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Supply Ecosystems and The Concept of Resilience – A Literature Review

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Purpose: *Established approaches to supply chain management are increasingly being challenged due to disruptive events that neglect the dynamics and interdependencies of supply chains. Supply ecosystems form a new theoretical view of the supply chain that is more in line with systemic thinking, although it is unclear how these can contribute to increased resilience.*

Methodology: *Based on the assumption that supply ecosystems are complex adaptive systems with a dynamic capacity to adapt to changes in an environment and evolve, we conducted a systematic literature review of 24 peer-reviewed journal articles.*

Findings: *The review identifies the attributes of complex adaptive systems making them resilient and matches these with the concept of supply ecosystems. The resulting framework demonstrates how supply ecosystems contribute to increased resilience through the systemic nature.*

Originality: *The paper extends research on supply ecosystems by conceptualizing them as complex adaptive systems and identifying attributes that can contribute to system resilience. Thus, the study contributes to the emerging research of supply ecosystems.*

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1 Introduction

Over the past years, supply chains (SCs) have followed a management trend to reduce costs while increasing efficiency (Ivanov, 2020). While these optimizations could lead to a competitive advantage in the market, they also increased the vulnerability of many SCs to external shocks (Craighead, Ketchen and Darby, 2020). Various disruptions ranging from interruptions in the transportation or production process, epidemic outbreaks, and global pandemics have highlighted this vulnerability, as many companies have been unable to compensate for the loss of performance caused by these disruptions (Scholten, Stevenson and van Donk, 2020). With this sudden attention, the research field of SC resilience gained significant attention in recent years (Hohenstein, et al., 2015). Especially after the Covid-19 pandemic, many scientists have been engaged in this research area, which has led to new aspects and perspectives of resilience (Chowdhury, et al., 2021). However, while much research on this topic focuses primarily on the resilience that can be developed by the focused company, more recent approaches propose that resilience is achieved not only at the individual level but also within the broader network of actors that are part of a SC (Adobor, 2019; Novak, Wu and Dooley, 2021; Münch and Hartmann, 2022).

In this context, several studies discuss new organizational forms of SCs, such as shifting to an extensive supply ecosystem (SE) as a means to enhance resilience (Ivanov and Dolgui, 2020; Mollenkopf, Ozanne and Stolze, 2021). SEs consists of interdependent actors who coordinate their activities, leading to close cooperation and ensuring business continuity (Stolze, Mollenkopf and Flint, 2016). Thereby, SEs enable joint decision-making and the creation and sharing of knowledge between the different actors (Scholten and Schilder, 2015). As a result, SC stakeholders' evolve from isolated, local suppliers to ecosystem-wide, systematic, and intelligent actors (Ivanov and Das, 2020). This degree of involvement suggests a change in the hierarchical arrangement of companies, which in turn leads to increased innovation dynamics (Luo, 2018). To hold together diverse actors and enable collaboration, SEs need to balance structural flexibility and integrity, overcome cognitive disparities between the actors, and rely on an architecture of participation (Lusch and Nambisan, 2015). To meet these

requirements, digital industrial platforms are increasingly being implemented (Teece, 2017), as they act as a technological basis for complementary solutions and a market intermediary between different groups of actors (Gawer, 2014).

In recent literature, ecosystems are often described as complex adaptive systems (CAS) from a theoretical perspective due to their structural composition and properties (e.g., Roundy, Bradshaw and Brockman, 2018; Phillips and Ritala, 2019). Several studies have examined SC resilience from the CAS perspective (e.g., Day, 2014; Zhao, Zuo and Blackhurst, 2019; Adobor, 2020). Although first studies have adopted the CAS concept and underlying characteristics in ecosystem research (e.g., Adner and Kapoor, 2010; Ansari, Garud and Kumaraswamy, 2016), it is not yet evident which characteristics of SEs correspond to the characteristics of CAS. Therefore, this study aims to answer the following research question: *Which characteristics of SEs are consistent with the characteristics of CASs, and how do these characteristics influence the resilience of the SEs?*

A systematic literature review is conducted to answer the research question. First, it examines the characteristics of this system and whether it is suitable to be considered an CAS. In particular, this context explores whether this organizational form is a more appropriate approach to an CAS lens on resilience. Second, emergent characteristics that contribute to resilience beyond CAS theory are elaborated to develop an understanding of the resilience capabilities of SEs.

The remainder of the paper is structured as follows. In section 2, an overview of the theoretical background is given by explaining supply chain resilience and CAS as core elements of this study. The methodological approach is explained in section 3. In section 4, supply ecosystems are conceptualized as CAS by identifying which characteristics of supply ecosystems correspond to the characteristics of CAS and how these characteristics result in increased resilience. In addition, implications for practice are given and limitations and further research needs are outlined.

2 Theoretical Background

2.1 Resilience in The Context of Supply Chains

The concept of resilience, which originates in social psychology (Sitkin, 1992), was adapted to a variety of disciplines over time, such as ecology, engineering, risk- and disaster management, and information systems (Ramezani and Camarinha-Matos, 2020), demonstrating its multidimensional and multidisciplinary nature (Massari and Giannoccaro, 2021). In SC management, many approaches to define SC resilience have emerged over time, and authors have often stressed the lack of a unified definition (Tukamuhabwa, et al., 2015). Nonetheless, authors such as Massari and Giannoccaro (2021) observed general research streams that mainly point in two directions. The authors classified a static and a dynamic perspective that is predominantly represented in literature (Wieland and Durach, 2021). The static perspective on resilience refers to "[…] the system's ability to absorb disturbance and bounce back to the original equilibrium state maintaining its core functions when shocked" (Massari and Giannoccaro, 2021, p. 1). In contrast, the dynamic perspective represents "[…] the ability to adapt to a disturbance by moving towards the original but even new, more favorable equilibrium states" (Massari and Giannoccaro, 2021, p. 1). According to Novak, Wu and Dooley (2021), the static equilibrium-based perspective on SC resilience has to deal with shortcomings since it often rather analyzes the resilience of a focal firm more than the resilience of the entire SC. They argue that the recurring equalization of resilience achieved by the firm and resilience achieved by the entire SC leads to this misinterpretation. Other authors like Borekci, Rofcanin and Gürbüz (2014) also pointed out that the resilience of multiple actors in the SC is greater than the sum of the resilience of the individuals. In this context, the systemic aspect of SC resilience is often highlighted by authors (Adobor, 2019), leading to CAS as a theoretical foundation (Choi, Dooley and Rungtusanatham, 2001; Nilsson and Gammelgaard, 2012; Adobor and McMullen, 2018; Zhao, Zuo and Blackhurst, 2019). This grounding in theory seems reasonable since resilience has been described as an adaptive phenomenon (Shastri, et al., 2014; Wieland, 2021) as, on the one hand, SCs face a dynamic environment and must adapt to changes in the environment if they are to survive (Choi, Dooley and Rungtusanatham, 2001) and,

on the other hand, the activities of individual actors also affect the SC environment (Adobor and McMullen, 2018).

2.2 Complex Adaptive Systems

CASs focus on the adaptability of a system and emerged out of complexity theory (Schneider and Somers, 2006). According to its ability to incorporate a more realistic picture of systems that feature complex interwoven structures, it has an advantage over most SCM metrics that often lack the ability to examine the dynamism or evolution of a system (Pathak, et al., 2007). CASs generally describe an interconnected network of autonomous and rational decision-making agents that responds in an adaptive way to changes in the environment as well as other agents in the network (Choi, Dooley and Rungtusanatham, 2001; Tukamuhabwa, et al., 2015). Agents may represent individuals, a division, or an entire organization, depending on the scale of analysis (Choi, Dooley and Rungtusanatham, 2001). They are guided by norms, values, and beliefs that are shared by the system, so-called schemas (Schein, 1992). Causal dynamics, for example in the form of similar goals or concerns within an CAS, apply to every level of the system (Wycisk, McKelvey and Hülsmann, 2008). Individual agents may pursue their own goals but end up causing system-wide similar patterns to emerge (Tukamuhabwa, et al., 2015). CASs are scalable, which facilitates their capability to adapt.

Choi, Dooley and Rungtusanatham (2001) outlined a set of central internal mechanisms of CASs: First, CASs are characterized by being emergent and self-organizing – systemic behavior occurs through the parallel and simultaneous activities of agents, which give rise to nascent structures, patterns, and properties (Choi, Dooley and Rungtusanatham, 2001; Pathak, et al., 2007). The second mechanism is network connectivity. CAS can be described as an aggregation of connections between agents, and their level of connectivity determines the complexity of the network (Choi, Dooley and Rungtusanatham, 2001; Pathak, et al., 2007). The higher the level of connectivity, the more interrelationships between agents exist (Dooley and van de Ven, 1999). However, a critical point of complexity exists that should not be crossed (Kauffmann, 1993), as the establishment of new interrelationships slows down and the system loses efficiency (Choi, Dooley and Rungtusanatham, 2001). The third internal mechanism of an CAS is

dimensionality. It defines the freedom of agents in the system to act autonomously (Dooley and van de Ven, 1999). While control in the form of rules and regulations ensures greater predictability of the system, less control allows for more autonomous decision-making of agents and, therefore, more emergent outcomes that are typically more creative (Choi, Dooley and Rungtusanatham, 2001). An increase in connectivity decreases dimensionality as autonomous acting is impaired by a high number of inter-relationships (Pathak, et al., 2007). The fourth aspect is the environment, which is characterized as dynamic and rugged. Dynamism develops when the agents must adapt to a fluctuating environment, affecting the way they perceive their environment or the schemas they follow (Pathak, et al., 2007). Adjustments in CASs are nonlinear regarding the initial alterations (Pathak, et al., 2007), resulting in events having disproportionately negative or positive implications for the system (Wycisk, McKelvey and Hülsmann, 2008). The environment is rugged because of the system's components that are tightly coupled and interconnected, creating local optima, which can blur the conception of an overall optimal state (Choi, Dooley and Rungtusanatham, 2001). Lastly, the aspect of coevolution is presented as an important feature of an CAS (Choi, Dooley and Rungtusanatham, 2001; Tukamuhabwa, et al., 2015). Agents adapt to a shifting environment to maximize their fitness, so they learn from the system's responses and modify their schemas (Pathak, et al., 2007; Wycisk, McKelvey and Hülsmann, 2008; Day, 2014). Therefore, the coevolution of an CAS happens between its members, the system as a whole, and its environment (Choi, Dooley and Rungtusanatham, 2001; Pathak, et al., 2007).

3 Systematic Literature Review

To answer our research question of whether SEs are suitable for an CAS-based perspective on resilience and what emergent attributes they feature, we conducted a systematic literature review. As a well-established methodology in evidence-based practice, it allows for a scientific approach while comprehensively summarizing all relevant existing information on a research topic in a way that seeks to minimize bias

(Denyer and Tranfield, 2009). An systematic literature review also leads to replicable and transparently analyzable results (Rousseau, Manning and Denyer, 2008).

We adapted the five-step process for systematic literature from Denyer and Tranfield (2009), beginning with narrowing the scope and formulating a clear research question (Tranfield, Denyer and Smart, 2003). This work aims to provide a base for future research on SEs. Especially its emergent features are investigated to explore whether SEs are a fitting concept for the utilization of an CAS lens on resilience. Possible resilience-inducing properties are also observed.

The next step was to locate relevant literature. Scopus was selected as a primary source of literature because it is one of the largest databases with 76 million entries available while also containing articles from all notable publishers (Baas, et al., 2020). To check whether relevant literature is excluded, Business Source Complete was used as a complementary database. Figure 1 shows the search string and the applied filters. As current literature defines the components of SEs inconsistently, especially when it comes to business ecosystems, the search string was constructed in a less detailed manner to minimize the risk of leaving out relevant data. The observed publication time range started in 2012 because of the occurrence of SEs-related literature mostly after the beginnings of industry 4.0, which set focus on technologies that are crucial for the development of digital industrial platforms. Examples would be, amongst others, the internet of things, cloud computing, and big data. By searching the databases with the search string, 5524 documents were found.

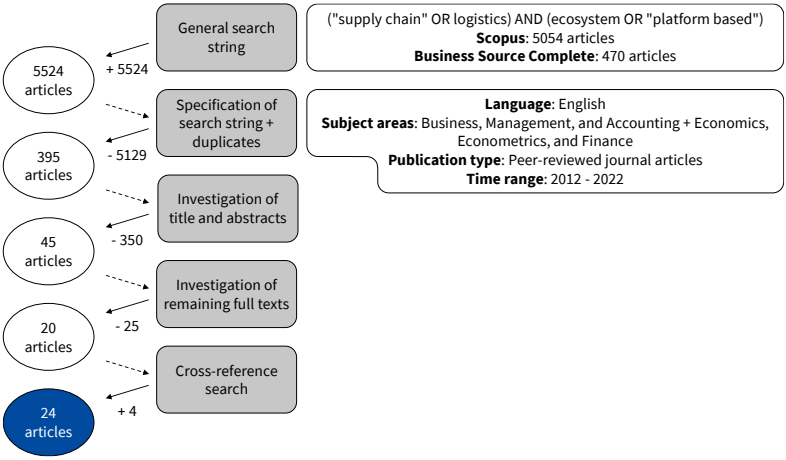

Figure 1: Study selection and evaluation process

Figure 1 also visualizes the process used to select and evaluate studies in the third phase. After the application of time range, publication type, subject area, and language criteria, duplicates were eliminated, which resulted in 395 articles. To ensure scientific quality, only journals with a VHB-Jourqual ranking of C and above were considered relevant for review. Next, the title and abstracts of all remaining results were checked. Publications that did not focus on ecosystem or platform approaches on SCs were sorted out, which narrowed down the amount of potentially relevant articles to 45. The remaining articles were read thoroughly. 25 additional articles were eliminated in the process as they pursued ecosystem approaches that were out of the scope. Finally, a cross-reference search was carried out. Through forward and backward search, as proposed by Webster and Watson (2002), the final number of articles increased to 24.

The fourth step was to analyze and synthesize the final pool of literature. To explore the resilient capabilities of SEs, essential ecosystem and CAS-based resilience capabilities were utilized as a foundation to analyze for its interplay with resilience. For the systematic analysis of capabilities, the publications of Tukamuhabwa, et al. (2015) as well as Ramezani and Camarinha-Matos (2020) were chosen as the foundation for the

systematic analysis of capabilities, as they provide a well-structured, detailed summary of their respective resilience approaches, reducing the risk of missing important capabilities.

Analysis was fundamentally guided by open coding, according to Strauss and Corbin (1990). By constantly comparing the similarities and differences of the data and by forming categories of conceptionally similar data, open coding allows for analyses to be carried out with less subjectivity and bias (Strauss and Corbin, 1990).

The fifth step concludes the systematic literature review by reporting and using the results. In this case, the utilized ecosystem and CAS-based resilience categories were assigned to the elaborated emergent features of an SE and discussed.

4 Results and Discussion

4.1 Conceptualization of Supply Ecosystems as Complex Adaptive System to Increase Resilience

Based on the analysis of the underlying characteristics of SEs and the elaboration of Tukamuhabwa, et al. (2015) on how CAS attributes induce resilience in the previous section, it is possible to examine the compatibility of SEs with key features of CASs and make connections to how exactly these features promote resilience in an SEs. Additionally, the utilization of digital industrial platforms to organize ecosystems results in additional features affecting the ecosystem. Table 1 lists the CAS attributes that are reflected in SEs and gives an overview of the moderating role of a digital industrial platform on CAS attributes.

Table 1: Observed CAS attributes in SEs and the moderating role of digital industrial platforms

Reference	Ability to learn	Adaptability	Coevolution	Scalability	Multi-scale / heterogeneous agents	Connectivity / interaction (+) *	Dimensionality (-) *	Self-organization and emergence (-) *	Schemas (+) *
Adner (2017)			X		X				X
Aarikka-Stenroos and Ritala (2017)	X		X		X	X		X	
Argyres, Bercovitz and Zanarone (2020)									X
Ben Letaifa (2014)	X	X	X					X	X
Benitez, Ayala and Frank (2020)	X		X		X	X		X	X
Ceccagnoli, et al. (2012)							X		
Gawer (2014)					X	X	X		X
Gawer and Cusumano (2014)									X
(Giannakis, Spanaki and Dubey, 2019)	X			X		X			X

Reference	Ability to learn	Adaptability	Coevolution	Scalability	Multi-scale / heterogeneous agents	Connectivity / interaction (+) *	Dimensionality (-) *	Self-organization and emergence (-) *	Schemas (+) *
Graça and Camarinha-Matos (2017)		x	x	x	x	x		x	x
Gupta, Mejia and Kajikawa (2019)	x				x		x		
Hein, et al. (2020)	x	x		x	x		x		x
Hermes, et al. (2020)			x	x	x	x			x
Huang, Kang and Chiang (2020)	x		x		x	x	x		x
Jacobides, Cennamo and Gawer (2018)	x		x	x		x	x		x
Jovanovic, Sjödin and Parida (2021)	x		x	x	x	x			x
Ketchen, Crook and Craighead (2014)	x	x		x	x				x
Lin, et al. (2021)	x		x		x	x			

Reference	Ability to learn	Adaptability	Coevolution	Scalability	Multi-scale / heterogeneous agents	Connectivity / interaction (+) *	Dimensionality (-) *	Self-organization and emergence (-) *	Schemas (+) *
Liu, Aroean and Ko (2019)	X					X			X
Riquelme-Medina, et al. (2021)	X	X	X			X			X
Rong, et al. (2015)	X	X	X			X			X
Uusitalo and Laine (2022)	X			X				X	
Wagner (2021)		X			X	X			
Wang and Miller (2020)				X					X
∑	15	7	12	9	13	14	6	5	18

** The direction in which changes occur is marked with + or - and indicates the positive and negative moderating effects a digital industrial platform.*

Coevolution and adaption together were identified most and turn out to be inherent to an SE since actors of the ecosystem adapt and coevolve their roles in the system over time (Moore, 1996). This enables them to adapt to disruptive events and possible changes in their environment. The system considers its environment as it competes and collaborates with other organizations (Moore, 1996; Ketchen, Crook and Craighead, 2014). This circumstance can improve its ability to detect and uncover internal and external threats faster (Tukamuhabwa, et al., 2015).

Schemas emerge in the form of norms and rules that are established by individual members or hub firms (Jacobides, Cennamo and Gawer, 2018), which can include strategies to enhance the system's resilience. In this respect, the reliance on a digital industrial platform introduces an additional layer to the schemas that apply for SEs, since platforms impose their own set of rules on the members (Rietveld and Schilling, 2021). This however has direct implications for the aspect of self-organizational and emergence, as well as the dimensionality of SEs. On the one hand, self-organization as well as emergent outputs of agents, which potentially enhance the adaptability of the system by enabling self-organizing processes, are encouraged by the open structure of the ecosystem. Rules and standards set by hub firms may apply, but they only follow a regulating agenda (Jacobides, Cennamo and Gawer, 2018). They do not prevent members from making their own decisions. On the other hand, the reinforced governance introduced by a platform leader that exercises control over the system and its complementors (Gawer, 2014) counteracts this initial effect to some degree. The same holds true for the dimensionality of SEs, which determines how efficiently members can contribute to self-organization and emergence (Tukamuhabwa, et al., 2015).

While the ecosystem generally allows for autonomous behavior, the platform may impose restrictions on that, as members have to follow the platform's underlying structure and utilize its boundary resources in order to efficiently interact with the SE (Hein, et al., 2020). SEs naturally consist of collaborating, heterogenous/multiscale agents, as their possible members range from individual suppliers or buyers to entire organizations (Moore, 1996), which, despite following their own goals, still aim to enhance the overall health of the system (Wagner, 2021). Therefore, they collectively contribute to the resilience of the system. Furthermore, integrated digital industrial platforms enable easy access to the system, which is why complementors not only directly belong to an SE but can also collaborate without actually being embedded into it (Hein, et al., 2020).

The existing interdependencies within SEs favor nonlinearity as an emergent feature. Accordingly, disruptions concerning any member of an SE can have far-reaching consequences for the system as a whole. Network connectivity and interaction are highly present, as relationships within SEs are interdependent (Ketchen, Crook and Craighead,

2014), and members closely work together to co-create value, facilitating cooperation in cases where the system is threatened. Further amplification of connectivity is achieved through facilitating boundary resources such as standardized interfaces that a platform introduces to an SE (Gawer, 2014).

Its connectivity also complements the ability of an SE to learn. Knowledge is shared between members to mutually benefit their own as well as the system's success. This organizational learning leads to the emergence of system-wide competencies (Ketchen, Crook and Craighead, 2014), of which resilience is a part.

Finally, members of an SE interdependently work together while being guided by schemas. This allows for scalability by making causal dynamics applicable to the whole system. It facilitates the building of resilience by ensuring that the same ambitions are present for a resilient system across all levels of the SE. Rapid deployments of resilience-inducing measures could be enabled this way, especially with the connectivity benefits that a digital industrial platform provides.

4.2 Further resilient attributes of SEs

Apart from the CAS-based perspective, additional resilient properties can be observed in an SEs, which originate in both their construction as an SE and their integration of a digital industrial platform (see Table 2).

Table 2: Resilience characteristics related to the ecosystem aspect of SEs

Reference	Flexibility	Agility	Cohesiveness	Redundancy	Visibility	Simplicity	Evolvability
Aarikka-Stenroos and Ritala (2017)			E				P
Adner (2017)			E				P

Reference	Flexibility	Agility	Cohesiveness	Redundancy	Visibility	Simplicity	Evolvability
Argyres, Bercovitz and Zanarone (2020)			E				
Ben Letaifa (2014)			E				
Benitez, Ayala and Frank (2020)			E				
Gawer (2014)			E	P		P	P
Gawer and Cusumano (2014)				P		P	
Giannakis, Spanaki and Dubey (2019)					P		
Graça and Camarinha-Matos (2017)		E	E				
Gupta, Mejia and Kajikawa (2019)			E				
Hein, et al. (2020)				P			P
Hermes, et al. (2020)				P		P	P
Huang, Kang and Chiang (2020)			E				
Jacobides, Cennamo and Gawer (2018)			E			P	
Jovanovic, Sjödin and Parida (2021)			E	P	P		P
Ketchen, Crook and Craighead (2014)	E		E				
Lin, et al. (2021)				P	P	P	P

Reference	Flexibility	Agility	Cohesiveness	Redundancy	Visibility	Simplicity	Evolvability
Liu, Aroean and Ko (2019)			E				
Riquelme-Medina, et al. (2021)	E	E	E				
Rong, et al. (2015)							P
Uusitalo and Laine (2022)					P		
Wagner (2021)		E					
∑	2	3	14	6	4	5	8

Note: E = ecosystem; P = digital industrial platform

As the results show, cohesiveness is represented most in an SEs. The property can be found in the form of trust that is built between members of the system (Benitez, Ayala and Frank, 2020), ensuring its continuity. Trust can emerge thanks to the rules and norms that are set in place for members of SEs. It reduces uncertainty about how partners will act (Benitez, Ayala and Frank, 2020), which benefits the system in case of a disruptive event.

The ability to evolve comes in second place. An SE has evolving features which enhance its adaptability besides its coevolutionary aspect. The platform of an SE also evolves, namely its architecture and governance, which change over time as the system becomes more open and inclusive for complementors (Jovanovic, Sjödin and Parida, 2021). More diverse complementors enhance the system's ability innovative capabilities (Gawer, 2014), which enables an SE to respond more innovatively to disruptive events and, thus, increasing its resilience.

Another feature that should be mentioned is facilitated redundancy in an SE, which is enabled by the systems architecture. By having multiple assets that perform the same function, redundancy ensures the system's stability in case of disruption-related performance drops of individual members (Ramezani and Camarinha-Matos, 2020). The modular platform architecture of an SE allows for easy access to the system and the option to substitute modules (Hein, et al., 2020). It therefore can facilitate measures such as the implementation of multiple sourcing and backup suppliers, if required.

An SE features simplicity to some degree, as it reduces complexity in the system through its modular structure (Gawer, 2014). It also features visibility, which benefits from the high transparency regarding information flow, enabled by the close relationships within the ecosystem and its facilitation through interfaces the digital industrial platform provides (Gawer, 2014).

Agility and flexibility could be detected least frequently. These two properties, nevertheless, can be found, namely in the collaborative nature of the system (Graça and Camarinha-Matos, 2017). For instance, the sharing of knowledge enables flexible responses to market changes (Graça and Camarinha-Matos, 2017), which can be caused by a disruptive event. Implemented norms and rules (schemas) enable agility by increasing the interoperability of processes and products (Graça and Camarinha-Matos, 2017), which accelerates the system's ability to respond to threats.

4.3 Theoretical Implications

This study identifies which characteristics of CAS are reflected in SEs and thus provides a conceptual explanation of why supply ecosystems and the use of digital industrial platforms lead to increased resilience. Thus, the study complements previous studies that assume that SEs represent a new organizational form of supply chains reflecting today's changing business dynamics (Ivanov and Dolgui, 2020; Mollenkopf, Ozanne and Stolze, 2021). In this way, the study can be positioned within the emerging stream of research in supply chain management that argues that resilience goes beyond a mere 'being' and corresponds more to a 'becoming', which results from the interaction between the system and the environment (Nilsson and Gammelgaard, 2012; Wieland, 2021; Wieland and Durach, 2021). The results provide a list of attributes that make SEs

resilient from a CAS perspective, providing a basis for further research that can reveal how this resilience emerges at the enterprise and ecosystem levels (Roundy, Bradshaw and Brockman, 2018; Phillips and Ritala, 2019).

4.4 Managerial Implications

From a management perspective, the results of this study provide an overview of how SEs as CASs can lead to increased resilience. The adaptability of the system is shown to have a major impact on its resilience. Therefore, practitioners should set their focus beyond an equilibrium-based perspective on resilience, as it does not suffice to be able to recover from a disruption merely. A system should rather be capable to adapt and evolve in the process of overcoming it, emerging from the disruptive event as a stronger version of its previous self. With such an approach, managers could turn a disruption into an opportunity to develop their organization further. One way to achieve this is to open up to other organizations and their interactions, building ecosystems in the process. The implementation of a digital industrial platform can further facilitate certain aspects of the adaptability of these ecosystems. However, it should also be evaluated whether the ecosystem sets up a digital industrial platform or if it joins an already existing one to hone its resilience capabilities further. The establishment of a digital industrial platform can prove difficult if resources or know-how is missing, as a platform requires the successful central implementation of technology in the system.

4.5 Limitations and Further Research

As with other studies, there are some considerable limitations to this work that arise from the research. The first limitation results from the methodological approach of the study. Even though in this paper the studied literature has been searched and evaluated in a systematic, transparent, and reproducible manner (Tranfield, Denyer and Smart, 2003; Denyer and Tranfield, 2009), the data sample does not guarantee completeness. Firstly, in order to limit the scope of the study, the formulation of the search string only included literature with a direct link to SCs or logistics. Consequently, potentially relevant publications investigating SEs may have been missed if the articles were not tagged with these keywords. Second, research on the components of ecosystems is extensive but

declines dramatically when it comes to how the concept is defined as an SE. Even though studies have focused on this construct, especially in the recent past (e.g., Ivanov and Dolgui, 2020; and Mollenkopf, Ozanne and Stolze, 2021), the literature so far lacks a conceptualization of SEs. Third, this study provides only an initial analysis that SEs can be assumed to be CAS based on their characteristics. Future studies need to build on this assumption and analyze through exploratory research what capabilities the SE needs to develop to increase resilience and at what level (e.g., system level or individual level) these capabilities emerge.

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