt, and grow in turbulent environments in order to be resilient (Wieland and Durach, 2021). There is an understanding of SCRes as a homogeneous result of multiple tiers of interactions; however, as identified by De Sá *et al.* (2020) and Paul *et al.* (2021), a need to strengthen resilience within and across SC links exists, too. This is the case as SCRes is not an one-time event, and should emerge from previous experiences and interest to develop specific strategies (Pettit *et al.*, 2013). As Hendry *et al.* (2019) point out, capabilities need to be developing in the face of disruptions.

Hence, we suggest an analytical framework (see Figure 1) that combines the previously mentioned streams of arguments. Based on their pre-turbulence strategy and experience, firms will react to a turbulent environment by taking actions. These actions will be based on the firms' interpretation of the turbulence and lead to a learning based on the action. To do so, they seek information, interpret it, and act according to their interpretation (Huber, 1991). To understand this learning, the empirical investigation is grounded on the SC sustainability actions for which underlying justifications have been discussed with the case firms. In analyzing them, we first characterize the actions and their rationales against the SC scales addressed (Novak *et al.*, 2021) and the learning capabilities mobilized (March, 1991; Silvestre *et al.*, 2020). Based on this characterization, links between SC sustainability actions and SCRes approaches are identified to understand how SCRes is built. Second, we adopt the arguments on the distinctiveness of engineering, ecological, and social-ecological SCRes approaches (Adobor and McMullen, 2018; Wieland and Durach, 2021) pursued in the face of a turbulent event and investigate how the specific SCRes approaches shape the SC sustainability trajectory over time (Silvestre, 2015).

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3. Methodology

To investigate SCs' resilience and sustainability trajectories in turbulent environments, case studies were chosen as the research method since they prove useful for investigating complex phenomena and their real-world context, and enable the analysis of multiple sources of data that can be triangulated to enable a more nuanced understanding of phenomena (Eisenhardt, 1989; Voss *et al.*, 2002; Yin, 2018).

3.1 Research design and case selection

An exploratory multiple case study was conducted to understand what SC sustainability actions and how SCRes were adopted during the COVID-19 pandemic. Ten large companies across five industries in six European countries present empirical basis (see Table 1 below) and the SC sustainability actions are the unit of analysis.

The case sampling followed common guidelines as well as a structured and purposeful logic including literal replication (i.e., searching for similar cases) and theoretical replication (i.e., searching for contrasts; Eisenhardt and Graebner, 2007; Yin, 2018). This approach allowed us to achieve richness of information and to limit the number of cases necessary to gain comprehensive insights. We realized this by choosing the sample according to two selection criteria: (1) We investigate cases in industries facing different magnitudes of restrictions caused by the pandemic and reactions to it (i.e., differences on the functional scale; Novak *et al.*, 2021). This range varies from food producers and supermarkets being considered as systemically very important during the pandemic – and thus being less restricted – to airlines being considered of lowest importance in the pandemic's early phases and thus more restricted in their typical operations. (2) The replication logic bases on differences in the importance of global parts of the case firms' SCs (i.e., differences on the spatial and functional scale; Novak *et al.*, 2021). Adopting this logic, we firstly aimed to build a core set of cases that cover key European industries, such as manufacturing and food. For these industries, we covered cases that are characterized with differing importance of global supplies. Secondly, we amended this core set of cases with cases from other industries that are characterized by globally homogeneous SC patterns. The latter encompasses for example the textile sector in which hardly any large firm can rely on European Union (EU) suppliers only, but which in turn shows extreme dependence on non-EU suppliers. On the other hand, the airline is operating mainly in Europe and is thus an example of (very) low dependence on global supplies. As a result,

we base our analysis on a comprehensive coverage of the main factor of the replication logic, i.e., dependence on global supplies, as suggested by Yin (2018).

3.2 Data collection

In total, 19 knowledgeable medium- to top-level firm representatives were interviewed between July 2020 and February 2021. As the research setup is cross-functional, we approached informants from the operations, SC, and sustainability function of the firm. Whenever possible, we asked for more than one respondent to avoid a single informant bias. All interviews were conducted in English and German and lasted on average 54 minutes. The research scope is limited to European interviewees and their perspectives with some minor reflections on African, South American, and Asian suppliers. Table 1 illustrates detailed information for each case.

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To develop the interview guideline, a research protocol was applied to ensure the reliability of the data (Yin, 2018). The interview guideline (see supplementary file A) aimed to reflect on what SCRes related actions were conducted in the cases as well as the interviewees' interpretation of how and why the actions were adopted. To this end, the guideline centered on SC sustainability actions before and during the pandemic, SCM related learning during the pandemic, and the envisioned path of the case firm as well as industry after the pandemic. This focus during the interviews on actions, learnings, and future plans allowed for a clear deductive identification of the specific SCRes approach (engineering, ecological, and social-ecological) during the following data analysis, as described below.

All interviews were conducted remotely via Skype, Zoom, or MS Teams, and recorded given the participants' consent. Interview notes were taken during these interviews and secondary materials (e.g., annual reports, website content) were collected to triangulate the primary data and gain additional information (Eisenhardt, 1989). A total of 39 sustainability reports, annual reports, and communications have been collected for relevant years before and during the pandemic to support the primary data analysis.

3.3 Data analysis, validity, and reliability

The data were analyzed through a combination of inductive and deductive content analysis (Mayring, 2010). The inductive approach was applied during the identification of relevant SC sustainability actions and their scope across the SC. For the scope of the actions, we relied on the SC scales by Novak *et al.* (2021) who suggest to investigate which parts of the SC are addressed by an action (i.e., spatial scale), which time frame is taken for an action (i.e., temporal scale), and how the action changes or manifests the governance of the SC and its environment (i.e., functional scale). The actions were first defined individually through open coding of key quotations (Strauss and Corbin, 1990). These quotations represented each of the actions and changes implemented by companies facing the pandemic (see supplementary file B). Thereafter, a grouping of the actions into the SC scales was realized through axial coding (Strauss and Corbin, 1990), which helped to inductively identify the SC sustainability trajectories. All coding was conducted manually and supported by the MAXQDA software that facilitates the definition and documentation of codes, categories, and coded text passages.

The deductive approach was applied to characterize the previously defined SC sustainability actions according to pre-defined categories: regarding the sustainability dimensions addressed and the adopted SCRes approaches (Adobor and McMullen, 2018; Wieland and Durach, 2021), the capabilities leveraged through the actions (Pettit *et al.*, 2010), and the sustainability dimensions addressed. The SCRes approaches are based on the extensive characterization of the three approaches by Adobor and McMullen (2018) which were later enriched by Wieland and Durach (2021). Based on these two papers, a coding scheme was defined that centers on the approaches' key orientations of efficiency-based capabilities for engineering SCRes, adaptive capabilities for ecological SCRes, and collaborative capabilities oriented to growth and renewal for the social-ecological SCRes approaches. These key orientations are supported by multiple sub-items that represent the deductive coding scheme and along which the coding was conducted (Mayring, 2010).

By applying multiple rounds of analysis by all three authors, we used a double-check approach in which each interview was independently coded by two authors before a discussion among all three authors was conducted. The aim of this process was to achieve an "alignment of interpretation" (Seuring and Gold, 2012, p. 547) and to reach consensus on the final coding. In cases of disagreement of the two coding authors, the third author, who did not code an interview, took the role of the devil's advocate to guide the decision towards one interpretation. This process

aimed to ensure inter-coder reliability and ensured that clear SC sustainability actions were identified in relation to COVID-19.

Based on this, a within-case analysis was established to better understand each case's context in terms of industry, dependence on global supplies, and pre-pandemic sustainability experience (Pratt, 2009). The latter especially encompasses the TBL dimensions focused on in the pre-pandemic sustainability strategy and the time since when the strategy was exercised. To reduce the manuscript's descriptive parts and its length, we emphasize the differences in conducted SC sustainability actions, adopted SCRes approaches, and SC sustainability trajectory in a cross-case analysis in Section 4.

The overall research process was carefully planned and documented in a transparent and reproducible manner, meeting the demands for sound qualitative empirical research (Eisenhardt, 1989; Yin, 2018). To ensure the validity and reliability of our study, we followed four tests (Yin, (2018): (1) a clear sampling logic encompassing for example sufficient variety in the investigated SC contexts, products as well as supply and demand patterns. This approach increases external validity as it mitigates the lack of generalizability which is often a challenge in qualitative research. (2) construct validity was ensured during data collection by building the semi-structured interview guideline based on the previously outlined theory on SC learning, SC sustainability, and SCRes. Furthermore, data triangulation was applied using multiple sources of data. (3) internal validity was built by means of pattern matching across interviews and theoretical grounding. Moreover, the transcribed (and if necessary translated) data were checked with the interviewees to prevent misinterpretations and obtain their permission. (4) reliability was created by providing as much transparency of the research process as possible (e.g., sampling logic, generation of the interview guideline, conduct of interviews, coding).

4. Findings

4.1 Within-case analysis: SC sustainability experience before and during the pandemic

To investigate connections between SC sustainability and SCRes for each case, we identify to what extent SC sustainability has been exercised as a strategy before and during the pandemic. Table 2 presents an overview of the open coding of the sustainability experience within each case. While columns two to four evidence the pre-pandemic sustainability actions, the final column presents 31

inductively coded SC sustainability actions, i.e., the unit of analysis. The latter will lead us to better understand the SCRes approaches taken during the pandemic.

---------- INSERT TABLE 2 APPROXIMATELY HERE ----------

When summarizing the cases, three sustainability profiles become evident. First, five case firms (1, 2, 3, 4, and 8) strongly focus on environmental and economic sustainability in their SC sustainability strategy before the pandemic. This is closely related to reducing carbon emissions and developing technological solutions to harmful pollution impacts. Similar SC actions were taken during the pandemic when these case firms were mainly interested in finding (economic) solutions for staying in the market.

Second, for the cases 5, 7, and 9, SC sustainability actions related to social, economic, and environmental issues were important before and during the pandemic. As evidenced in the SC sustainability actions during the pandemic, these cases maintained and even enlarged their SC sustainability actions in the face of the turbulent environment, i.e., the pandemic. Moreover, the interviews and most recent secondary data underline that the actions taken during the pandemic will persist in the long-term.

Finally, two cases illustrate medium importance to one of the three TBL dimensions. Case 6 shows strong environmental and economic sustainability, but medium social sustainability. Case 10 shows strong economic and social sustainability, but medium environmental importance. In the latter two cases, the pandemic actions are mentioned to be exercised during the time limited to the pandemic.

Through the comprehension of SC sustainability experience and previous engagement, we can better identify how firms learn SCRes in turbulent environments. Therefore, we analyze the interviews and secondary data to identify if the pre-pandemic sustainability strategy was exercised for one, two, three, or more years. We find that cases 2 and 4 started their recent strategy in 2019, case 5 in 2017, and the other cases more than three years before the pandemic. From a learning perspective, it can be expected that the cases 2, 4, and 5 are bound to the earlier phases of learning loops, i.e., set-up and operating, while the other cases have more potential for the later phases of sustaining and updating (Cormack *et al.*, 2021) that also enable to develop SCRes further. Interviewee *9a* mirrors this by stating "*you don't build your foundations during a crisis, but you test your foundations during a crisis, and if you have solid foundations, we expect to be stronger*

with our suppliers after this crisis, and because it is a let's say "test and learn" in terms of partnership". Based on this within-case identification of SC sustainability experience, further information is required in terms of how SCRes was faced and explored in these cases.

4.2 Cross-case analysis: SCRes approaches during the pandemic

After understanding the case firms' previous SC sustainability experience, we next investigate the magnitude of the COVID-19 outbreak for these firms to better comprehend how firms learn SCRes through SC sustainability actions. Table 3 illustrates a multi-scale analysis of how each case firm designed its pandemic SC sustainability actions. Additionally, we present the SCRes capabilities that were amplified to respond to the outbreak. In the axial coding, three different SCRes approaches were found according to which our data is presented.

---------- INSERT TABLE 3 APPROXIMATELY HERE ----------

4.2.1 Engineering SCRes approach

Five of the ten cases exhibited a clearly efficiency-oriented approach to addressing the pandemic (Table 3), i.e., the turbulence that defines engineering SCRes (Adobor and McMullen, 2018). These cases aimed to bounce back to a previous state (Holling, 1996) by conducting SC sustainability actions focused on a short-term control of supplies and thus a short-term focus on the temporal scale. On the spatial scale, actions like localizing supplies and risk management actions such as enlarged inventories or task forces for enhanced short-term flexibility all focused on the closest SC partners, and thus stabilizing or even reducing the spatial scale of the SCM. As shown in Table 3, only case 4 conducted actions on the SC level in its decisions of risk management and social audits. However, the aim was still to bounce back to the previous state by following an engineering approach. In the words of interviewee *4a*, "*we implemented a crisis management also within the topic for our firm but as well towards our suppliers, where we* […] *created so called risk tower*". Within this established but limited space of the firm and some suppliers, the actions focus mainly on fortifying the case firms' internal capabilities that are seen as central to the SC capability. To this end, the actions reinforce the pre-pandemic functional set-ups by means of audits and control actions.

Social and environmental sustainability are not the main concerns in the engineering approach. Instead, it might lead to long-term economic sustainability even though the decisions are centrally

made based on short-term actions. This economic sustainability is achieved by refining well-established structures and SC spaces in the sense of exploitation learning. Accordingly, Table 3 lists ‘flexibility in sourcing’ and ‘visibility’ as two main SCRes capabilities amplified in minimum three cases. These cases used exploitation learning to maintain pre-pandemic SC sustainability actions. For this end, they also exploited capabilities such as: ‘anticipation’, ‘adaptability’, and ‘collaboration’. Mobilizing these capabilities reinforces their pre-pandemic functional set-ups, mainly in terms of SC sustainability. From a learning perspective, engineering SCRes thus clearly represents an exploitation learning aiming to refine previous patterns to bounce back.

4.2.2 Ecological SCRes approach

Three cases were found that mainly apply adaptive capabilities signifying the ecological SCRes approach (Adobor and McMullen, 2018). These cases focused on adapting their functional set-ups in different SC spatial scales (see Table 3). Such changes required an adaptation of supply and demand patterns; for example, shifting demand from disrupted customer segments to others whenever possible (e.g., case 6). Furthermore, these modifications focused on balancing the interests of case firms’ SC partners and stakeholders, represented by the spatial scales of the SC level or beyond. For instance, cases 5 and 10 developed SC actions that transcended the transactional border. This occurred in case 10 when establishing home delivery during lockdowns (although their supermarkets were open) as “*the logistics teams took a bit more of the community angle as well, and so they didn't stop the usual CO_2 reduction and that type of stuff, which is very bottom line beneficial as well*” *[10a]*. This represents an exploration learning for the newly introduced home deliver that at the same time exploits experiences in CO_2 reduction. Yet, these reactions and underlying changes were mainly limited on the temporal scale to times characterized by lockdowns or contact restrictions. Therefore, the decisions were taken in a short-term time scale which helped to avoid SC sustainability drops during the pandemic.

Due to the limited time frame, these actions are not seen as a major change in the long-term SC sustainability aims and potentials. Nevertheless, ecological SCRes actions proved a high level of cooperation among the SC partners and high adaptability in the face of turbulence, as suggested by Adobor and McMullen (2018). This can clearly be observed in Table 3 through the SCRes capabilities ‘anticipation’, ‘visibility’, and ‘adaptability’ mobilized by two of the three cases. These capabilities are represented by a mix of exploitation and exploration learning according to the

cases' targets during the pandemic. For instance, case 10 exploited existing logistics structures using the 'adaptability' capability to support local communities, and at the same time explored the 'financial strength' capability to guarantee sustainability of its suppliers.

From a learning perspective, the ecological SCRes approach keeps the spatial scale fixed, just like the engineering SCRes approach, but leverages exploration capabilities in the functional SC scale for new management actions in these structures.

4.2.3 Social-Ecological SCRes approach

Two cases reacted to the pandemic with collaboration-based actions for renewing the supplier management in the face of change, as suggested in the social-ecological approach (Adobor and McMullen, 2018; Wieland and Durach, 2021). The related actions of cases 7 and 9 aim to support suppliers in ensuring their sustainability as well as employment and support transparency such as communicating with suppliers beyond control. In their core, these actions intend to establish new or enlarging functional set-ups to update SCM processes according to the needs of the surrounding social system. Such enlargement is related to a larger spatial scale as both cases transcended the SC level by caring for the viability of suppliers' employee livelihoods and communities. These challenges encompass mainly supplier staff off-setting risks due to lacking order volumes. In addition, we observed that both cases are among those that exercise sustainability for a while already, which enables them to consider the long-term consequences of their decisions even during a pandemic. In effect, the social-ecological actions focus on supporting the suppliers' and stakeholders' interests in favor of long-term SC sustainability performance. We perceive in this analysis that a sustainability path had already been developed before the pandemic.

The interest in long-term SC sustainability shows an evident leverage of exploration learning by enlarging previous sustainability-conscious functional set-ups to parts of the SC that were previously less governed by the case firms. We found in this SCRes approach the most prominent representation of learning as there is a change in managers' behavior to cope with the pandemic without losing the previous SC sustainability experience. Such exploration is found to be supported by 'financial strength' and 'collaboration' capabilities. However, in contrast to the engineering and ecological SCRes actions, a pure exploitation of previous functional set-ups would result in a collapse of the SCs' operational capabilities due to staff off-setting. Thus, other capabilities were exploited such as 'visibility' and 'flexibility in sourcing' to ensure full exploration.

For example, case 7 aims to ensure its social SC sustainability by making sure that supplier employees remain employed and paid even though the case firm could not order new supplies at that time. Interestingly, the firm's suppliers are based both in the eastern EU and Asia. Despite identical social sustainability aims regarding continued working and payment conditions, a remarkable difference in the SC sustainability action was observed. When managing the Asian partners, this case firm was "*making sure that* [supplier] *workers are not taking the worst part. So, even though you're not able to guarantee* [order] *volumes, you want the factory to assure that it has paid those wages, assurance is granted that workers during the whole time are paid for holidays and given paid leave*" *[7a]*. To enable the required supplier cash flow, the firm did not apply standard procedures of cancellation and payment but explored and introduced a new one based on the following action: "*We had this dialogue with the suppliers and* […] *they asked us for advanced payments in some cases and we granted it on the basis of trust. We haven't received anything, but we will help you set up and then we can both advance, but they didn't lay off workers. And they've been able to survive quite well.* [Moreover,] *our company did not cancel a piece with orders in the whole pandemic* […] *even if we didn't know whether we were going to sell it" [7a]*. In order to ensure the same aim with the EU suppliers, the case firm found that these "*had the advantage that European countries had already government funds readily available*" *[7a]*. As a result, the action was realized in a more control-oriented, i.e., engineering, SCRes approach by checking "*with every single one of them* [EU suppliers] *that they were making use of this government funds to ensure wages for the workers*" *[7a]*. In essence, case 7 ensured that existing government schemes were used, which mirrors an exploitation learning. The adoption of the different approaches in this action is related to the substantial differences in the spatial scale, but even more the functional scale of having government funds available or not. From a SC sustainability perspective, the more exploration capabilities are mobilized, the better the firms seem to be engaged with SC sustainability, even in turbulent environments.

4.3 Cross-case synthesis: The influence of SCRes learning on SC sustainability trajectories

Throughout the research process, we identified that the SCRes approach firms use to manage their SC actions influences how sustainability actions are prioritized and applied to cope with the turbulent environment caused by COVID-19. Although all case firms have a SC sustainability strategy, there is a change in the intensity of the sustainability learning path for half of the cases.

Figure 2 illustrate how each case's sustainability trajectory was affected by the SCRes learning. For example, engineering resilience-oriented firms focused on economic actions, which foremost serve survivability and bypassed sustainability. At the same time, we found that social-ecological resilience-oriented firms raised their learning path, i.e., their SC sustainability trajectories. Silvestre (2015) argues that trajectories are affected in turbulent environments, which seems to be further amplified by turbulences of the magnitude of COVID-19 (Silva and Nunes, 2022). To better understand these phenomena and links among them, we consider each approach in detail.

---------- INSERT FIGURE 2 APPROXIMATELY HERE ----------

As noted in Figure 2, we consider the firms' different pre-pandemic SC sustainability experiences and analyze the trajectories after the turbulent shock. Section 4.1 showed that understanding a firm's previous SC sustainability experience helps to explain some reasons for the learning and the decisions taken during the turbulence. However, for the analysis of the trajectories we have focused on the timeframe of the pandemic only due to the available data. In addition, the COVID-19 pandemic hit the case firms at different times within the first quarter of 2020 and still impacts them differently to date. Such a perspective leads us to understand that short-time refers to those actions taken within this period of the pandemic. Based on this information, we can better understand each trajectory.

4.3.1 The flat SC sustainability trajectory: engineering SCRes approach and set-up learning

Engineering resilience is known as a firm's ability to bounce back to its previous equilibrium, which stabilizes the SC sustainability trajectory after a disruption. The adoption of an engineering SCRes approach likely stops the sustainability learning path and flattens the trajectory's slope during a period of time. This can be linked to the exploitation learning relying on a set-up stage of learning. The set-up is the first learning process to understand the SC sustainability trajectory (Cormack *et al.*, 2021). Thus, to embed sustainability in SCRes, firms need to focus on efficiency and exploitation of what they already know. The set-up process is well observed when firms focus on the firm-level spatial scale and short-term decisions to reinforce pre-pandemic actions. It can also result from inertia from previous SC sustainability action adoption (Roy *et al.*, 2018). For instance, case 3 implemented four actions focused on economic sustainability, despite having an

environmentally focused and well-defined sustainability strategy. Their actions involve enlarging in-house production and inventories, which indicates a search for solutions which allow to reach the pre-pandemic equilibrium in the period after the first lockdowns. Based on the previous strategy of vertical integration and environmentally oriented sustainability, the learning about the SC scales and social sustainability was limited right from the outset of the turbulence, leading to a stabilization of the previous SC sustainability trajectory. This is also indicated by secondary data from 2022 which underlines the same strategic aspects of integration and environmental sustainability (see Table 2).

Another example is presented by case 4 which is concerned with the SC level and emphasizes sustainability as an important aspect as "*[it] definitely helps to get a better understanding of your supply chain and the risks inherent in your supply chain*" *[4b]*. However, the SC sustainability actions were developed to ensure the company's sustainability performance by risks reduction through an improvement and extension of a risk tower developed during their previous SC sustainability trajectory. Due to this focus on exploitation, the level of learning seems relatively low. This is again underlined by secondary data evidencing stability in the sustainability strategy during the pandemic (see Table 2).

In general, we found that firms following engineering SCRes have built a flat SC sustainability trajectory which represents a continuation of their previous limited engagement with sustainability. We noted that these cases are not applying the entire TBL perspective in their SC strategy and aim to bounce back during a crisis as they have a focus on short-term, internal needs and maintenance of existing actions. These findings support our understanding that sustainability and resilience have limited connections when they focuse only on a more efficiency-based SCRes approach due to the hampering of further learning.

4.3.2 The flat ascending SC sustainability trajectory: ecological SCRes approach and operating learning

Ecological resilience is characterized as bouncing forward, seeking a new equilibrium, and thus implicating change and new actions in the SC sustainability trajectory. The adoption of an ecological SCRes approach likely changes the sustainability learning path as well as the trajectory's slope during a limited period of time. The trigger for change and adaptability occurs through a combination of exploitation and exploration capabilities for SCRes learning. We therefore observe

that the SC sustainability trajectory is affected in the operating learning process as the firm relies on previous actions to ensure adaptability (Cormack *et al.*, 2021). For instance, Table 3 presents that the cases related to ecological SCRes mobilized the SCRes capabilities 'anticipation', 'visibility' and 'adaptability'. Based on this, we propose that the operating process of learning is represented by adaption in the functional set-ups, which are differently affected by time and space (Novak *et al.*, 2021). Ecological resilience solutions spur more learning than the engineering SCRes approach related to changes in the functional set-up with considerations that do not only focus on the own ability to overcome the turbulence, but also on SC partners.

Three cases were linked to this resilience approach demonstrating that firms still struggle to look forward when developing SC sustainability actions. As previously mentioned, these cases centered on short-term decisions, but they affect the SC sustainability trajectory as whole as represented in Figure 2. During a turbulence, firms seem to stabilize their main actions and develop some temporary actions to ensure SC performance. Still, it is evident that the ecological SCRes approach takes a strong focus on economic sustainability. Although Table 2 shows that these cases have a stronger focus towards the TBL than the cases in engineering SCRes, a strong focus on short-term decisions interested in survivability instead of sustainability became evident. Due to the magnitude of the turbulence this is acceptable; however, there is a mismatch between the aim of bouncing forward and the strong focus on economic sustainability only. The findings show that more efforts are necessary to ensure that exploitation and exploration learning lead to enhanced trajectories.

4.3.3 The ascending SC sustainability trajectory: social-ecological SCRes approach and updating learning

Social-ecological resilience rejects the idea of equilibria altogether. It advocates a bouncing forward and broadening the scale of responses including further SC partners to rise the SC sustainability trajectory. Thus, opportunities may emerge from the faced disruption (Wieland, 2021). The adoption of a social-ecological SCRes approach likely boosts the sustainability learning path and rises the trajectory's slope. We can understand such a perspective due to the need to mobilize the so-called updating learning (Cormack *et al.*, 2021). Once a firm has already implemented clear and stabilized SC sustainability actions, it can explore new possibilities of learning from that during a crisis. We found that our cases applying social-ecological SCRes

established new or enlarged functional set-ups and exercised them on larger spatial and temporal scales. Based on this, there is a continuous learning process in terms of SC sustainability trajectories, even when unexpected events are experienced and changes in the SC structure manifest (Silva and Nunes, 2022).

For example, case 9 provides a clear understanding of how the scale increased. The case faced severe demand reductions, endangering some suppliers. The case firm built on a culture of leadership considering "*suppliers as part of our company, as part of our ecosystem, as part of our extended company" [9a]*. The case firm explored new behaviors like reduced payment times, giving away short-term monetary benefits in favor of avoiding heightened supplier capital costs or even supporting supplier survival, seen as a long-term commitment. The case illustrates that the SC sustainability trajectory can be followed by all SC members through a constant joint learning process by considering suppliers as part of the extended company. In this case, there is an ongoing exchange with supplier because "*we have solid foundations,* [and] *sustainability is so critical during this crisis.* [...] *It has become even more critical* [to their long-term vision of business] *and that's what we discuss and share with our suppliers" [9a]*.

Beyond the supplier support actions just outlined, case 7 illustrates how transparency actions, such as social audits, needed to evolve during the turbulence. Like other competitors, the case firm relies on industry-wide acknowledged social audits whenever available. This is an efficient and control-based approach applicable in stable times. Facing however a pandemic and the – previously unthinkable – disruption of textile brands' production orders, the previous audits were outdated both in terms of results and scope. Considering the planning of new orders in the face of uncertain demand on the one hand, and the known need of suppliers to either produce or fire their staff on the other, case 7 engaged in a revised transparency process. This process aimed to explore if the suppliers were able "*to wait another month* [for new orders] *without compromising on the social conditions of workers*" *[7a]*. By doing so, new supplier actions as well as transparency requirements related to supplier stakeholders were established because of the social sustainability orientation of the firm. During future demand fluctuations, case 7 will now be able to take responsible action that ensures the sustainability of its SC alongside its production capacity. These examples show how exploration learning based on SC sustainability actions can inform SCRes and sustainability trajectories during the pandemic.

5. Discussion

This paper investigated how firms' sustainability actions affect their SCs' resilience and sustainability trajectories in turbulent environments. It thus addresses a set of knowledge gaps and contributes to theory and practice as outlined below.

5.1 Theoretical contributions

By answering our research question "*how do firms' sustainability actions affect their SCs' resilience and sustainability trajectories in turbulent environments?*", we provide a better understanding of the link between SCs**'** sustainability actions and resilience, which is still underdeveloped in literature (Negri *et al.*, 2021). Moreover, this research responds to existing calls for theorizing on COVID-19 (Chowdhury *et al.*, 2021). In doing so, we explored the SC learning perspective to understand how the 31 SC actions related to sustainability helped to build SCRes. Our findings show that a link exists between SC sustainability actions and SCRes, therefore this study is among the first to provide case-based evidence and reasoning on the adoption of engineering, ecological and social-ecological resilience in a SC context. Section 4.2 characterizes the single SCRes approaches based on the conceptual distinction of the control and efficiency-orientation of the engineering approach, the adaptive and flexible nature of the ecological approach, and the more systemic and collaborative focus of the social-ecological approach.

Beyond this distinction, there is a need for further debate moving beyond the previously mainly conceptual elaborations on SCRes (Adobor and McMullen, 2018; Wieland and Durach, 2021). Based on an application of the SC scales proposed by Novak *et al.* (2021), we found that the SC sustainability actions in turbulent environments are exercised within the same scope of SC scales as previous SC sustainability experience. Consequently, we propose that the adoption of a certain SCRes approach relies on how sustainability is embedded in a firm.

First, the engineering approach enables the intended bouncing-back and the efficient control of a turbulence by stabilizing the pre-turbulence SC actions throughout the incident. Our findings show that this is realized by reducing the SC parts to be monitored and raising the frequency as well as intensity of control actions within these parts. While this reduced focus seems to be a natural reaction to the stress caused by a turbulence, we moreover show that this reduction at the same time limits what the SC can learn from the turbulence. A bouncing back focuses on minimized risks, but in turn offers also minimized potentials for long-term resilience and sustainability gains.

Second, the ecological approach is sensitive to temporary functional changes in the SC and covers actions that aim to adapt the SC to these changes. In some sense, ecological actions also aim to bounce-forward, but they apply to cases in which unchanged SC actions would lead to detrimental outcomes and are thus not applicable. Nonetheless, we see that ecological actions push the adaptability of the SC and can thus train the SC partners for enhanced cooperation and flexibility after the turbulence. They thus provide some learning that enables enhanced resilience and sustainability of the SC in the longer run. Moreover, our results indicate that an ecological approach also considers supplier or customer interests and can thus build trust and commitment in the SC that can be leveraged in future crises. Therefore, it seems beneficial to us if SC risk and sustainability managers prepare alternative functional set-ups within their existing SC networks to address future turbulences.

Finally, the social-ecological approach actions acknowledge that the turbulence has revealed some SC learning that require SCRes to go beyond previous SC actions, i.e., functional set-ups, and consider a wider set of SC stakeholders. Moreover, this learning indicates that the required changes are long-lasting and thus require an evolution of previous SC actions as suggested by Adobor and McMullen (2018). Even more than the ecological approach, the social-ecological approach is found to strengthen the trust and cooperation ties between a wider set of SC members, which can be seen as an investment into the future development of the SC. This holds at least in terms of resilience and sustainability on which the actions immediately aim but can also be leveraged to explore cooperation with new partners, i.e., on a wider spatial SC scale, and to explore new or updated SCM actions and routines, i.e., enhancements on the functional SC scale.

Overall, we find that the focus on exploitation learning in the engineering SCRes approach can reinforce the inertia associated to the adoption of new and more sustainable SCM actions (Roy *et al.*, 2018) which could likely limit future SC learning. Beyond this, the combination of mainly exploitation and some exploration learning in the ecological SCRes can be seen as a first, but limited, instance of overcoming this inertia. Finally, we find the social-ecological SCRes approach to be based on extensive sustainability-related strategies for which the adoption inertia has been overcome years ago already. In effect, we expect the latter two SCRes approaches to enable both exploitation and exploration learning in the future.

We thus contend that the catalytic effect of a turbulence can only be fully leveraged if an organization has previously prepared for this by implementing related strategies and resources.

Turning to the SC scales by Novak *et al.* (2021), we theoretically framed the pandemic as a complex multi-scale event. More precisely, we demonstrate that SC sustainability learning is affected by the particular resilience approaches mobilized, which rely on spatial, temporal, and function factors. We found that SCRes capabilities (Pettit *et al.*, 2010; 2013) are directly connected with learning through exploitation and exploration (March, 1991). A related debate was developed by Pereira *et al.* (2021) who studied suppliers' learning to cope with the pandemic. In our study, this happened differently per cases and actions, which aligns with the proposal of Silvestre *et al.* (2020) and Cormack *et al.* (2021).

Some cases have their actions moving in journeys shaped by the SCRes approach used to face the turbulence. Therefore, our results presented in Section 4.3 provide insights on how the SC sustainability trajectories of our cases were affected by the pandemic. We found three paths: flat, flat ascending, and ascending SC sustainability trajectories. They are directly affected by how SCRes is learned and applied by each case in their sustainability journey. In this sense, we illsutrate that SCs' sustainability and resilience overlap and interchangeably provide inputs to enhance each other's performance (Fahimnia and Jabbarzadeh, 2016; DesJardine *et al.*, 2019; OECD, 2020; Paul *et al.*, 2021; Sarkis, 2021).

5.2 Managerial contributions

Despite the conceptual calls for the adoption of ecological and social-ecological SCRes approaches (Adobor and McMullen, 2018; Wieland, 2021; Wieland and Durach, 2021), we find that managers mainly adopt an engineering approach in the face of a multi-scale turbulence, such as COVID-19. This is to a certain extend a natural reaction to the complexity of the turbulence since the engineering approach focuses on the reduction of SC scale and exploitation of the SC capabilities leveraged to establish SCRes. Our study provides managers with a more nuanced and diverse set of SC sustainability actions to be considered and guidance on how to reflect on managerial actions as well as how to enlarge the SC scale focused. However, a move towards ecological or social-ecological SCRes approaches is not easily done, requiring that firms establish and exercise related strategies and resources well before the turbulence. This also holds for a move beyond the investigation of purely economic SC actions into social and environmental SC sustainability actions for which our results evidence resilience benefits from taking a TBL approach to SCRes.

Consequently, our findings help managers to simultaneously cope with two key challenges of SCM to date: Facing a complex and dynamic turbulence like the COVID-19 pandemic and its resulting erratic supply and demand patterns, while at the same time managing SC stakeholders' increasing SC sustainability demands (Bateman *et al.*, 2021; Hajmohammad *et al.*, 2021). As a baseline implication, we find that long-term investments in exploration of for example sustainability, integrating wider spaces in the SC, and preparing for at least temporal shifts in functional set-ups offer substantial potentials to enhance SCRes and sustainability before and during a turbulence. To embrace a comprehensive sustainable SCM perspective on SCRes, we thus propose managers to consider moving beyond the control-oriented engineering resilience approach towards larger SC scales, by adopting a social-ecological resilience approach.

Finally, a managerial contribution arises from our findings on a strong institutional environment, like the EU, as a part of the functional scale contingency for the adoption of the efficiency-based engineering approach. This strong institutional environment and its beneficial impact on the suppliers' resilience during the turbulence of the COVID-19 pandemic can be seen as an argument for managers that balances the operational costs of EU suppliers (Klymenko and Lillebrygfjeld Halse, 2021).

6. Conclusion

In this study, we linked SC sustainability actions and SCRes approaches through a SC learning perspective. We found a somewhat circular relationship in which pre-turbulence sustainability experience shapes the actions and learning during the turbulence, i.e., a time of stress, in which firms focus on the core of their pre-turbulence experiences. The latter then shapes the development of the SC over time and can thus enable or limit the SC's progress to resilience and sustainability. Turbulent environments in SCs require that companies adapt according to the existing resources and strategies to first establish and ensure their resilience and second move forward from this basis.

Our multi-case study is among the first to provide empirical evidence on how SC sustainability actions can enhance SCRes capabilities by adopting either an engineering, ecological, or social-environmental SCRes approach. Our findings propose contingencies on SC scales in terms of space, time, and function for the adoption of the three approaches which can guide future research and practice. This paper thereby contributes beyond the COVID-19 pandemic context, as the introduction of SCRes approaches can be debated in relation to other vulnerabilities or disruptions.

The same perspective can be applied to the use of SC scales to understand different SC disruptions using a sustainability perspective or not.

Four main limitations of the study need to be acknowledged that can simultaneously guide future research.

First, the data collection concentrated exclusively on European firms limiting the scope of the findings mainly to this context. Managers outside of Europe need to compare the turbulence and the functional set-ups they faced to European ones to judge the applicability of the findings to their firms. Future research could thus investigate case firms and their SCs outside Europe or better in multiple regulatory, i.e., functional, contexts. Interesting extensions could consider the USA with its less protective labor rights while having otherwise relatively well comparable development and economic indicators. Southeast Asia and especially China also present relevant investigation contexts, due to their role as global manufacturing and logistics hubs that link through their SCs to virtually any context and industry globally.

Second, the cases encompass one firm per SC providing information of the SC as a whole. This creates some bias for the validity of the information on suppliers and customers. Nevertheless, the study focus, i.e., the SC actions could be captured directly from the informants involved in their execution. Moreover, three of the ten cases are based on single interviews, despite many efforts to collect more interviews from these cases. This causes some degree of single-source bias although the majority of cases relys on multiple interviews. Future studies could enlarge the data collection to multiple interviews per firm in dyads or triads of SC partners to capture their interaction and development in more detail. Additionally, future research could further develop the contingency factors into more fine-grained scales going beyond our basic notions of existing vs. non-existing or high vs. low.

Third, the deductive coding in the data analysis adopts pre-defined concepts such as the SCRes approaches that have not been extended and could thus limit our analysis to these concepts potentially bypassing others. Consequently, future research could broaden the investigation by adopting further concepts on SCRes and enabling capabilities or developing updated frameworks on the issue.

Fourth, similar to other studies before, we see our results potentially limited due to the fact that the investigated phenomenon is dynamic and still ongoing (Lorentz *et al.*, 2021). Despite many expectations, also during the interviews, new waves of the pandemic keep hitting globally and thus

also influence the chosen European context. Our results thus require future validation against the latest or even upcoming developments of this specific turbulence. This call for empirical follow-up and especially longitudinal studies presents our final proposed research direction.

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Tables and Figures

Table 1 – Case firm and interviewee demographics.

Case	Industry	Country	Replication logic		Interviewee(s)	Interview duration (hours)
1	Manufacturing (energy)	France	a) Medium importance industry b) High dependence on global supplies	*1a* *1b*	Business Development Manager Supplier Industrialization Manager	01:09 00:45
2	Manufacturing (energy)	Norway	a) Medium importance industry b) High dependence on global supplies	*2a* *2b*	VP Business Development Chief Commercial Officer	00:44*
3	Manufacturing (windows)	Italy	a) Medium importance industry b) Low dependence on global supplies	*3a* *3b*	Chief Executive Officer Head of SC Management	01:08*
4	Manufacturing (automotive)	Germany	a) Medium importance industry b) Low dependence on global supplies	*4a* *4b* *4c*	Senior VP Purchasing & Supplier Management Sustainability Head of the Sustainability Strategy and Projects Specialist Sustainability Strategy & Stakeholder Engagement	01:04*
5	Food	Italy	a) High importance industry b) Medium dependence on global supplies	*5a* *5b*	Sustainability Manager Supply Manager	00:55 00:52
6	Food	France	a) High importance industry b) Low dependence on global supplies	*6a*	Head of Sustainability Management	00:42
7	Textile	Italy	a) Medium importance industry b) High dependence on global supplies	*7a*	Head of Sustainability Management	02:08
8	Airline	Austria	a) Low importance industry b) Low dependence on global supplies	*8a* *8b* *8c*	Purchasing Manager Environment Manager Airbus Fleet Coordinator	00:33 00:35 00:38
9	Manufacturing (cosmetics)	France	a) Medium importance industry b) High dependence on global supplies	*9a* *9b*	Head of Sustainable Purchasing International Purchasing Manager	00:45 00:37
10	Retail	UK	a) High importance industry b) Medium dependence on global supplies	*10a*	Head of Procurement – Logistics and Supply Chain	00:48
	Total					**13:23**

*Notes: * denotes joint interviews.*

Table 2 – SC sustainability experience within cases

Case	Pre-pandemic (before the turbulence)			During the pandemic (turbulence)
	Summary SC sustainability experience	**Balance of SC sustainability dimensions**	**Key quotations from data gathered**	**SC sustainability actions**
1	The main target of this case was to manufacturer products with eco-friendly label and a wish of a greener future. With a strong 'made in France' brand, there is an interest for the case to design solutions for lower environmental impact.	Econ: high Env: high Soc: low	• *Case 1 reaches world-class Product Carbon Footprint (PCF), improving its supply chain and optimizing continuously its Life Cycle Analysis (LCA) to reduce its impact on the environment. (Webpage, 2019)* • *We consider sustainability as an environmental issue, for instance. One aspect is the carbon footprint that is required to produce all the raw materials in the value chain. [1a]*	• Regionalizing supply (in Europe) • Sourcing locally
2	For many years, the case was engaged in identifying climate technology solutions to reach a sustainable future with clean energy for all. Therefore, long-term cooperation with multiple SC players was developed.	Econ: high Env: high Soc: low	• *The solar industry will continue to experience strong growth as a key driver to de-carbonizing global energy supply. Case 5 has a unique competitive position in this market by enabling ultra-high efficiency solar cells with an inherently low carbon footprint. (Webpage 2019)* • *We are very much involved in those discussions. In particular, low CO2 footprint which is one of our big competitive advantages producing in Norway with hydropower electricity. [5a]*	• Regionalizing supply • Replacing disrupted customers
3	Case 3 is a highly vertically integrated manufacturing firm with a sustainability strategy being focused on material and process innovation for reduced environmental impact. It works as an ecological sustainability leader for its products in material efficiency as well as recyclability.	Econ: high Env: high Soc: low	• *Our aim is the following: everything we sell north of the alps is also produced north of the alps and the same for the south. [3a]* • *When we started to work on sustainability, we worked on the topic of packaging in our supply chain. [3b]* • *We can constantly improve our windows and at the same time produce them using fewer materials and less energy. For example, our frame profiles are designed so that all materials can be separated with little effort according to type. This makes them 100 percent recyclable. (Webpage, 2022)*	• Enlarging in-house production • Diversifying multiple sourcing to multiple countries • Enlarging inventories • Enlarging the scale of SC monitoring • Replacing face to face exchange to stay innovative

Table 2 (continued) – SC sustainability experience within cases

Case	Pre-pandemic (before the turbulence)			During the pandemic (turbulence)
	Summary SC sustainability experience	**Balance of SC sustainability dimensions**	**Key quotations from data gathered**	**SC sustainability actions**
4	The main target of case firm 4 in terms of sustainability focus strongly lies in environmental performance within the firm, while SC sustainability is limited to scope 3 energy savings, human rights audits and supplier self-assessments. The diesel gate scandal starting from 2015 is identified as a major push towards the (environmentally oriented) sustainability strategy.	Econ: high Env: high Soc: low	• *What we see is that the sustainability requirement of our customers have even under COVID-19 still increased, maybe the focus changed a bit more from environmental issues towards social issues like health and safety, but also regarding human rights in the in the supply chain for example. [4b]* • *Strong focus on environmental sustainability and business models realted to it, such as the transformation of mobility. This is strongly driven by the Diesel-gate scandal. For social sustainability the focus almost exclusively on internal employees and on human rights due diligence due to customer demands and regulation. [4a, 4b, 4c]* • *Social sustainability actions are limited to aid projects and global science talent scholarships both before and within the pandemic (Sustainability Report 2019 and 2021, Webpage 2021)*	• Creating a risk tower • Ensuring employee health and safety • Conducting social audits
5	Case 5 pursues a clear TBL sustainability strategy that acknowledges the firm's responsibility for the non-European farmers' wages, education, and health. For the environmental domain, the focus is more on the European suppliers and the firms European facilities.	Econ: high Env: high Soc: high	• *Sustainable supply is a strategic aim that has been underlined by founding a dedicated department in 2017. [5a]* • *Focus on environmental sustainability in production and European supplies for example through saving packaging materials. [5b]* • *Focus on socio-economic sustainability in non-European supplies such as Vanilla and cocoa though cooperation with local Foundations that provide professional and personal training and education (5a; 5b; Sustainability Report 2020)* • *Raised sustainability aims in all three dimensions for 2025: increased engagement in sustainability certification, anti-deforestation, community development (Webpage, 2021)*	• Updating risk analysis to COVID specificities • Communicating with suppliers to ensure lead times • Helping suppliers overcome COVID
6	The main target of Case 6 is to develop a sustainable value chain in different parts of the agriculture sector. There are many actions to reduce environmental impact and a	Econ: high Env: high Soc: medium	• *The suppliers' code of conduct explains the Case's 6 requirements with respect to protection of the environment and respect for social practices, working conditions, health and safety. (Sustainability Report 2019)* • *We continue with the same [sustainability] strategy that was defined in 2019. [...] there is no like major changes in the strategy at this stage. [6a]*	• Building a risk management task force • Demand shift from B2B to B2C

high working condition culture internally for its staff.

Table 2 (continued) – SC sustainability experience within cases

Case	Pre-pandemic (before the turbulence)			During the pandemic (turbulence)
	Summary SC sustainability experience	**Balance of SC sustainability dimensions**	**Key quotations from data gathered**	**SC sustainability actions**
7	Case 7 applies a full-fledged TBL approach, which is continuously developed since 2012. Both the major social and environmental issues are supervised by means of a cooperation with third-party organization to achieve an independent and professional verification and management of sustainability.	Econ: high Env: high Soc: high	• *In 2012 the Sustainability Department was established officially. […] A year later, we joined Fair Wear Foundation [social sustainability focus] and changed the Code of Conduct […] Clean Clothes Campaign [environmental sustainability focus] was our next step [7a]* • *The well-being of people is at the center of the attention of the company first, we mean everyone who is involved in making our products – not just our employees" (Webpage, 2022)* • *To monitor and limit the impact on our partners, we put in place an advanced due diligence approach. …We paid particular attention to ensuring that employment contracts were not terminated, with the emergency being used as an excuse. We recommended that communication with workers on the measures to be taken is clear and that the trade union, where present, is involved as far as possible. (Social Report 2020)*	• Reducing supplier environmental impact • Choosing other transportation modes to free lead times • Communicating with suppliers beyond control • Ensuring good working/payment conditions despite being unable to order at the same time
8	The main target of case firm 8 in terms of sustainability concerns economic survival and environmental progress. SC aspects play a subordinate role and focus on anti-corruption and human as well as labor rights commitments.	Econ: high Env: high Soc: low	• *Already 2009 our firm has agreed with the stakeholders on a climate protection strategy. The focus lies in the reduction of CO2 [and] noise emissions." [8a]* • *The firm's "Four-Pillar Sustainability Strategy" exclusively lists environmental aims (Webpage (1), 2022)* • *Suppliers are required to comply with anti-corruption measures and the ILO Declaration on fundamental principles and rights at work while there are no environmental requirements (Purchase terms, 2017; Webpage (2), 2022)*	• Re-negotiating supply contracts • Communicating with suppliers beyond control

Table 2 (continued) – SC sustainability experience within cases

Case	Pre-pandemic (before the turbulence)			During the pandemic (turbulence)
	Summary SC sustainability experience	**Balance of SC sustainability dimensions**	**Key quotations from data gathered**	**SC sustainability actions**
9	Since many years, case 9 is committed to sustainability in multiple levels. The raise of new actions are taken to ensure that sustainability is part of the SC strategy and widespread to different global SC parts. Environmental and social actions have been taken to ensure effective practice and performance over time.	Econ: high Env: high Soc: high	• *[Since 2009] suppliers are encouraged to develop carbon emissions reduction goals and [since 2013] to join the water disclosure project. (Sustainability Report, 2019)* • *[Implement sustainability] first within our operations, and after that when we are exemplary [we are] able to cascade this commitment in our supply chain with our suppliers. And that's also something very important in our vision for sustainability. We don't ask our suppliers something we are not able to meet. [9a]* • *Climate is changing considerably the capacity to guarantee the sourcing of some raw material, and it becomes a competitive advantage for Case 9 to secure some supply chains by doing [social sustainability]. [9b]*	• Sourcing locally • Conducting social audits • Extending long-term cooperation • Supporting suppliers to ensure their sustainability and employment
10	As a retailer this case is caring on how to manage multiple suppliers mainly in terms of social compliance. There are many environmental rules to be followed as well, but in general it seems that the relationship with suppliers are more transactional and more related to requirements.	Econ: high Env: medium Soc: high	• *We strive to be a fair partner – paying a fair price to suppliers, supporting local communities and ensuring good working conditions for everyone working in our business and supply chains. (Webpage, n.p.)* • *Sustainability for us is maintaining, access to goods, but being able to move around quickly and also where we've got a strategic aim to source from a particular location, for example bananas from Africa or South America citrus groups, because when we source from those locations, we tend to put a lot more emphasis on checking company credentials. [10a]* • *They [investors] don't necessarily correlate CO2 reduction and wheels off the roads as sustainability. What they focused more on is packaging. They tend to focus more packaging and focus more on the community. [10a]*	• Conducting social audits • Establishing home delivery and community support • Supporting suppliers to ensure their sustainability and employment

Table 3 – Cross-case analysis of supply chain resilience approaches

	Case	SCRes capabilities	Main characterization of the cases' SC sustainability actions within the SC scales		
			Spatial scale	**Temporal scale**	**Functional scale**
Engineering SCRes approach	**1**	Flexibility in sourcing	Firm level	Short-term actions	Reinforcing pre-pandemic functional set-ups
	2	Flexibility in sourcing Adaptability Visibility	Firm level	Short-term actions	Reinforcing pre-pandemic functional set-ups
	3	Capacity Flexibility in sourcing Anticipation Visibility Collaboration	Firm level	Short-term actions	Reinforcing pre-pandemic functional set-ups
	4	Adaptability Anticipation Visibility	Supply chain level	Short-term actions	Reinforcing pre-pandemic functional set-ups
	8	Flexibility in sourcing Efficiency Collaboration	Firm level	Short-term actions	Reinforcing pre-pandemic functional set-ups
Ecological SCRes approach	**5**	Anticipation Visibility Organization	Beyond supply chain level	Short-term actions	Adapting functional set-ups
	6	Anticipation Adaptability	Supply chain level	Short-term actions	Adapting functional set-ups

	10	Visibility Adaptability Financial strength	Beyond supply chain level	Short-term actions	Adapting functional set-ups
Social-ecological SCRes approach	**7**	Collaboration Adaptability Visibility Flexibility in sourcing Financial strength	Beyond supply chain level	Long-term actions	Updated SCM processes
	9	Flexibility in sourcing Visibility Collaboration Financial strength	Beyond supply chain level	Long-term actions	Updated SCM processes

Figure 1: An integrative approach to study SCRes and SC sustainability in turbulent environments.

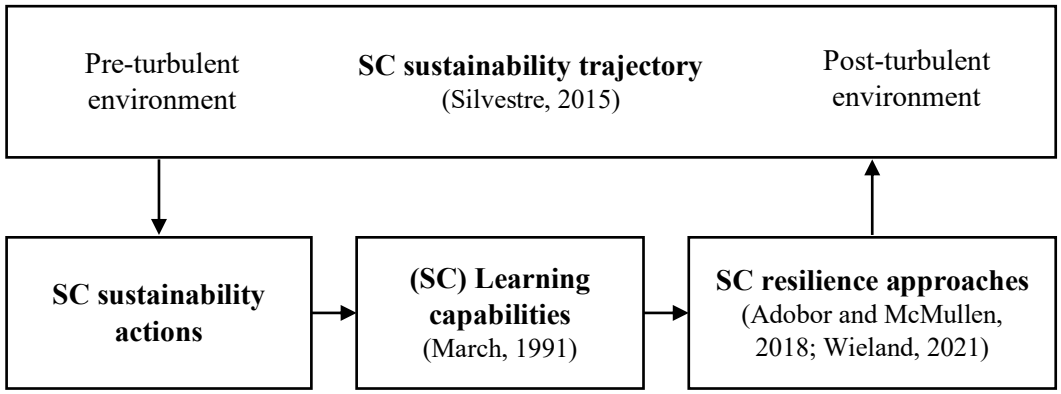

Figure 2: Case wise plot of SCRes learning throughout the SC sustainability trajectories