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Looking inside the panarchy: reorganisation capabilities for food supply chain resilience against geopolitical crises

Ceren Altuntas Vural
Department of Technology Management and Economics, Chalmers University of Technology, Gothenburg, Sweden
Gokcay Balci
Institute for Transport Studies, University of Leeds, Leeds, UK
Ebru Surucu Balci
Business Analytics, Circular Economy and Entrepreneurship, School of Management, University of Bradford, Bradford, UK, and
Aysu Gocer
Department of Logistics Management, Izmir University of Economics, Izmir, Turkey

Abstract

Purpose – Drawing on panarchy theory and adaptive cycles, this study aims to investigate the role of reorganisation capabilities on firms' supply chain resilience. The conceptual model underpinned by panarchy theory is tested in the agrifood supply chains disrupted by a geopolitical crisis and faced with material shortage. The study considers circularity as a core reorganisational capability and measures its interplay with two other capabilities: new product development and resource reconfiguration capabilities to achieve supply chain resilience.

Design/methodology/approach – A quantitative research design is followed to test the relationships between circularity capabilities, resource reconfiguration capabilities, new product development capabilities and supply chain resilience. A cross-sectional survey is applied to a sample drawn from food manufacturers who are dependent on wheat and sunflower oil as raw material and who are faced with material shortages in the aftermath of a geopolitical crisis. Measurement models and hypotheses are tested with the partial least squared structural equation modelling (PLS-SEM) based on 324 responses.

Findings – The results show that new product development and resource reconfiguration capabilities fully mediate the relationship between circularity capabilities and supply chain resilience. In other words, the food producers achieved supply chain resilience in response to agrifood supply chain disruption when they mobilised circularity capabilities in combination with new product development and resource reconfiguration capabilities.

Practical implications – The findings suggest that producers in the agrifood industry and even those in other industries need to develop circularity capabilities in combination with new product development and resource reconfiguration capabilities to tackle supply chain disruptions. In a world that is challenged by geopolitical and climate-related crises, this means leveraging 3R practices as well as resource substitution and reconfiguration in new product development processes.

Originality/value – The study explores the release and reorganisation phases of adaptive cycles in a panarchy by analysing the interplay between different capabilities for building supply chain resilience in response to disruptions challenging supply chains from higher levels of the panarchy. The results extend the theoretical debate between circularity and supply chain resilience to an empirical setting and suggest the introduction of new variables to this relationship.

Keywords Circular economy, Panarchy theory, New product development, Resource reconfiguration, Adaptive cycles, Resilience, Food industry, Supply chain disruptions

Paper type Research paper

1. Introduction

Extant research has focused on discovering how supply chains (SC) prepare, respond and recover from the disruptions that shape their external environment (Pettit *et al.*, 2010; Ponomarov and Holcomb, 2009; Christopher and Peck, 2004;

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Jüttner and Maklan, 2011; Sheffi, 2005). However, particularly after the COVID-19 pandemic, scholarly attention turned towards understanding how SCs should continuously transform to become more resilient in a multi-layered, dynamic environment (Wieland, 2021; Sarkis *et al.*, 2020a; Sodhi and Tang, 2021; El Baz and Ruel, 2021). The resource and material shortages triggered by the pandemic revealed the vulnerability of the highly interdependent and overconnected global SC structures (Mena *et al.*, 2022). On the other hand, the turbulent post-pandemic era is characterised by concurrent disruptions caused by geopolitical crises, economic sanctions, trade wars and logistics bottlenecks, all resulting in a shortage economy (Ivanov and Dolgui, 2022). SCs must dissolve former structures, reorganise, reconfigure and develop new capabilities for continuous adaptation and transformation in response to these disruptions.

Geopolitical disruptions are characterised by wars, terrorist acts, conflicts or disputes between nation-states that affect the course of peaceful relations (Caldara and Iacoviello, 2018), which in turn hinder the smooth flow of goods and services in global SCs. In a recent review, Bednarski *et al.* (2024) list BREXIT, China's Belt and Road Initiative, US-China trade wars and national regulations against the COVID-19 pandemic as major geopolitical disruptions affecting global SC flows. During the aftermath of these events, the Russia–Ukraine War (Alam *et al.*, 2024) and the Red Sea crisis (Politico, 2024) exacerbated SC disruptions. Geopolitical crises result in compounding pressures (Roscoe *et al.*, 2022) that manifest in the form of delays, interruption of logistics networks and increased costs due to tariffs and resource shortages (Bednarski *et al.*, 2024). The ripple effects from these concurrent crises indicate a long-lasting shortage economy where labour, capital, energy, materials and component supplies will continuously be disrupted, and further research is required to understand reconfigurable SCs to achieve supply chain resilience (SCRES) (Ivanov and Dolgui, 2022).

Among these geopolitical crises, the Russia–Ukraine War has triggered severe pressure on agricultural commodities (Li and Song, 2022). Russia and Ukraine collectively produce approximately 30% of global grain exports and 65% of sunflower exports (Aminetzah and Denis, 2022), creating a significant dependence on these countries for continuous supply. Approximately 50 countries rely on Ukraine and Russia for at least 30% of their wheat imports, while 26 countries import more than 50% of their wheat from these two countries (FAO, 2022). According to a study conducted by Mottaleb *et al.* (2022), a 50% decrease in wheat exports from Russia and Ukraine might increase food manufacturers' costs by about 15%. On the other hand, geopolitical crises are not the only ones posing a threat to agrifood SCs. While their seasonality and perishability further complicate these SCs, agrifood output is also severely affected by climate change, extreme temperatures and its negative consequences on global food harvest (The Economist, 2022). These conditions, exacerbated by geopolitical conflicts (Qin *et al.*, 2023), resulted in an increase from 135 million to 345 million in the number of people facing acute food insecurity since 2019 (WFP, 2022).

Agrifood SCs, threatened by natural resource scarcity due to climate change and raw material shortages due to geopolitical tensions, exhibit the interconnectedness of multi-layered systems. The socio-ecological approach to SCRES acknowledges this multi-layered structure by borrowing from panarchy theory and investigates the interplay between the planetary, political-economy and the SC levels (Wieland, 2021). According to this view, SCRES is about the SC's transformability after absorbing the disturbance's impact for a certain period (Holling, 1996; Wieland, 2021). Hence, the resilience of agrifood SCs that are being disrupted by the pressures posed by the multiple layers of panarchy is shaped by their abilities to adapt and transform to new conditions.

Previous research reveals how resource dependencies increase during disruptions (Spieske *et al.*, 2022) and uses resource dependence theory (RDT) to explore how buffering and bridging strategies are used to reduce or manage these dependencies (Kalaitzi *et al.*, 2018, 2019). The literature suggests digital dynamic capabilities (Belhadi *et al.*, 2024), relocation and SC redesign (Roscoe *et al.*, 2022; Bednarski *et al.*, 2024), technology (Bednarski *et al.*, 2024) and circular economy (CE) (Nygaard, 2023) as strategies to tackle with resource shortages caused by geopolitical disruptions. Other studies use panarchy theory to study the different adaptation phases during a disruption. Vega *et al.* (2023) investigate the ambidexterity capabilities that are mobilised during different phases of the adaptive cycles of a panarchy, whereas Küffner *et al.* (2022) focus on the reorganisation phase and unlock the different buffering and bridging strategies used by automotive companies in response to material shortage. Several gaps remain unexplored, though.

Firstly, strategies such as geographical diversification, relocation (Roscoe *et al.*, 2022) or supplier diversification (Küffner *et al.*, 2022; Spieske *et al.*, 2022) might not be feasible for certain contexts such as agrifood SCs where the raw materials are geographically concentrated at particular regions (Liu *et al.*, 2023). Besides, these structural changes are quite costly and can be accomplished only in the long term (Attinasi *et al.*, 2023). In this case, localised solutions like CE might be needed. CE has been suggested as a measure to improve the resilience of SCs (Sarkis, 2021; Wieland *et al.*, 2023; Rogan *et al.*, 2022; Nygaard, 2023), but the empirical relationship between the two is yet to be explored. Although without referring to CE, Bell *et al.* (2013) have proposed closed-loop SCs (CLSCs) as a strategy to respond to resource scarcity and material shortages. Kalaitzi *et al.* (2018, 2019) unpacked how CLSC activities, such as recycling or resource recovery, are applied within supplier–buyer relationships as buffering strategies to achieve resource efficiency and competitive advantage. However, circularity as an internal firm capability is yet to be studied as an antecedent of SCRES, neither in isolation nor in combination with other firm capabilities.

Secondly, the literature calls for more empirical and contextual research addressing geopolitical disruptions and material shortages. Further research is required to understand how SCs can transform into more resilient entities in response to the larger crises, particularly geopolitical ones, we are facing after COVID-19 (Wieland, 2021). Bednarski *et al.* (2024) particularly underline the need to study firms with SCs strongly dependent on Ukraine or Russia and how they maintain SC continuity during an armed conflict. Alam *et al.* (2024) also point out the need to study grain SCs and how to manage the ripple effects of disruptions on these chains. Last but not least, Kalaitzi *et al.* (2019) state that studies about SC strategies to manage resource scarcity are usually conceptual, thus calling for more empirical research.

Departing from this discussion, this study aims to investigate the role of reorganisation capabilities on firms' SCRES. The conceptual model is informed by panarchy theory and underpinned by the adaptive cycles, particularly the reorganisation phase of the adaptive cycles. The relationships in the model are tested in the context of agrifood SC disruption when the Ukraine–Russia War threatened the smooth flow of grain and seeds. Panarchy theory is relevant in this context as agrifood SCs are already under the impact of the climate crisis, which is putting pressure on them from the planetary layer (Wieland, 2021; Rogan *et al.*, 2022). On the other hand, the Ukraine–Russia War and the associated geopolitical crisis negatively impacted the political-economic layer (Alam *et al.*, 2024). When these pressures trigger raw material shortages in agrifood SCs, they are pushed towards the release and reorganisation phases of adaptive cycles, and they need to mobilise certain reorganisation capabilities to overcome the crisis.

In our model, we introduce circularity capabilities (CCs), resource reconfiguration capabilities (RRCs) and new product development capabilities (NPDCs) as reorganisation capabilities and we theorise on their interplay to enhance resilience at the SC level. Our results show that NPDCs and RRCs fully mediate the relationship between CCs and SCRES. In other words, the food producers were able to achieve SCRES in response to agrifood SC disruption during a geopolitical crisis when they mobilised CCs in combination with NPDCs and RRCs. These empirical findings provide a new explanation for the widely discussed positive relationship between CE and SCRES in the literature (Sarkis, 2021; Rogan *et al.*, 2022; Le *et al.*, 2023). We argue that CE is not the sole indicator of SCRES, but it needs to be combined with other reorganisation capabilities to achieve this outcome. Our results contribute to the SC management literature by providing insights about how to build SCRES in response to geopolitical crises (Bednarski *et al.*, 2024; Wieland *et al.*, 2023) by extending the theoretical discussion on the relationship between CE and SCRES to an empirical setting (Rogan *et al.*, 2022) and by making a first attempt in measuring the interplay between reorganisation capabilities drawing on panarchy theory and adaptive resilience cycles (Wieland, 2021). This aligns with Gebhardt *et al.* (2022), who call for using other theories to explain the nuances of the relationship between CE and SCRES more thoroughly. Findings also contribute to the literature by providing empirical evidence on how to mitigate resource shortage risks (Bell *et al.*, 2013; Kalaitzi *et al.*, 2018) and make a valuable contribution by studying grain SCs that were faced with severe raw material shortage during the beginning of Ukraine–Russia conflict (Alam *et al.*, 2024).

The rest of the paper is organised as follows. In Section 2, we lay out the theoretical underpinnings of the model by elaborating on panarchy theory and adaptive cycles. Then, we develop our hypotheses by discussing the relationship between CCs, NPDCs, RRCs and SCRES. In the Sections 3 and 4, we present our research design and our findings. We conclude with a discussion of our findings and further implications.

2. Theoretical background and hypothesis development

Geopolitical conflicts have recently been disrupting SCs following increased protectionist policies of governments such as BREXIT and trade wars between the USA and China (Bednarski *et al.*, 2024) and, ongoing armed conflicts and hostilities in different regions such as the war between Ukraine–Russia and Houthi assaults on commercial vessels around the Red Sea. These long-standing conflicts are causing shortages of critical raw materials and components as experienced in semiconductors (Tse *et al.*, 2024), cobalt supply (Liu *et al.*, 2023), helium supply (Siddhantakar *et al.*, 2023) and agrifood materials (Mottaleb *et al.*, 2022). While the literature offers various strategies and capabilities for resilience against disruptions (Han *et al.*, 2020), thorough review conducted by Bednarski *et al.* (2024) underlines long-lasting and macro-level impacts of geopolitics and suggests a special focus on the resilience of SCs when facing with geopolitical disruptions.

Studies investigating SCRES tools and strategies amid geopolitical conflict are scarce. Moradlou *et al.* (2021) document that SC managers have decided to relocate their manufacturing facilities after BREXIT. Roscoe *et al.* (2020) find that pharmaceutical companies implement several proactive strategies like dual supply of materials and reactive strategies, such as increasing stock levels and changing transport routes. Moradlou *et al.* (2024) examined how firms in the UK and the USA can be resilient against COVID-19, USA–China trade war or Brexit and suggest partitioning internal subunits, reconfiguring supplier networks and creating parallel SCs as resilience strategies. These studies suggest effective tools to build SCRES against geopolitical disruptions, yet they consider geopolitics generically without focusing on the material shortage problem.

The literature investigating SCRES against resource shortages arising due to geopolitics offers several solutions. Belhadi *et al.* (2024) find that digital dynamic capabilities can help agrifood SCs to become more resilient against geopolitical conflicts. Alam *et al.* (2024) investigate grain SC disruption due to the Russia–Ukraine conflict and find geological sourcing diversification, cashflow management and supplier clustering as enablers of resilience. Others suggest backing up suppliers, capacity agility and buffering stocks as resilience solutions to tackle disrupted resources (Bode *et al.*, 2011). Nygaard (2023) discusses the potential of CE as a tool to mitigate the risk of energy material shortages due to the Russia–Ukraine War. Departing geopolitics studies, Gebhardt *et al.* (2022) find that circularity can reduce resource dependencies in SCs.

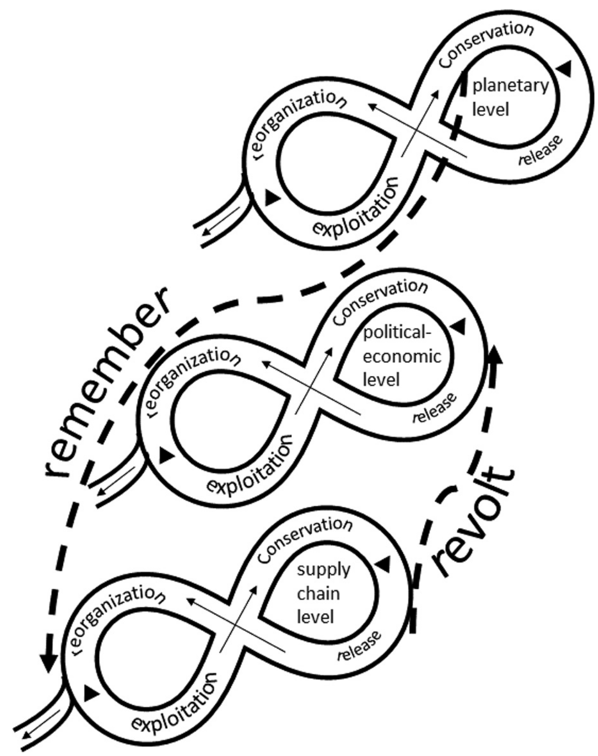
Circularity, indeed, can be a solution to withstand material shortages. Product or process redesign that reduces and substitutes scarce resources or recycles, reuses and remanufactures existing resources would enhance resource efficiency by creating buffers (Kalaitzi *et al.*, 2019). However, this requires firm-level operational competencies that enable a comparative resource advantage (Bell *et al.*, 2013) where former resources are released, reshuffled, transformed and reorganised to adapt to the shortage conditions and transform into a better state. Panarchy theory offers such a dynamic approach to SCRES that fosters adaptive responses to change by expanding on the concept of SCs as complex adaptive systems embedded in interconnected, multi-layer adaptive cycles (Wieland, 2021). In this respect, the panarchy perspective is used in line with the aim of this research as it enables building on the environmental dynamics that shape a SC (Azadegan *et al.*, 2013) and focusing on how organisations strategically release and reorganise resources to achieve transformative SCRES (Wieland, 2021; Mirzabeiki and Aitken, 2023). In our study, the environmental dynamics are the planetary pressure imposed through the climate crisis and the geopolitical disruption caused by the Ukraine–Russia War, where both are causing raw material shortages for agrifood SCs and require a transformative change.

The theoretical background of the study is underpinned by panarchy theory. There are other theories that focus on the complex dependencies within SCs. For instance, RDT posits that the organisations are under pressure of reciprocal interdependence with the parties in its environment for the provision of vital resources, and these resource dependencies are managed by intra- or inter-organisational arrangements for mitigating power imbalances and mutual dependencies (Pfeffer and Salancik, 2003; Casciaro and Piskorski, 2005). Market power is achieved through stabilised resource flows, which in return ensures survival and sustainable growth (Pfeffer and Salancik, 2003; Hillman *et al.*, 2009) and improves resilience to material scarcity and shortages (Bell *et al.*, 2013; Kalaitzi *et al.*, 2018, 2019). A stability motive shapes the strategic responses to disruptions through buffering and bridging (Bode *et al.*, 2011; Spieske *et al.*, 2022) rather than by a transformation motive towards the transition to a new state along an adaptive cycle (Wieland, 2021). Panarchy theory provides the opportunity to recognise and manage the dependencies existing with multiple environmental contingencies, or the "multiplexity" of these relationships (Hillman *et al.*, 2009) by reinterpreting the SCs as socio-ecological systems embedded in a multi-level structure. In contrast to the classical theories, panarchy theory sees the SC linkages as a core feature that allows the system to increase its internal controllability by accumulating structural capital that is periodically released and reorganised to activate evolution through adaptive cycles (Holling, 2001; Mirzabeiki and Aitken, 2023; Wieland, 2021)

2.1 Panarchy theory and adaptive resilience cycles

The basic premise of panarchy theory resides in the ecological resilience thought and "the nested set of adaptive cycles operating at distinct scales" (Holling, 2001). SCs are socio-ecological complex adaptive systems (Rogan *et al.*, 2022) that co-evolve with the unpredictable world surrounding them. The adaptive cycles of a panarchy (Holling, 2001; Gunderson and Holling, 2002) provide a valuable framework for understanding how complex adaptive systems like SCs react, adapt and transform (Adobor, 2020; Wieland, 2021) in response to disruptions or environmental dynamism (Azadegan *et al.*, 2013) that is pushing for change. Wieland (2021) uses the four phases of these adaptive cycles to explain SCRES from an ecological resilience lens (Figure 1). This work describes the first two phases of exploitation and conservation as the stages where the SC accumulates materials, labour and other resources and builds a SC based on them. In time, this creates a lock-in effect on the accumulated resources and contracted relationships, resulting in over-connectedness and vulnerability

Figure 1 Nested set of adaptive cycles



Source: Based on Holling (2001) and Wieland (2021)

to external shocks. When the SC can no longer withstand these shocks, the release and reorganisation of resources begin.

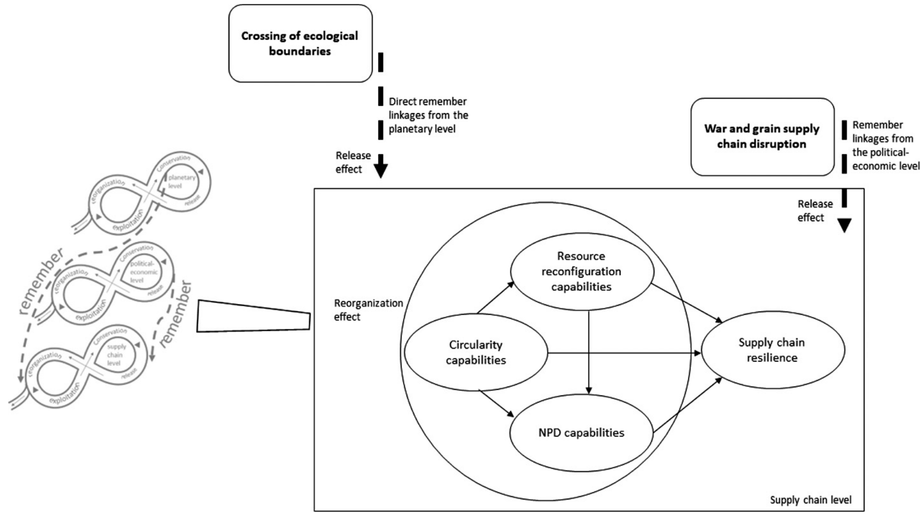
The release phase of adaptive cycles occurs when existing SC structures are dissolved (Wieland, 2021), and the accumulated SC capital in structural configuration and relationships is released and redistributed (Mirzabeiki and Aitken, 2023). The reorganisation phase occurs when existing resources are reshuffled alone or combined with new resources and relationships (Holling, 2001). According to Holling (2001), the first two phases (front loop: exploitation and conservation) maximise accumulation and production, whereas the second two (back loop: release and reorganisation) maximise invention and reassortment. This research focuses on the back loop, release and reorganisation phases under the impact of cross-level, "remember" and "revolt" linkages in a panarchy.

2.2 Release and reorganisation phases to build SCRES: a theoretical model

From this theoretical discussion, we zoom in to the SC level in a panarchy under the influence of cross-level remember linkages, which impose a release effect on existing configurations. We investigate how reorganisation manifests at the SC level to achieve resilience (Figure 2).

The upper side of the figure illustrates the remember linkages coming from the higher levels of the panarchy that set the conditions of the context we study. Global warming and crossing of ecological limits take place at the planetary level and put pressure on linear SCs via a direct remember linkage, causing raw material shortages and pushing for a transition to

Figure 2 Theoretical model



Source: Authors' own work

circularity (Wieland, 2021; Adobor, 2020; Rogan *et al.*, 2022). On the other hand, the wars and political conflicts taking place at the political-economic level disrupt trade and production, which results in a lack of material availability and unstable flows at the SC level. The ongoing war in Ukraine triggered the disruption in agrifood SCs. It pushed for a release effect in these chains operating in their conservation phase, where they heavily depended on wheat and sunflower oil as raw materials (Aminetzah and Denis, 2022). The theoretical model builds on the response from the SC level to these remembered linkages: transition to circularity on one side and SCRES practices on the other side and unpacks the reorganisation capabilities required to link these two ends.

While the existing SC structures dissolve during the release phase, the reorganisation phase is characterised by new ideas and innovation and these structures move towards renewal (Adobor, 2020). It is described as a reshuffling of resources, reassortment, change and variety (Holling, 2001). Based on the former literature that underlines the potential of CE activities to respond to resource scarcity or shortages (Bell *et al.*, 2013; Kalaitzi *et al.*, 2018, 2019) and to enhance SCRES (Wieland *et al.*, 2023; Rogan *et al.*, 2022), the study considers circularity as a core reorganisational capability. CCs, such as resource substitution from localised by-products or recovered waste, can lead to the availability of alternative and close supply sources (Sarkis *et al.*, 2020b), thus supporting and mitigating the negative impacts of resource shortages. On the other hand, the reorganisation phase in a panarchy requires innovatively combining existing and new resources (Holling, 2001), which calls for the inclusion of RRCs (Queiroz *et al.*, 2022) into the inquiry. In addition, restorative design, which is a fundamental CE principle (Ellen MacArthur Foundation, 2013), can, for instance, be leveraged by new product development (NPD) practices in an organisation (Pinheiro *et al.*, 2018; Kamp Albæk *et al.*, 2020). We group CCs, RRCs and NPDCs as reorganisation capabilities in a panarchy and investigate the interplay between them to achieve SCRES.

Scholars have been advocating the potential of CE to achieve improved SCRES (Wieland *et al.*, 2023; Rogan *et al.*, 2022) through resource substitution from localised by-products or recovered waste (Sarkis *et al.*, 2020b). Former literature acknowledges the potential of circularity practices such as recapturing and recovering scarce resources to mitigate the risks of shortages and even create a comparative advantage (Bell *et al.*, 2013). Particularly in the case of geopolitical threats, recycling, substitution and close collaboration with suppliers for these causes emerge as relevant buffering and bridging strategies that help to reduce dependence (Kalaitzi *et al.*, 2018). On the other hand, recent research suggests that CE practices might increase interdependence and generate more risk, thus calling for a more nuanced understanding of the relationship between circularity and SCRES (Gebhardt *et al.*, 2022).

The transition of linear SCs to circular SCs in response to the changes happening at the planetary level requires the development or acquisition of specific CCs (Walker *et al.*, 2023). CE is inherently grounded in the principles of restorative and regenerative design of materials and products, minimising resource consumption and waste and investing in natural capital (Ellen MacArthur Foundation, 2013; Batista *et al.*, 2018; De Angelis, 2018). CCs address these basic principles, and they refer to the set of interrelated organisational practices which support the reducing, reusing and recycling (3R) of resources to transform the existing system into a closed-loop system (Centobelli *et al.*, 2021) and to achieve a common sustainable goal (Zeng *et al.*, 2017). As they indicate a fundamental change in the existing SC structures and require the inflow of new or alternative materials, parts and goods from multiple channels, they are labelled as reorganisation capabilities in our model.

However, CCs might not solely be adequate to achieve SCRES in this context, which is based on the ability to change some processes radically while restoring others (Craighead *et al.*, 2020) and is characterised by reassortment, change and variety (Holling, 2001). The diversified resource base through

3R activities must be realigned and restructured to cope with environmental challenges. As new circular resource pools are developed, they must be combined with existing resources (Kennedy and Linnenluecke, 2022; Vega *et al.*, 2023). The ability of organisations to combine, shuffle and reshuffle both existing and new resources is called RRC (Queiroz *et al.*, 2022). It is categorised as a reorganisation capability by definition as it aligns well with Holling's (2001) description of the reorganisation phase directly.

Finally, we introduce NPDC as the third reorganisation capability in our model. Product innovation, which is closely related to a firm's NPD practices, is one way of redefining business processes during the reorganisation phase of a panarchy towards a CE (Rogan *et al.*, 2022). NPD includes multiple innovations related to products, such as introducing entirely new products, reinventing/improving existing products to meet market needs, or introducing existing products to new markets (Durmuşoğlu, 2009). NPDC refers to organisations' ability to develop and launch new products (Ernst *et al.*, 2010) and expand their product range (Dubey *et al.*, 2021) to satisfy market needs. NPDC relates both to circularity through circular product design (Kamp Albæk *et al.*, 2020; Aguiar *et al.*, 2022) and SCRES through its ability to facilitate flexibility, responsiveness (Malhotra *et al.*, 1996) and diversification (Lin *et al.*, 2021) which are fundamental resilience enablers. Without effective NPDCs, CE initiatives might not make it to the end-product design successfully.

The theoretical model builds on the interplay between the reorganisation capabilities we defined above. In the next section, where these relationships are explained, we argue that RRCs and NPDCs operationalise CCs and enable SCRES to be achieved in response to a disturbance from the higher layers in the panarchy.

2.3 Hypothesis development

Based on our theoretical model, we hypothesise the relationships between reorganisation capabilities and SCRES. Panarchy theory and adaptive resilience cycles inform our model by setting the conditions that lead to the reorganisation phase at the SC level. We hypothesise that CC, RRC and NPDC interaction enhances firms' SCRES within this context.

2.3.1 CCs and SCRES

CE refers to a systemic shift towards reducing the use of resources, reusing them in multiple loops and recycling them to eliminate the leakage of waste (Kirchherr *et al.*, 2017), which results in narrowing, slowing and closing of resource loops (Bocken *et al.*, 2016). SCRES is the ability of a SC to respond to disruptions by adapting to and coping with changes the disruption brings while maintaining awareness and operating as usual (El Baz and Ruel, 2021). Reducing, reusing and recycling will enhance resilience in the SC against disruptions (Fisher *et al.*, 2020; Sarkis *et al.*, 2020a) through diversification of materials and resources (Walls and Paquin, 2015; Centobelli *et al.*, 2022) and supply base (Gebhardt *et al.*, 2022). Both reducing and reusing practices decrease dependency on virgin raw materials and lower the risk of material scarcity and supply shortages (Kennedy and Linnenluecke, 2022). Similarly, recycling practices reduce the dependency on virgin raw materials (Kalaitzi *et al.*, 2018, 2019) and decrease the exposure to geopolitical risks (Yamamoto *et al.*, 2022), thus enhancing SCRES.

Though the literature implies a positive conceptual relationship between circularity and SCRES (Sarkis *et al.*, 2020b; Wieland *et al.*, 2023) through mitigation of resource scarcity risks (Bell *et al.*, 2013), existing scholarly evidence provides inconclusive findings. For instance, circularity practices such as product re-design are found to enhance resource efficiency in SCs but are not directly influential on competitive advantage (Kalaitzi *et al.*, 2019). Further evidence indicated that circularity practices can increase dependence on circular SC structures and reduce SCRES (Gebhardt *et al.*, 2022). Hence, to understand the nuances between these variables, we hypothesise that CCs related to 3Rs enhance the ability of organisations to cope with SC disruptions and increase their SCRES. This leads to our first hypothesis:

H1. CCs influence firms' SCRES positively.

2.3.2 CCs and RCCs

CCs mobilised through reduce, reuse and recycle practices provide new and alternative resources. By introducing new variety, these resources enhance the ability of organisations to reshuffle and restructure their resource base. RRC refers to a firm's capacity to restructure the existing resource base or reconfigure new resources to achieve targeted opportunities (Queiroz *et al.*, 2022; Khan *et al.*, 2020). Reconfiguration is an iterative process affected by the firm's internal and external environment (Khan *et al.*, 2021). Particularly when the external environment changes because of disruptions, the firm would need more comprehensive resource renewal (Helfat *et al.*, 2009). CE practices, such as reducing virgin raw material, reusing leftover materials, recycling and reprocessing, can help achieve reconfiguration capabilities. Moreover, CE encourages a sustainable approach by strategically managing resources and reducing waste. Firms that invest in CE perform in a way that preserves and maximises the value of the resources during their life cycles (Bag *et al.*, 2019; Kennedy and Linnenluecke, 2022), ultimately benefiting firms' RRCs. Hence, we propose the following hypothesis:

H2. CCs influence firms' RRCs positively.

2.3.3 CCs and NPDCs

Many of the CCs, particularly those related to reducing practices, address product design strategies at the primary phases of the product life cycle (Bocken *et al.*, 2016; Babbitt *et al.*, 2021; Burke *et al.*, 2023). CE aims to value products, components and materials at their highest utility through restorative design (Webster, 2015) leveraged by NPD practices (Pinheiro *et al.*, 2018; Kamp Albæk *et al.*, 2020). Aguiar and Jugend (2022) suggest that transformation towards circularity could be achieved by incorporating circularity into the NPD process. Although this approach increases the complexity of the entire process compared to the conventional version, it also introduces a creative and innovative environment while increasing the environmental and economic benefits (Subramanian *et al.*, 2019). Hence, CCs might enhance the NPDCs of organisations such as the ability to expand their product range (Dubey *et al.*, 2021), improve their existing products (Durmuşoğlu, 2009) or search, collect and use information in the form of R&D practices (da Costa *et al.*, 2018). This leads to our third hypothesis:

H3. CCs influence firms' NPDCs positively.

2.3.4 RRCs and NPDCs

Organisations' ability to introduce new products to satisfy market needs depends widely on their ability to access, acquire, combine and recombine various resources. NPD creates uncertain conditions for firms as the newly introduced products might succeed or fail depending on many conditions. The ability of the firm to restructure and reconfigure its resource base during such situations of uncertainty is crucial (Sirmon *et al.*, 2007). Firms must continuously renew, augment and adapt their resources in dynamic environments to achieve superior performance. Blending different resources or transforming existing and new resources into novel resource combinations contributes to NPDC, which provides a competitive advantage (Lawson *et al.*, 2015). The ability to restructure and reconfigure resources leads to success in NPDCs (Zhang and Wu, 2017). Hence, we build our fourth hypothesis accordingly:

H4. RRCs influence firms' NPDCs positively.

2.3.5 RRC and SCRES

Structuring the resource portfolio and bundling resources in various ways is vital to not only survival but also success in turbulent environments (Sirmon *et al.*, 2007). SC disruptions create conditions that lead to resource scarcity or disturbances in processes and flows. Resource reconfiguration is vital for firms operating in scarcity situations due to disruptive events (Queiroz *et al.*, 2022). Resource realignment is pivotal in disruptions while the environment is altering (Ambulkar *et al.*, 2015). Reconfiguration and redeployment of resources enable SCs to cope with disruption impacts and recover from them (El Baz and Ruel, 2021), thereby improving overall resilience. Recombining resources during disruptions would lead to a dynamic adaptation of firms for building SCRES (Conz and Magnani, 2020), which leads to our fifth hypothesis:

H5. RRCs influence firms' SCRES positively.

2.3.6 NPDCs and SCRES

Towards and during the reorganisation phase in panarchy, resilience increases because the system opens for innovation and new opportunities emerge (Holling, 2001). If NPDCs are leveraged successfully, these new opportunities can be used to build SCRES. The diversity created by these new opportunities enables SCRES since potential gaps can be filled by a diverse range of materials and products (Walls and Paquin, 2015). Although the literature is quite limited regarding the impact of NPD on SCRES, NPDCs such as the ability to expand the existing product range through either introducing new products or making modifications to existing products and exploiting information resources through R&D activities (da Costa *et al.*, 2018; Dubey *et al.*, 2021) might allow flexibility and responsiveness to meet changing market needs (Malhotra *et al.*, 1996). Flexibility and responsiveness are the two widely referred antecedents of SCRES (Kamalahmadi and Parast, 2016). NPDCs can also influence SCRES positively by facilitating diversification in an organisation's product line and reducing dependence on specific materials and supply bases. SC disruptions impose pressure on organisations' ability to meet market needs, but firms succeeding in NPDCs could provide alternative solutions during such market conditions. Moreover, NPD is closely related to R&D activities and adopting new technologies, which is also positively associated with SCRES (Naghshineh and Carvalho, 2022). This leads to our sixth hypothesis:

H6. NPDCs influence firms' SCRES positively.

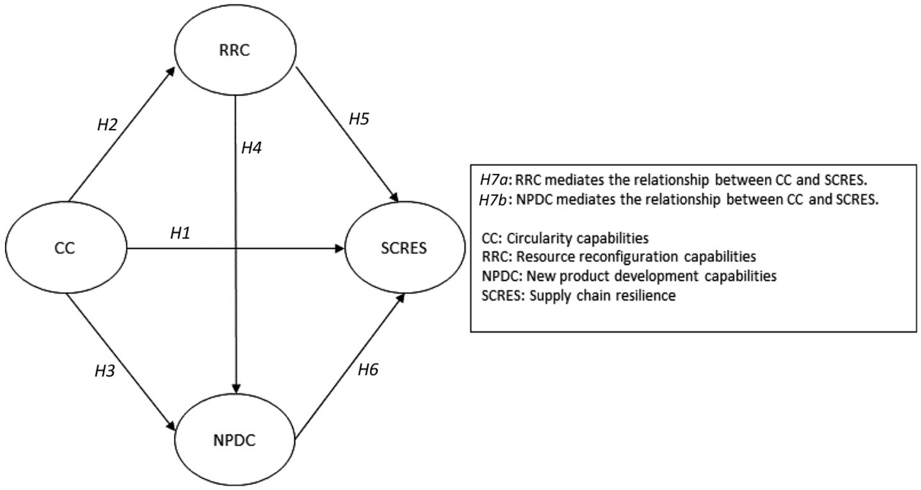
2.3.7 The interplay between reorganisation capabilities and SCRES

While CCs enable organisations to minimise their resource use, improve their production efficiency and transform their linear economic growth system into a closed loop through 3R practices (Centobelli *et al.*, 2021), these might not be adequate to achieve SCRES independently. The discussion highlighting the positive impact of both CCs and RRCs on SCRES indicates the necessity of combining such capabilities. The ability to reshuffle both existing and new resources is inherent to the reorganisation phase in a panarchy (Holling, 2001). However, Ambulkar *et al.* (2015) found that resources alone are insufficient to support resilience; they need to be combined and recombined in innovative ways. CCs provide a diverse set of alternative resources through 3R practices (Walls and Paquin, 2015; Centobelli *et al.*, 2022), which, in scarcity situations caused by disruptions, can act as an alternative resource base for resource reconfiguration practices. Resource reconfiguration enables organisations to respond quickly to changes in resource availability and environmental conditions (Khan *et al.*, 2021). Hence, we argue that, although SCRES can be achieved when CCs related to 3R practices are present, this relationship is expected to be stronger when the resources acquired from CCs are reconfigured successfully.

On the other hand, the increased risk of resource shortages requires SCs to adapt CE principles, which require system-wide innovation and unveil opportunities in the NPD process leveraged by innovative design (Burke *et al.*, 2023). Building CCs and getting access to alternative resources through reuse, reduce and recycle practices to build SCRES is not adequate. These resources should be used in NPD processes to enhance the existing product range or to offer new products to satisfy market needs.

Risks associated with critical materials are mitigated by circularity, especially when facilitated by product design activities for substitution (Peck *et al.*, 2015). This underlines the importance of aligning the NPD process with CE principles for managing risks (Nyström *et al.*, 2021; Aguiar and Jugend, 2022). Product design within NPD processes needs to be continuously adjusted to change external factors to reduce the risks triggered by the transition to CE (Nyström *et al.*, 2021) and mitigate other SC risks. Hence, although CCs related to 3R practices indicate enhanced SCRES (Fisher *et al.*, 2020; Kennedy and Linnenluecke, 2022), combining these capabilities with NPDCs would result in stronger SCRES.

Figure 3 Research model



Source: Authors' own work

Drawing on this discussion, we propose the below listed mediating relationships, which highlight the interplay between reorganisation capabilities in a panarchy and SCRES:

H7a. A firm's RRCs mediate the relationship between CCs and SCRES.

H7b. A firm's NPDCs mediate the relationship between CCs and SCRES.

Figure 3 below illustrates our research model.

3. Methodology

We followed a quantitative research design to test the relationships between CCs, RRCs, NPDCs and SCRES. The data was collected using a survey that was applied to a sample drawn from food manufacturers that are dependent on wheat and sunflower oil as raw materials. The measurement model and hypotheses were tested using the partial least squared structural equation modelling (PLS-SEM) approach.

3.1 Research context, sampling and data collection

We have tested our hypotheses in the context of wheat and sunflower oil shortage risk arising from Russia's invasion of Ukraine. Russia and Ukraine are among the largest exporters of wheat and sunflower seed, which are basic ingredients of various food products (OECD, 2022). The war poses a significant risk to food SCs, especially in particular countries, which may lack fundamental ingredients to manufacture their food products (Hellegers, 2022). The high risk of the crisis necessitates changes towards more sustainable alternative ways of consumption and production to ensure food SCRES (Ben Hassen and El Bilali, 2022; Sun *et al.*, 2022). That is, SCs should seek more circular production and alternative new products. Hence, the context is ideal for testing relationships between CE capabilities, NPDC and SCRES.

A self-administered online survey [1] is implemented for food manufacturers and processors located in Türkiye to test the research model. The sample is drawn from manufacturers that process wheat, sunflower seed and their derivatives in their production to reflect the food supply challenges resulting from the Russian invasion of Ukraine. The UN underlines wheat and sunflower seed as two primary food raw materials disrupted by the war in Ukraine (FAO, 2022; pg. 65). Türkiye is an ideal location to implement the survey as it is the third largest wheat-importing country with a very high dependence on wheat and sunflower oil from Russia and Ukraine, for example, over 85% of imported wheat and over 90% of imported sunflower oil are from these two countries (FAO, 2022). Moreover, being one of the top 10 food-producing countries in terms of gross production value (FAOSTAT, 2022), Türkiye hosts an extensive food and agriculture industry with approximately US $23bn in food exports in 2021 (TGDF, 2022). Türkiye also hosts leading international food manufacturers, including but not limited to Nestle, Unilever, Bunge, Cargill, Mondelez and Oetker.

The sampling is formed through member lists of the three largest chambers of industries (Istanbul Chamber of Industry, Aegean Chamber of Industry and Ankara Chamber of Industry). Members of these three chambers are in different regions, hence representing different geographical coverage in Türkiye. Members are first filtered through their NACE codes. Relevant NACE segments likely to use wheat and sunflower derivatives are selected (e.g. 10.41, 10.42, 10.61, 10.71, 10.72 and 10.86). Furthermore, micro- and small-sized organisations (less than 50 employees) are omitted from the list due to the lower chance of receiving high-quality responses from those organisations about circularity, NPDC and SCRES. A total of 1,228 firms are identified as the study's target population. A total of 324 responses have been collected (approx. 26% of the population). The data is collected between May and July 2022. These dates are important as, during this time, the food crisis was accelerating and grain corridor agreements were not in place.

Table 1 illustrates the respondent profiles and their firm characteristics. Results indicate that over 70% of respondents have at least seven years or more experience in the food industry. Over 80% of responses came from respondents

Table 1 Profile of respondents

Profile	Frequency	%
Age		
18–25	9	2.8
26–34	86	26.5
35–44	131	40.4
45–54	75	23.1
55 and more	23	7.1
Experience		
1–3 years	39	12.0
4–6 years	49	15.1
7–9 years	67	20.7
10 years and more	169	52.2
Department in the organization		
Top management *	71	21.9
Logistics and transport	22	6.8
Production and operations	95	29.4
Marketing	51	15.7
Procurement	74	22.8
Others	11	3.4
Number of employees		
50–249	124	38.3
250 and more	200	61.7
Food product type		
Intermediate products	66	20.4
Packed consumer products	224	69.1
Unpacked consumer products	34	10.5

Notes: *Top-level managers not being a part of a specific department, for example, country managers, regional managers, CEO or founders
Source: Authors' own work

representing managerial levels, such as general manager, production manager and sales manager, while less than 20% came from specialists, such as logistics specialists and procurement specialists. Respondents exhibit a balanced diversity in terms of departments in which they work, such as procurement, marketing, production and operations. Most of them manufacture packaged consumer food products, whereas 20% represent intermediate food production, such as cooking oil and flour and 10% represent unpacked consumer food products, such as bagels and bread.

3.2 Measurement development and research quality

This study has operationalised first-order reflective constructs adopted from the literature. The content validity of measures is checked through five expert interviews with respondents selected from the food SC industry with at least ten years of experience. Measures were found appropriate in terms of their relevance, clarity and structure. Expert interviews also helped with the selection of measurement items from relevant literature. Circular capabilities are adopted by Zeng *et al.* (2017). Seven items reflecting the most appropriate ones for food manufacturing were borrowed from the original list. Some items were eliminated to build a concise measurement instrument. For instance, repeated use of machine cleaning equipment was not deemed suitable for our research and, therefore, excluded. Another item about "enhancing energy efficiency of production equipment" was also found redundant by the experts as "reducing consumption of raw materials and energy" was believed to contain that meaning as well.

For SCRES, we borrowed the measurement items from El Baz and Ruel (2021). This part of the survey starts with a request from the respondents to consider a potential food crisis in wheat and sunflower supply arising from Russia's invasion of Ukraine while responding to the questions. This approach allows respondents to better evaluate SCRES by focusing on a clearly identified disruption. Description of the disruption is essential because disruptions vary in terms of their effects, magnitude and timespan. COVID-19, for instance, impacted food supply chain (FSCs) with demand fluctuations, lockdowns and logistics problems. On the other hand, a potential food crisis originating from Russia's invasion of Ukraine could affect FSCs by causing a shortage of raw food materials.

Items of NPDC are adopted from da Costa *et al.* (2018) and Dubey *et al.* (2021), while RRC items are borrowed from Queiroz *et al.* (2022). Unlike SCRES, these construct items are not asked to indicate a specific situation, such as an ongoing war or another disruption situation. This approach determines whether the generic NPD capability can help achieve SCRES during a specific disruption. Finally, we tested firm size as a control variable that might impact SCRES (Wong *et al.*, 2020). We have measured the number of employees for the firm size. Table 2 lists the measurement items used in the survey.

Research quality is assured by checking for content validity through expert interviews, measuring non-response bias and common method bias. Non-response bias may occur when some potential respondents do not want to participate in the survey. The survey is unlikely to suffer a non-response bias problem if there is no significant difference between early and late responses given to specific variables (Nikookar and Yanadori, 2022). We conducted an independent t-test and Levene's test of homogeneity of variances by using the first 50 and last 50 respondents as two categories of the grouping variable. The test results were non-significant (p-value > 0.05).

Common method bias may occur in survey studies when independent and dependent variables are asked in the same question form. Mackenzie and Podsakoff (2012) indicate that survey research is more susceptible to common method bias when respondents are unwilling or incapable of providing accurate answers. Several measures were taken to avoid this issue, following suggestions of Mackenzie and Podsakoff (2012). Firstly, complex and lengthy items were avoided, and the survey was kept short to ensure the respondents could answer questions without a hustle. To improve the motivation to respond accurately, respondents were informed that the survey was anonymous and the answers were to be used only for academic purposes so that they did not need to worry about confidentiality and business-related matters while responding. We did not ask them to reveal company names or any other information that might lead to tracking them to their identities. Data protection is ensured by storing results in one of the author's university databases, where strict rules are implemented through data security measures. We also tried to increase interest in the survey by underlying the significance of

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Table 2 Measurement items

Measurement items	Source(s)
Circularity capabilities (please indicate your level of agreement with the following statements)	
1 **Our firm is devoted to reducing the unit product manual input (CC1)**	Zeng *et al.* (2017)
2 **Product packaging materials are used repeatedly (deleted due to low factor loading)**	
3 **Our firm is devoted to reducing the consumption of raw materials and energy (CC2)**	
4 **Leftover material is used repeatedly to manufacture other products (CC3)**	
5 **Waste produced in the manufacturing process is recycled (CC4)**	
6 **Waste products from consumers are recycled (CC5)**	
7 **Waste is used after reprocessing to manufacture new products (CC6)**	
NPD capabilities (please indicate your level of agreement with the following statements)	
1 **We develop and manage new products well (NPD1)**	da Costa *et al.* (2018), Dubey *et al.* (2021)
2 **We exploit R&D investment to develop new products (NPD2)**	
3 **We speedily develop and launch new products (NPD3)**	
4 **We manage the overall new product development systems market well (NPD4)**	
5 **We successfully launch new products by using different / substitute materials (NPD5)**	
6 **Our organisation is actively expanding its own product range to meet the changing demands of the market (NPD6)**	
Resource reconfiguration capabilities (please indicate your level of agreement with the following statements)	Queiroz *et al.* (2022)
1 **We realign our firm resources and processes in response to environmental changes (RRC1)**	
2 **We reconfigure our resources and processes in response to the dynamic environment (RRC2)**	
3 **We restructure our resource base to react to the changing business environment (RRC3)**	
4 **We renew our resource base in response to the changing business environment (RRC4)**	
SCRES (considering a potential food crisis arising from the Russia—Ukraine War, to what extent do you agree with the following statements)	
1 **Our firm's supply chain is able to cope with changes brought by the supply chain disruption (SCRES1)**	El Baz and Ruel (2021)
2 **Our firm's supply chain is able to adapt to disruption caused by the supply chain disruption (SCRES2)**	
3 **Our firm's supply chain is able to provide a quick response to disruptions caused by the food crisis (SCRES3)**	
4 **Our firm's supply chain is able to maintain high situation awareness at all times (SCRES4)**	

Source: Authors' own work

the research and the role of their accurate responses for food SCRES amid recent disruptions. In addition to these procedural controls, we implemented statistical controls by applying Harman (1967) single-factor test. The first factor explained less than 50% (38.8.%) of the total variance explained by the model, suggesting non-bias response is not likely to impact our results. We further evaluated the model's inner variance inflation factors (VIF) as a multicollinearity test. Kock (2015) suggests that if all VIFs are equal to or lower than 3.3, the model is unlikely to suffer from common method bias in PLS-SEM models. All our inner VIFs range between 1.001 and 2.063, thus far below the recommended threshold value.

3.3 Data analysis

We used PLS-SEM (Version 4.0.9.6) to test the reliability and validity of the measurement model and examine the structural model. PLS-SEM, or variance-based SEM, is a multivariate statistical technique that explains relationships among endogenous and exogenous variables. PLS-SEM is recommended when the purpose of the study is to explore relationships between variables rather than theory confirmation or testing (Hair *et al.*, 2018). This approach fits our study because our purpose is not to validate the Panarchy theory but to explore relationships between resilience and reorganisation components by using the theoretical background of Panarchy. PLS-SEM is also helpful in the exploratory stage when the theory is still being developed (Nitzl, 2016). Panarchy theory is still developing to underpin SCRES (Wieland, 2021). Moreover, El Baz and Ruel (2021) suggest that SC risk management is somewhat arbitrary regarding the theoretical foundation. Accordingly, we have chosen PLS-SEM to explore relationships between constructs supported by a theory still in its developmental stage.

4. Results

4.1 Measurement model analysis

The measurement model is assessed considering the reliability and validity of measures. Firstly, internal consistency is assessed by checking Cronbach's alpha and composite

Table 3 Reliability, convergent validity and SFL

Construct	Cronbach's alpha	Composite reliability	AVE	SFL*	Number of items
CC	0.86	0.87	0.59	0.67–0.83	6
RRC	0.78	0.79	0.61	0.73–0.82	4
NPDC	0.84	0.84	0.55	0.72–0.76	6
SCRES	0.74	0.74	0.56	0.70–0.77	4

Note: *SFLs of each construct are significant $p < 0.001$
Source: Authors' own work

reliability scores. Values of all constructs (see Table 3) exceeded the suggested minimum threshold of 0.7 (Bagozzi and Yi, 2012). The convergent validity of constructs is evaluated considering their standardised factor loading (SFL) score, SFL significance level and average variance extracted (AVE) scores (Cheung and Wang, 2017). All SFL scores are above the suggested minimum threshold of 0.60 at $p < 0.001$ (Bagozzi and Yi, 2012), supporting convergent validity. AVE scores of all constructs also exceeded the recommended value of 0.50 (Hair *et al.*, 2018).

Finally, discriminant validity is assessed by checking whether the squared root of each construct's AVE value is higher than correlations with other constructs (Fornell and Larcker, 1981). No discriminant validity concern exists as square root AVE values are greater than correlations (see Table 4). Moreover, we implemented a heterotrait–monotrait ratio of the correlations (HTMT) to assess discriminant validity (Henseler *et al.*, 2016). HTMT values for all constructs in our model are lower than the threshold value of 0.85 (Hair *et al.*, 2018; Henseler *et al.*, 2016). Results of Fornell-Larcker and HTMT analyses demonstrate strong evidence for discriminant validity.

PLS-SEM does not depend on model fit, in contrast to covariance-based (CB) SEM (Hair *et al.*, 2019; Sarstedt *et al.*, 2014). Some other goodness of fit indices are also available for PLS-SEM, such as SRMR and rms Theta. However, the literature advises against presenting these indices because there has not been a comprehensive evaluation (Hair *et al.*, 2019). The goodness of fit indices is suggested to be presented when the study's primary goal is theory testing, like in the CB-SEM approach (Hair *et al.*, 2019; Sarstedt *et al.*, 2014). Hence, goodness of fit indices for the model are not presented in this study.

Table 4 Discriminant validity

Constructs	CC	RRC	SCRES	NPDC
CC	0.767			
RRC	0.525	0.779		
SCRES	0.433	0.562	0.751	
NPDC	0.608	0.644	0.59	0.743

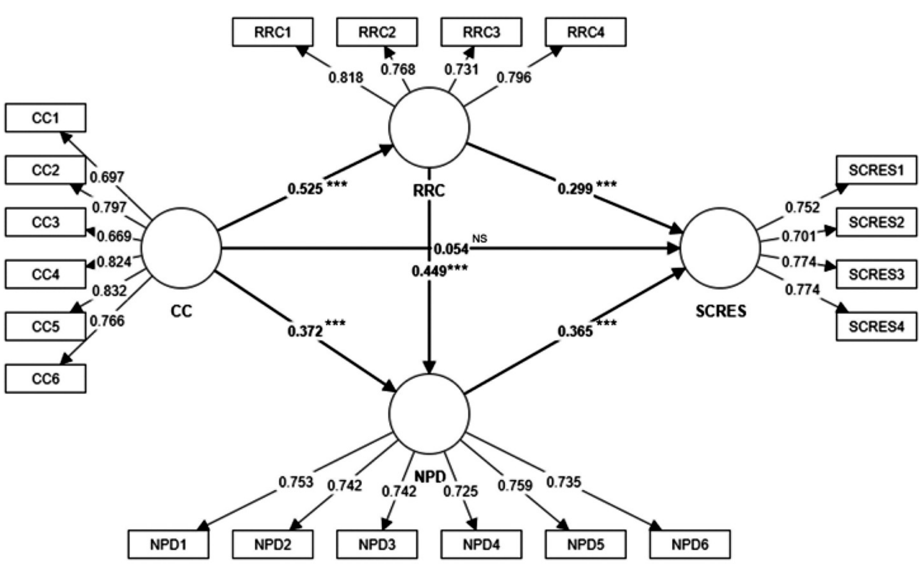
Source: Authors' own work

4.2 Structural model analysis

The structural model and path relationships (coefficients, significance levels and *t*-values) are tested using Bootstrapping with 5,000 sub-samples. Considering coefficient values and significance levels of direct path relationships (see Figure 4 and Table 5), our first hypothesis is not significant, suggesting CCs do not have a statistically significant direct impact on SCRES ($\beta = 0.054$, $p > 0.10$). CCs, on the other hand, positively influence RRCs ($\beta = 0.525$, $p < 0.001$) and NPDCs ($\beta = 0.372$, $p < 0.001$), hence confirming our second and third hypotheses. RRCs positively influence NPDCs ($\beta = 0.449$, $p < 0.001$) and SCRES ($\beta = 0.299$, $p < 0.001$), confirming H4 and H5. NPDCs positively affect SCRES ($\beta = 0.365$, $p < 0.001$), which confirms the sixth hypothesis. No significant relation exists between the control variable (firm size) and SCRES ($\beta = 0.018$, $p > 0.10$).

Our Hypothesis 7 proposed that the relationship between CCs and SCRES is mediated through RRCs (H7a) and NPDCs (H7b). The structural model in Figure 4 suggests that a full mediation effect exists. Full mediation, also called indirect-only mediation, occurs when the mediator variable fully explains the relationship between the independent and dependent variables. In other words, the effect of the CCs on SCRES becomes non-significant once mediator variables, NPDCs and RRCs, are removed. We have adopted the approach of Zhao *et al.* (2010) and implemented a bootstrapping method to test the mediation effect. 5,000 resamples are generated based on a random sampling with 97.5% level of bias-corrected confidence interval. Results indicate that the indirect relation between CCs and

Figure 4 Structural model path relations



Notes: ***Statistically significant ($p < 0.001$); NS: not significant ($P > 0.05$)
Source: Authors' own work

Table 5 Structural path relations

Path relations	β	*p* value	T value	Hypothesis
CC → SCRES *(H1)*	0.054	0.358	0.920	Rejected
CC → RRC *(H2)*	0.525	0.000	13.061	Accepted
CC → NPDC *(H3)*	0.352	0.000	6.615	Accepted
RRC → NPDC *(H4)*	0.449	0.000	7.597	Accepted
RRC → SCRES *(H5)*	0.299	0.000	3.886	Accepted
NPDC → SCRES *(H6)*	0.365	0.000	4.608	Accepted

Source: Authors' own work

Table 6 Specific indirect effects between CC and SCRES

Indirect effects	Indirect effect	T statistics	*p* values
CC → RRC → SCRES	0.157	3.525	0.000
CC → NPDC → SCRES	0.136	3.565	0.000
CC → RRC → NPDC → SCRES	0.086	3.685	0.000

Source: Authors' own work

SCRES is statistically significant ($\beta = 0.379, p < 0.001$). Table 6 presents specific indirect effects between CCs and SCRES, confirming hypotheses 7a and 7b. This result confirms the mediating relation between CCs and SCRES through NPDCs and RRCs.

Following the recommendation of Nitzl (2016), we calculated the statistical power of our model to ensure that full mediation results do not occur because of inadequate sample size. We followed Cohen's (1988) guideline to calculate a-priori minimum sample size requirement and post-hoc power analyses using Gpower software. The minimum sample size required was calculated as 119, while the post-hoc power test resulted in 0.999, well above the recommended 0.80 level.
It is also essential in PLS-SEM to report the coefficient of determination (R^2) for assessing the predictive accuracy of the structural model (Nitzl, 2016). Results show that the model has satisfactory explanatory power for SCRES ($R^2 = 0.407$, $p < 0.001$), especially considering the relatively fewer number of independent constructs of SCRES (Hair *et al.*, 2019). The R^2 could be as low as 0.10, depending on the context of the paper. The R^2 value of SCRES in our model (0.407) is similar to the results of other studies, such as Sturm *et al.* (2023), in which the R^2 value of SCRES is 0.348.

5. Discussion

Firms that try to reduce their dependencies and enhance their resilience through stabilising resource flows (Pfeffer and Salancik, 2003; Hillman *et al.*, 2009) are still exposed to multi-layered dependencies in mega disruptions. The geopolitical disruptions impacting global SCs from multiple angles and creating compounding material shortages require firms to adopt a more dynamic and transformative approach towards SCRES. This requires the mobilisation of reorganisation capabilities. Our study adopts a novel approach by empirically testing the role and interplay of reorganisation capabilities on a firm's SCRES, where the context is shaped by raw material shortage imposed through geopolitical disruption and negative climate conditions.

Panarchy theory enables viewing SCs as socio-ecological complex adaptive systems continuously evolving with nested sets of adaptive cycles operating at different scales and layers (Holling, 2001; Wieland, 2021). This perspective allows SCRES to be approached as a continuous adaptation to pressures from these distinct layers in a sporadic manner. Hence, in this study, SC pressures from different hierarchical layers motivated the use of panarchy theory and adaptive cycles approach to SCRES. Zooming into the reorganisation phase in particular, the interplay between CCs, RRCs and NPDCs was investigated to understand how these capabilities enable firms to transform and adapt to geopolitical disruptions. A structural model is built and tested using PLS-SEM to examine the relationship between CCs, RRCs, NPDCs and SCRES. We established six hypotheses for measuring direct impacts and two hypotheses to examine mediation relations. All hypotheses except for H1 suggest that CCs positively affect SCRES. CCs have a direct positive impact on RRCs and NPDCs (H2 and H3); RRCs have a direct positive impact on NPDCs and SCRES (H4 and H5); and NPDCs have a direct positive impact on SCRES. Mediation analyses confirm that CCs positively affect SCRES only through mediations of RRCs (H7a) and NPDCs (H7b). Our results confirm that circularity in isolation is not enough to achieve SCRES. However, it needs to be combined with RRCs and NPDCs to achieve SCRES during a material shortage crisis imposed by a geopolitical disruption.

These findings extend the previously proposed conceptual discussions linking CCs with SCRES through 3R practices (Fisher *et al.*, 2020; Sarkis *et al.*, 2020a; Sarkis, 2021; Rogan *et al.*, 2022) by indicating that CCs are translated into SCRES in response to material shortages when RRCs and NPDCs complement them. Pressures coming from remember linkages from the planetary and political-economic levels could cause SC disruptions, creating a risk of material scarcity and supply shortages. CE practices are already considered effective for building resilience in such situations through product and process redesign and associated reduction in dependency on scarce natural resources (Kalaitzi *et al.*, 2018, 2019), thereby mitigating the effects of geopolitical disruptions (Nygaard, 2023). However, we argue that CCs are insufficient to build SCRES when higher-level crises occur, moving the SCs into the reorganisation phase and making invention, reassortment, change and variety the priority (Holling, 2001). In that respect, it becomes highly critical to complement CCs with more innovative approaches to avoid scarcity of resources and build sustainable resilience.

Within the research context of this study, the disruption at the geopolitical level led to a high risk of wheat and sunflower seed scarcity in agri-food SCs. Although CCs, in terms of using alternative raw materials or changing product composition, could help to withstand the crisis for some time, our findings show that this is not adequate to build resilience for these food SCs. From a panarchy view, during the reorganisation phase of these SCs, it is necessary to mobilise RRCs (Queiroz *et al.*, 2022) to combine existing resources with new ones in an innovative way (Holling, 2001) and to enhance the restorative practices by activating NPDCs to provide resource substitution

(Pinheiro *et al.*, 2018; Kamp Albæk *et al.*, 2020) and thus, enable successful circular product design (Kamp Albæk *et al.*, 2020; Aguiar *et al.*, 2022), all of which will, in return, foster SCRES antecedents such as flexibility, responsiveness (Malhotra *et al.*, 1996) and diversification (Lin *et al.*, 2021). This holistic approach to resilience recognises the adaptive cycles inherent in multi-layer linkages (Wieland, 2021) and unpacks the capability mechanisms behind the strategies mobilised during the reorganisation phase (Küffner *et al.*, 2022).

Furthermore, our findings exhibit the interplay between these reorganisational capabilities and verify the direct positive impact of CCs on RRCs and NPDCs. The 3R practices related to CCs enable the reduction of dependency on raw materials and reducing or reusing waste. In that respect, new and alternative resources are regenerated, which provides opportunities for organisations to reshuffle and restructure their resource base (Queiroz *et al.*, 2022; Khan *et al.*, 2020). Besides, in CE, products, components and materials are re-valued through restorative design (Webster, 2015) leveraged by NPD practices (Pinheiro *et al.*, 2018; Kamp Albæk *et al.*, 2020), and this verifies the relationship between CCs providing opportunities to expand product range or develop new products. Within the context of the crisis that set the scene in this study, NPDCs are mobilised as a mechanism to tackle the material criticality issue inherent to food SCs. Circularity alone is not enough to directly tackle the issue of raw material scarcity in food production. It must be combined with innovative product design and development capabilities that are part of the NPD process. With a circular approach, these capabilities can be facilitated with a substitution mindset. NPD skills that foster raw material substitution that can eliminate the negative consequences of wheat or sunflower seed scarcity to a certain extent help achieve SCRES. However, an interaction between circularity and NPDCs are needed. Such a result is vital for future preparedness against similar crises as more and more SCs are being challenged by similar disruptions.

As Rogan *et al.* (2022) propose, the linear SC model and the damage that this model gives to the environment have created the conditions for a shift from the front loop of the adaptive cycle to the back loop. In other words, SCs need to release the existing resources and configurations built upon by the linear SCs. They need to reorganise to transition to a CE (Holling, 2001), open for innovation and capture new opportunities. Our findings empirically support this argument by showing how circularity and NPDCs, in combination, enable the release and reorganisation of resources during a crisis for food producers and consequently enhance the resilience of these food SCs. This provides the expansion of the product range by the introduction of new or modified products (da Costa *et al.*, 2018; Dubey *et al.*, 2021) or diversification in the product line, which reduces the dependence on certain materials and supply base, resulting in increased flexibility and responsiveness (Kamalahmadi and Parast, 2016). This is one way to demonstrate the response to the combination of ‘remember’ influences coming from the planetary level in terms of resource scarcity and coming from the political-economic level in terms of supply disruption due to political conflict. Our findings also confirm that the ability to combine, shuffle, reshuffle, restructure and reconfigure both existing and new resources leads to success in NPD (Zhang and Wu, 2017) and helps to cope with resource scarcity or disturbances (Queiroz *et al.*, 2022), improving overall resilience.

Firm-level operational competencies in the form of circularity practices create comparative resource advantages for firms facing material shortages or scarcity (Bell *et al.*, 2013). Hence, the nature and interplay of these competencies need to be understood better. This study’s interplay between CCs, RRCs and NPDCs attempts to explain the nuanced relationship between circularity and SCRES. Previous research used RDT to investigate the relationship between circularity practices and competitive advantage through enhanced access to raw materials at a lower cost (Kalaitzi *et al.*, 2019). While this relationship was not supported, evidence was found on the significance of the interaction between buffering and bridging strategies on competitive advantage (Kalaitzi *et al.*, 2019). We argue that our findings unpack the mechanisms behind these strategies and unveil the role of reorganisation capabilities as a facilitating mechanism for them.

6. Concluding remarks and implications

This study aims to explore the relationships between reorganisational capabilities and SCRES with a panarchy theory lens. A statistical analysis is performed to understand this relationship, a novel empirical effort as these constructs are mainly discussed at a conceptual level. However, empirical observation of them within specified settings is yet to be populated. In particular, the study combines the theoretical perspective from the adaptive cycles of a panarchy approach to SCRES with reorganisational capabilities, positioning CCs at the core complemented by RRCs and NPDCs as empowering mechanisms. The findings show that CCs influence SCRES through RRCs and NPDCs, which theoretically reflect the release and reorganisation phases of panarchical adaptive cycles.

6.1 Contributions and research implications

Our study is one of the initial attempts to explain the relationship between circularity and SCRES from a panarchy theory lens. We contribute to the socio-ecological approach to SCRES by studying SC disruptions caused by geopolitical tensions (Wieland, 2021; Wieland *et al.*, 2023). Geopolitical disruptions are causing compounding adverse effects for global SCs (Roscoe *et al.*, 2022) and need to be studied closely to understand and learn from how firms with SCs intersecting these challenged regions are adapting to these disruptions (Bednarski *et al.*, 2024). We take the theoretical discussion on panarchical adaptive cycles and the transformation to a CE (Rogan *et al.*, 2022) and apply it to an empirical setting within agrifood SCs challenged by a geopolitical crisis. By adding the RRCs and NPDCs into our measurement model and confirming their significance, we also contribute to the research that is called to investigate NPD in relation to circularity (Pinheiro *et al.*, 2018; Aguiar *et al.*, 2022) and to examine the role of resource reconfiguration (Queiroz *et al.*, 2022). This study is the first attempt to test a model with potential extension to other empirical settings or variables.

The literature suggests that CCs affect SCRES (Yamamoto *et al.*, 2022; Sarkis, 2021; Sarkis *et al.*, 2020a), yet very few studies empirically test the impact of CE on SCRES (Gebhardt *et al.*, 2022). Among the few, Le *et al.* (2023) found a positive relationship between CE practices and resilient production systems and Gebhardt *et al.* (2022) uncovered a relationship between CE and SCRES from an RDT perspective. Former literature using an RDT lens has studied circularity practices such as recycling, resource recovery or substitution as buffering strategies to tackle material scarcity and shortages (Bell *et al.*, 2013; Kalaitzi *et al.*, 2018, 2019). However, empirical studies looking into this relationship are scarce (Kalaitzi *et al.*, 2018), and a nuanced understanding of this relationship using alternative theories is needed (Gebhardt *et al.*, 2022). Our findings address these gaps and provide evidence for combining CCs with other reorganisation capabilities to achieve SCRES.

Furthermore, to the best of authors' knowledge, this study is among the first to investigate NPDC as a reorganisational capability and empirically test its impact on SCRES. Only a few studies have focused on similar constructs (e.g., Wieteska, 2020; Akgün and Keskin, 2014), yet the direct impact of NPDCs on SCRES and their mediating role between an independent construct and SCRES have not been thoroughly examined in previous studies. The positive impact of NPDCs on SCRES makes sense as NPD is positively associated with important SCRES antecedents such as flexibility, diversification and technology adoption. The positive impact of NPDCs particularly coheres in our research context as alternative products using substitute materials and/or product innovation can enable firms to be more flexible when a shortage of a certain material exists. Hence, our study is expected to start a new avenue in SCRES studies by proposing an understudied capability – NPDC – to mitigate SC disruptions.

According to panarchy theory, the reorganisation phase is the renewal phase (Adobor, 2020), where resources are reshuffled, revalued and regenerated (Holling, 2001), making innovativeness and change its integral part. In this study, we investigate a setting that is challenged by disruptions occurring at the higher levels of the panarchy and reorganisational capabilities are mobilised. We contribute to the literature by providing insights about how to build SCRES in response to geopolitical crises (Bednarski *et al.*, 2024; Wieland *et al.*, 2023), particularly in agrifood SCs that are relatively understudied but severely threatened by geopolitical and climate-related crises (Alam *et al.*, 2024). In this setting, RRCs and NPDCs are used as complementary to CCs to reorganise and achieve a stronger SCRES innovatively. Operationalising CCs through effective implementation of the 3R practices to regenerate alternative sets of resources is critical but insufficient in coping with material criticality and scarcity issues. Firstly, alternative resources need to be created through mobilising CCs. Then these resources need to be combined and recombined through innovative approaches (Ambulkar *et al.*, 2015) to expand the product range or develop new products by activating RRCs and NPDCs. Therefore, in addition to focusing on the transition to circularity for resilience, organisations should develop and exercise other capabilities such as RRCs and NPDCs.

6.2 Practical implications

Our findings emphasise the importance of three sets of reorganisation capabilities, one rather new and the other two relatively old. RRCs and NPDCs have been quite established for many firms particularly if they are involved in resource reshuffling and recombining or in research and development activities. On the other hand, CCs are more recent; they require new knowledge of materials or a new perspective on managing existing resources. In combination, they are proven to enhance SCRES for food SC companies. The results provide essential insights to food SC professionals to invest further in developing these capabilities for a more effective way to tackle SC disruptions.

Firstly, it is timely and relevant for the food industry and other manufacturing industries to incorporate circularity in resource reconfiguration practices and NPD processes. Such a move not only enhances SCRES but also can create first-mover advantages with new, circular products. Besides, blending, shuffling and reshuffling both existing and new resources and transforming them into novel resource combinations will also contribute to NPD. In that respect, virgin raw materials could be used or wasted materials could be reused through recycling and reprocessing. For example, Toast Brewing uses surplus bread, which could have been discarded, to brew beer (Toast Brewing, 2024). This process ensured resiliency as it used new resources to produce beer and reduced food waste, making the food SC more circular.

Thinking about the substitution of raw materials with alternatives can be one of the potential strategies that practitioners can follow. The utilisation of substitute materials will not only enhance NPD and, thereby, SCRES but also ensure a more sustainable food SC. For instance, as the demand for meat products continues to rise, the impact of meat production on the environment also increases; using plant-based alternatives to meat products can be an example of the material substitution of raw materials with alternatives. Another potential strategy for practitioners is building new flows of by-products from within or outside the industry and enabling a closed-loop system. Coffee roasting leads to a significant amount of waste in the form of coffee ground, which is discarded as waste. Nevertheless, rich in nutrients, coffee grounds can be used as a fruit and vegetable growth substrate. Food waste is a severe source of greenhouse gas emissions when sent to landfills. However, when food waste is processed in a biogas plant, it can be used to produce biogas, a renewable energy source.

Building new supplier relationships with unconventional raw material producers that can provide alternatives to contested commodities might be another strategy for practitioners. For example, a company called SeaMore has developed a range of food products that use seaweed as a primary ingredient, including pasta, wraps and bacon alternatives, instead of wheat and sunflower oil (SeaMoreFood, 2023). The company has built new supplier relationships with seaweed farmers to ensure a sustainable and high-quality supply of seaweed. By developing a new SC for seaweed and working closely with suppliers, SeaMore has created new and circular products that meet consumer demand for healthy and eco-friendly alternatives to traditional foods.

Our results suggest that agrifood SCs can reconfigure resources by using alternative materials in their production and offering new products to the market. This suggestion has also been reaffirmed in practice by leading SCs. Unilever, for instance, turned into rapeseed oil in Knorr products when faced with a sunflower oil shortage due to the Ukraine-Russia conflict. Similarly, McGain Foods also released a new product to the market by switching to a blend of sunflower-rapeseed oil amid the sunflower shortage due to the geopolitical conflict. These reorganisation capabilities allowed SCs to respond to the disruption and maintain operations and customer service as usual.

Our results offer practical implications for other SCs as well. For instance, for i models, BMW switched to using carbon fibre-reinforced plastics, which was the result of BMW's commitment to sustainability and innovation, instead of aluminium or steel for the car body. This enabled BMW to reduce the vehicle's weight while ensuring safety standards. The lighter weight enabled energy efficiency and lengthened the electric vehicle's range on a single charge. Similarly, RRC emanates from CE practices, ensuring SCRES against disruptions for different industries. For example, Adidas partnered with Parley for the Oceans, an organisation that collects plastics from oceans. Adidas processes the material and uses it in clothing and shoes. Such examples show how different industries respond to climate crises and build SCRES.

6.3 Limitations and future research

In this study, we focused on a specific setting, which limited the empirical evidence to those food producers that use wheat and sunflower seeds in their production. This was done intentionally as the studied setting was characterised by a geopolitical crisis threatening these materials' flow. The results can be generalised to other food SCs and other manufacturing industries that may suffer from the shortage of critical raw materials or intermediate products. However, RRCs and NPDCs might not be the only facilitators of the connection between circularity and SCRES. Other skills and capabilities which might mediate or moderate this relationship require further attention. Moreover, the release and reorganisation phase of the adaptive cycles in response to a disruption deserves further qualitative and quantitative research that explains how these phases are managed and the antecedents resulting in a successful transformation for enhanced SCRES.

On the other hand, the raw material shortage context in this study implies significant resource dependencies, which call for further research using RDT. Such research can investigate a specific geopolitical disruption setting and study buyer-supplier dyads during such a disruption. How SC actors mobilise reorganisation capabilities, release old dependencies and reorganise new dependencies, for instance, with new CLSC partners, and how the power relationships change when circularity practices dominate over traditional linear practices are potential areas for further research.

Note

1 No ethical approval is required, all data is anonymised.

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Corresponding author

Ceren Altuntas Vural can be contacted at: ceren.altuntasvural@chalmers.se