

Antifragility, Resilience, and Collaborative Networks of SMEs: a Theoretical Foundation

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Response to Reviewers' Comments

Dear reviewers,

Thank you very much for your valuable comment. We have revised the paper according to the comments. Therefore, we have a response as a report of revisions made in the article. The responses are tabulated as follows.

No.	Reviewers' Comments	Authors' Response
Reviewer 1		
4.	Quality of communication: The improvements in language are noticeable and have enhanced the paper's readability. However, throughout the manuscript, there are instances where the reference to Markey-Towler (2018) appears with slight variations, which could create confusion for readers. For example, in one section, the reference is spelled as 'Makey-Towler', in another as 'Maker-Towler', instead of 'Markey-Towler'	We have made revisions following the comments. The references to Markey-Towler (2018) are misspelled, and we have revised them to the correct spelling.

Antifragility, Resilience, and Collaborative Networks of SMEs: a Theoretical Foundation

Abstract

Purpose: The dynamic of the business environment has escalated the competition and uncertainty, which is challenging business survivability, particularly for small and medium enterprises (SMEs). SMEs attract researchers due to their unique characteristics that have limited resources but great flexibility and adaptability. Furthermore, Collaborative Networks (CNs) have been proposed by business scholars as a critical strategy to gain resilience and antifragility. However, the concept of antifragility and its relation with CNs is still vague in the SME sector. Therefore, this study aims to develop a complete understanding regarding 1) the emerging knowledge that is critical in explaining antifragility in the business sector based on co-citation and thematic analysis; 2) the relation between resilience and antifragility in emerging business research; 3) the relation between CNs and antifragility in emerging business research; and 4) a framework of antifragility in the SME context.

Design/methodology/approach: Bibliographic Analysis and Systematic Literature Review are performed to reach the research objectives. We use co-citation and thematic analysis to identify the map of emerging knowledge and the related concepts, which are the fundamentals of antifragility. Furthermore, we use a systematic literature review to determine the relation of antifragility, resilience, and CNs in the SME context.

Findings: Antifragility is a higher level of survivability compared to resilience. Antifragile SMEs could gain an advantage from the uncertain business environment. However, both in resilience and antifragility, SMEs should become active learners. Furthermore, CNs are proposed as the gateway for SMEs to manage their resource limitations. The conceptual framework of Antifragile SMEs is presented as the theoretical contribution of this manuscript.

Originality: This article explains the knowledge structure of antifragility in the business sector, particularly among SMEs. Based on bibliometric data, we describe critical characteristics or mental states entrepreneurs should have when facing uncertainty. Furthermore, we propose a conceptual framework for antifragile SMEs where active learning and positive psychology are the pillars, and CNs are critical ingredients of antifragility in SMEs.

Keywords: *Antifragility, Resilience, Collaboration, SMEs, Autopoiesis*

Introduction

Business dynamics are increasingly challenging due to intense competition, dynamic market expectations, massive technological innovation, and environmental uncertainty. It makes researchers increasingly concerned about the issue of the survival of business entities (Burnard & Bhamra, 2019; Eggers, 2020; Kamalahmadi & Parast, 2016; Klein & Todesco, 2021). Especially after the COVID-19 crisis, which has challenged the survival of various business and economic sectors. Researchers and business practitioners have become motivated to investigate the topic of resilience and antifragility in the business field (Branicki et al., 2018; Corvello, Straffalaci, et al., 2022; Ramezani & Camarinha-Matos, 2019b). Although terminology related to resilience and antifragility has been around for quite some time, especially in psychology and personal development (Garmezy, 1978; Manyena, 2006; Taleb, 2007, 2012), the application of these concepts in the business sector has just developed in the last decade and has begun to be widely discussed in the last three years.

In the SME sector, the survival rate was also an issue even before the COVID-19 pandemic. Based on OECD data in 2016, 30% of SMEs failed in the first three years, and more

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than 50% went bankrupt in the first five years (OECD, 2016). However, scientific research regarding SMEs' resilience and antifragility is still rare. Whereas Corvello et al. (2022) and Branicki et al. (2018) indicate that SMEs have the advantage of flexibility and adaptability in facing a crisis, giving them more chance to become resilient or even antifragile. Indeed, it was interesting that SMEs have a survival issue and a better opportunity to gain an advantage in the catastrophic business environment at the same time. This paradox also opens a research gap that needs to be filled. Therefore, the theoretical and empirical investigation regarding resilience and antifragility in the SME sector is needed to understand the concept comprehensively.

According to Taleb (2012), the antifragile entity can gain from prediction error of random events by regenerating the system itself in the long run. At the same time, Taleb (2012) also mentions that the simpler system is better as it could reduce the multiplicative chains of the unanticipated effect. These characteristics seem relevant to the SME's features. The concept of resilience also proposes a similar tone. The resilient organization should be able to recognize and seize opportunities quickly, moving fast and anticipating collisions by taking advantage of change (Jamrog et al., 2006; McCann, 2004). Regarding this issue, Branicki et al. (2018) suggested that SMEs must pay attention to capacity building, leveraging relationships, and activating experiment ability and creativity in response to a crisis.

Furthermore, collaboration is an emerging strategy that business researchers propose as a significant alternative to gain antifragility and resilience (Camarinha-matos & Afsarmanesh, 2006; Dickinson et al., 2014; Ramezani & Camarinha-Matos, 2020). For SMEs, collaborative networks (CNs) probably have the potential to help them anticipate bankruptcy by optimizing it inside their business ecosystem (Ramezani & Camarinha-Matos, 2019a). However, studies related to resilience and antifragility that focus on the CNs aspect in the SME sector are scarce. Thus, practical understanding regarding how CNs would optimize SMEs' resilience and antifragility is still vague. Therefore, this study aims to answer the following research questions:

1. What is the emerging knowledge that is critical in explaining antifragility in the business sector based on co-citation and thematic analysis?
2. What is the relation between resilience and antifragility in emerging business research?
3. What is the relationship between CNs and antifragility in emerging business research?
4. What is the conceptual framework of antifragility in the SME context?

We use bibliometric analysis and a systematic literature review of the published articles related to the topic to find the answers. These methods enable researchers to construct knowledge maps for particular issues. This study contributes to delivering a complete understanding of the growth of knowledge regarding antifragility and its relation with resilience and CNs strategy. We also elaborate on the antifragility framework in the SME context to explore its unique potential in generating SME antifragility. We also propose the conceptual framework of antifragile SMEs and suggest further research directions.

Method

We used bibliometric analysis and systematic literature review (SLR) to gain a comprehensive understanding related to the growth of knowledge about Collaboration, Resilience, and Antifragility in the SME context. The concurrent use of bibliometric analysis and SLR is due to the limited amount of publications discussing antifragility in the SME context. Therefore, firstly, we developed a fundamental understanding of antifragility using bibliometric analysis. Secondly, we specified our knowledge by using SLR in the more specific areas related to antifragility, that is, resilience, collaboration, and SMEs. This systematic procedure helped the development of evidence-based reviews through relevant and credible academic sources (Cook et al., 1997; Tranfield et al., 2003). We used multiple approaches to

understand the conceptual framework and coherent theoretical stories by summarising the comprehensive evidence (Fink, 2019; Okoli, 2015; Webster & Watson, 2002).

Article Selection Protocol

The list of articles in this study was collected from the Scopus database. We used the Scopus database because it is a relatively large repository and contains many significant and reputable channels. We did it four times to get the list of articles. The first search was done to collect the list of articles for bibliometric analysis, while the rest were for the SLR. The search keys for each step are outlined in Table 1.

Table 1. Search Keys

No.	Group	Search Key
1.	Antifragility (Bibliometric)	TITLE-ABS-KEY (antifragility) AND (LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "ECON") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "DECI")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "p") OR LIMIT-TO (SRCTYPE , "j"))
2.	Antifragility and Resilience	TITLE-ABS-KEY(antifragility AND resilience) AND (LIMIT-TO (SUBJAREA , "BUSI")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "p") OR LIMIT-TO (SRCTYPE , "j"))
3.	Antifragility and Collaboration	TITLE-ABS-KEY (antifragility) AND TITLE-ABS-KEY ("collaborative network" OR "collaborative networks" OR collaboration) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "p") OR LIMIT-TO (SRCTYPE , "j"))
4.	Antifragility and SMEs	TITLE-ABS-KEY (antifragility) AND TITLE-ABS-KEY (sme OR smes OR "small business" OR "small-medium enterprise" OR "small-medium enterprises" OR "small and medium enterprise") AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "p") OR LIMIT-TO (SRCTYPE , "j"))

We limited the search area only to “Business, Management, and Accounting”, “Economics, Econometrics, and Finance”, “Decision Science”, and “Social Science” subject areas as these are the most relevant to describe SME business activity. Furthermore, we also limited the source type only to journals and proceedings. Finally, we limited the language only to English-language manuscripts collected. The first key search resulted in 63 (sixty-three) articles (in July 2023), while the second search resulted in twelve documents, the third search resulted in eight documents, and the fourth search resulted in six documents. We used all the collected articles in the first key search for bibliometric analysis. In contrast, the collected documents in the second, third, and fourth key search resulted in intersecting articles. Therefore, we located the intersect articles to the most relevant group according to the topics. Besides, the irrelevant articles were omitted from the list. Finally, the second group (Antifragility and Resilience) contained eight documents, the third group (Antifragility and Collaborative Network Strategy) contained six documents, and the fourth group (Antifragility in SMEs) contained four documents.

Data Analysis

In the bibliometric analysis phase, we used co-citation and thematic analysis to map knowledge structure regarding antifragility in economics and business fields. R studio with bibliophily package was performed to do the bibliometric analysis. Co-citation analysis was beneficial to understand the pattern of knowledge growth in the related issue (Boyack & Klavans, 2010; Small, 1973), while thematic analysis was beneficial to understand the emerging topic that is considered or has been discussed in existing research (Tranfield et al., 2003). The bibliometric analysis used a keyword plus field and was limited to only 50 words in clustering. We merged the synonyms, including: "human" and "humans"; "antifragility" and "antifragile"; "system dynamics" and "system dynamics modeling"; "accident prevention" and "accidents" and "accident". We also deleted non-relevant words, including article, equipment design, research work, case report, design/methodology/approach, beer, biomedical engineering, brain, and child. After that, we re-analyzed the data. From the bibliometric analysis result, we observed both co-citation and thematic clusters and networks. The clusters were generated according to the references that were generally seen to be repeatedly cited together by the primary articles (Culnan, 1986). These references were considered related and then included in one cluster when mapped. References that were rarely or never cited together were not included in one cluster (Culnan, 1986). In the thematic analysis, common keywords of the primary articles were considered to have thematic similarities, so they were included in one cluster (Marshakova-Shaikevich, 2005; Marshakova, 1981). In contrast, keywords rarely or never shown together were separated from the cluster. After that, we reviewed the articles and defined the topic discussed by the co-citation articles to comprehensively understand the intellectual structure of the co-citation articles and the thematic result.

Furthermore, we used a systematic literature review to deepen our understanding of antifragility from several specific issues, including resilience, CNs, and SMEs. The comprehensive mapping of knowledge was essential to provide insight and guidance for researchers, practitioners, and policymakers to act on further research, knowledge development, and practice related to antifragility in SMEs (Okoli, 2015; Tranfield et al., 2003). From the three groups of listed articles, we explored a unique framework suitable for expressing antifragility strategy for SMEs.

Results

Co-citation and Thematic Analysis

The co-citation analysis result, in Figure 1 and Table 2, shows that the co-citation articles can be grouped into two clusters. The first cluster tends to consist of the older articles and the main sources of the antifragility concept. The second cluster tends to consist of later articles and responses to the uncertainty due to technology disruption, market uncertainty, and the COVID-19 crisis. Furthermore, the thematic analysis result, in Figure 2 and Table 3 shows that the themes can be grouped into six groups. We observed the betweenness centrality value as it indicates to what extent the node is in the middle of a path that connects other nodes in the network, meaning the related articles with high betweenness centrality are revolutionary in the network (Brandes, 2001; Chen et al., 2010; Freeman, 1977). The result indicates that not every cluster has strong betweenness centrality. It was normal because the topic of antifragility is relatively new in business research. Regarding these findings, we blended the co-citation and thematic analysis results, then regrouped the themes to deliver more systematic knowledge regarding the antifragility concept.

Antifragility, Uncertainty, and Learning Capacity

The terminology of antifragility came from Taleb (2012). That is why Taleb (2012) has the strongest betweenness centrality of the co-citation analysis. Furthermore, Ramezani (2020) proposed a comprehensive framework of resilience and antifragility in business entities using

a systematic literature review. That framework is probably strategic for further research in the related field so Ramezani (2020) has a high betweenness centrality. Ramezani (2020) proposed that resilience produces persistence in systems' response that requires business entities to have absorptive capacity, while transformative resilience requires adaptive and transformation capacity to generate dynamic stability. Moreover, antifragility enables the company to achieve more than stability but improvement. In this case, the company needs learning capacity to generate antifragility (Ramezani & Camarinha-Matos, 2020).

Hillmann & Guenther (2021) are the fourth strongest betweenness centrality in the co-citation analysis. They analyzed the intellectual roots of resilience at the organizational level. They argued that different disciplines have influenced various understandings regarding the organizational resilience concept; and then proposed developing an umbrella concept for a powerful conceptualization of the business phenomena. Furthermore, later researchers used Holling's (1973) perspective to describe the concept of resilience by proxying the logic of ecological discipline. Several studies also used Forrester's (1968) perspective in describing the dynamic environment or non-linear system on management and economic behavior. In line with the co-citation result, the thematic analysis also clustered related themes into cluster 1 (antifragility), including antifragility, resilience, uncertainty analysis, and enterprise engineering. It indicated that antifragility research in business is highly related to resilience. Furthermore, the trigger circumstance which encourages antifragility and resilience is uncertainty.

According to Taleb (2012), the concept of antifragility rises in response to the uncertainty or randomness in today's life circumstances. Individuals or organizations that have antifragility could not only survive but also gain benefits from its randomness (Chrousos, 2009; Corvello, Verteramo, et al., 2022; Johnson & Gheorghe, 2013; Ramezani & Camarinha-Matos, 2020). Some probably define stress or stressors as destructive antecedents (Chrousos, 2009), but antifragile individuals, communities, or organizations could define them as opportunities for growth (Blečić & Cecchini, 2017). According to the co-citation table, the term antifragility has taken attention and been discussed in a wide range of disciplines as randomness exists in cross-sector. Jacobs (1961) and Blečić & Cecchini (2017) researched resilience and antifragility in the context of building, city, and community, while Johnson & Gheorghe (2013) and Jones (2014) analyzed antifragility in the engineering systems context. Carpenter et al. (2001) and Cavanagh (2017) discussed resilience and antifragility from the socioecological point of view. After all, these cross-disciplinary studies have a similar understanding regarding the existence of randomness or shock event that challenges the stability of various productive sectors. In the business field, randomness is defined as the extreme event, shock, crisis, or uncertainty that affects the business catastrophically and challenges the company's survivability (Corvello, Verteramo, et al., 2022; Ramezani & Camarinha-Matos, 2020).

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Table 2. Co-Citation Network

No.	Node	Cluster	Btwnnss	Closeness	PageRank	Title	Topic
1	Taleb N.N. 2012	1	447,8667	0,003846	0,085563	Antifragile	Antifragility
2	Taleb N.N.	1	72,46667	0,002381	0,041934	Black Swan	Randomness
3	Holling C.S. 1973	1	4,8	0,001724	0,018915	Resilience and stability of ecological systems	Resilience
4	Ramezani J. 2020	1	141,5333	0,002469	0,045099	Approaches for resilience and antifragility in collaborative business ecosystems	Antifragility & Resilience
5	Jacobs J. 1961	1	0	0,002222	0,018184	The Death and Life of Great American Cities	Building, City, and Community
6	Hillmann J. 2021	1	42,33333	0,001754	0,028685	Disciplines of organizational resilience: contributions, critiques, and future research avenues	Resilience
7	Johnson J. 2013	1	0	0,002273	0,017584	Antifragility analysis and measurement framework for systems of systems	Risk and Disaster Management
8	Jones K.H. 2014	1	0	0,001626	0,010787	Engineering Antifragile Systems: A Change In Design Philosophy	Antifragile System (Computer)
9	Blecic I. 2017	1	0	0,002222	0,018184	On the antifragility of cities and of their buildings	Building, City, and Community
10	Carpenter S. 2001	1	0	0,002198	0,010456	From Metaphor to Measurement: Resilience of What to What?	Resilience (socioecological & environment)
11	Cavanagh C.J. 2017	1	0	0,001307	0,011786	Resilience, class, and the antifragility of capital	Antifragile & Resilience
12	Chrousos G.P. 2009	1	0	0,002198	0,010456	Stress and disorders of the stress system (article)	Stress system
13	De Bruijn H. 2020	1	0	0,002326	0,017425	Antifragility as a design criterion for modelling dynamic systems	Dynamic System Modelling/Decision System
14	Eisenhardt K.M. 1989	1	0	0,001681	0,018484	Building Theories from Case Study Research	Case-oriented process
15	Fiksel J. 2015-2	1	0	0,001681	0,018484	From risk to resilience: learning to deal with disruption	Resilience
16	Forrester J.W. 1968	1	0	0,002198	0,010456	Industrial Dynamics—After the First Decade	Dynamic (industry)
17	Knight F.H. 1921	2	39	0,003067	0,029208	Risk, uncertainty and profit	Uncertainty
18	Markey-Towler B. 2018	2	384	0,003984	0,026636	Antifragility, the Black Swan and psychology	Antifragility
19	Acs Z.J. 2014	2	0	0,003021	0,025317	National Systems of Entrepreneurship: Measurement issues and policy implications	Entrepreneurship System
20	Acs Z.J. 2012	2	0	0,003021	0,025317	Patents, knowledge spillovers, and entrepreneurship	Knowledge (Spillover)
21	Andersen T.M. 2008	2	0	0,003021	0,025317	The Scandinavian model—prospects and challenges	Welfare model
22	Armour J. 2006	2	0	0,003021	0,025317	The legislative road to Silicon Valley	Legal/policy model

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23	Baumol W.J. 2005	2	0	0,003021	0,025317	Education for Innovation: Entrepreneurial Breakthroughs versus Corporate Incremental Improvements	Innovation mind (entrepreneurship)
24	Baumol W.J. 1990	2	0	0,003021	0,025317	Entrepreneurship: Productive, unproductive, and destructive	Innovation mind (entrepreneurship)
25	Baumol W.J. 2010	2	0	0,003021	0,025317	The Microtheory of Innovative Entrepreneurship	Innovation mind (entrepreneurship)
26	Beltagui A. 2020	2	0	0,003021	0,025317	Exaptation in a digital innovation ecosystem: The disruptive impacts of 3D printing	Innovation/Supporting Ecosystems
27	Bhide A. 2008	2	0	0,003021	0,025317	The Venturesome Economy: How Innovation Sustains Prosperity in a More Connected World,	Innovation mind (entrepreneurship)
28	Bylund P.L. 2017	2	0	0,001919	0,004693	Where is the Austrian theory of collaborative orders?	Collaboration
29	Chiles T.H. 2004	2	0	0,003021	0,025317	Organizational emergence: The origin and transformation of Branson, Missouri's musical theaters	Complex systems/(Puspitasari & Ishii, 2016)Transformation
30	Cilliers P. 2000	2	0	0,003021	0,025317	What Can We Learn From a Theory of Complexity?	Learn
31	Dekker S. 2012	2	0	0,003021	0,025317	Drift into failure: From hunting broken components to understanding complex systems	Complex Systems/Failure Management
32	Dopfer K. 2004	2	0	0,003021	0,025317	Micro–Meso–Macro	
33	Eberhart R.N. 2017	2	0	0,003021	0,025317	Failure Is an Option: Institutional Change, Entrepreneurial Risk, and New Firm Growth	Failure Management
34	Elert N. 2019-1	2	0	0,003021	0,025317	The Collaborative Innovation Bloc: A New Mission for Austrian Economics	Collaboration
35	Elert N. 2019-2	2	0	0,003021	0,025317	The Collaborative Innovation Bloc: A Reply to our Commentators	Collaboration
36	Eliasson G. 2000	2	0	0,003021	0,025317	Industrial Policy, Competence Blocs and the Role of Science in Economic Development	Knowledge (Spillover)
37	Fenn G. 1995	2	0	0,003021	0,025317	The economics of the private equity market	Economics systems
38	Fortunato M.W.P. 2017	2	0	0,003021	0,025317	Advancing educational diversity: antifragility, standardization, democracy, and a multitude of education options	Antifragility (education)
39	Foss N.J. 1997	2	0	0,003021	0,025317	Austrian Insights and the Theory of the Firm	Firm Theory
40	Gilson R.J. 2003	2	0	0,003021	0,025317	Understanding Venture Capital Structure: A Tax Explanation for Convertible Preferred Stock	Venture Capital
41	Gompers P.A. 2001	2	0	0,003021	0,025317	The Money of Invention: How Venture Capital Creates New Wealth	Venture Capital

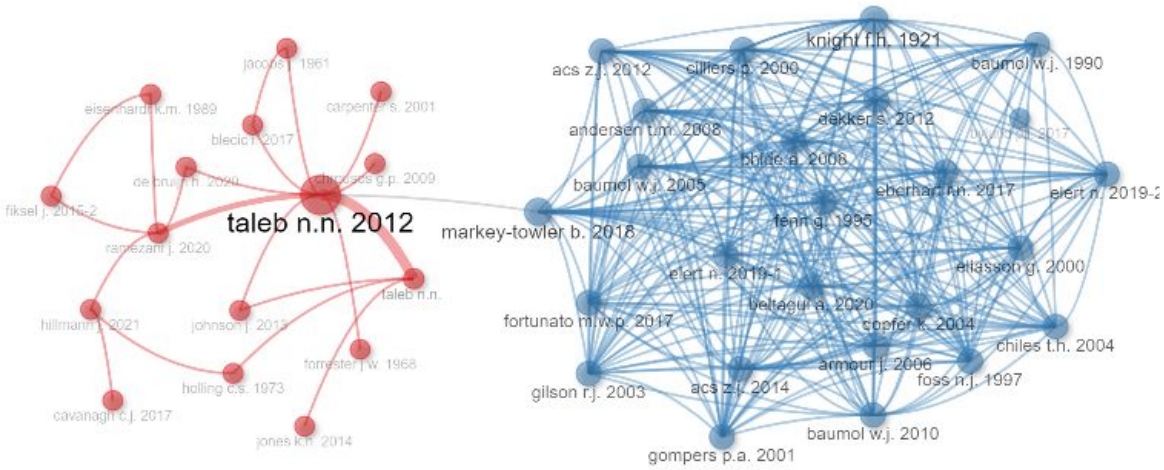


Figure 1. Co-Citation Network

Human and Psychological State

In the second cluster, the co-citation articles mainly focus on business and economics. The oldest article is Knight (1921), which explains the existence of risk and uncertainty that directly threaten company profit. Furthermore, the strongest co-citation article is Markey-Towler (2018), which proposes the psychological condition as the primary foundation to survive in the radically uncertainty of complex socioeconomic environment. It was reasonable to Markey-Towler (2018) have strong centrality and betweenness because that research uses multiple perspectives to describe antifragility, such as Jungian psychology; Schumpeterian, Kirznerian, and Lachmannian entrepreneurs; Ulrich Witt's notions of adaptability and imagination; and Caroline Gerschlager's agents of change concept. According to those concepts, Markey-Towler (2018) argues that a positive psychological state and entrepreneur mindset are critical to developing antifragility.

Similarly, Cluster 2 of thematic analysis also identifies human and complexity terms. It indicates that humans and complexity are discussed extensively in the emerging publications. Humans are the core actors who manage a company's complexity in passing randomness. Based on George Shackle's view, Markey-Towler (2018) argues that radical uncertainty is essential to human affairs as it makes human personal knowledge grow by supplying new apparent relations between objects and events in the world that do not exist in the individual's hitherto personal knowledge. The human mind would respond to radical uncertainty with the psychological process through perception-analysis-decision operations and then growing personal knowledge to be antifragile in response to that event (Markey-Towler, 2018). The antifragile response would supply insight into personal knowledge of how and why to act in the uncertain world to grow rather than rejecting the opportunity and then being stuck in the status quo (Markey-Towler, 2018).

Innovation Mind

The rest of the articles in cluster 2 do not show strong co-citation. However, we can observe the topics that the co-citation articles mainly discuss to see the map of knowledge relating to antifragility. That was important to give us an insight regarding the branch knowledge that emerged on constructing the antifragility concept and its practicality in the business sector. Baumol (1996), Baumol (2005), Beltagui et al. (2020), and Bhidé (2009) have explored antifragility or resilience from an innovation point of view. They generally argued that the innovation mind is the mental state entrepreneurs need to face uncertainty. Furthermore, there are two main topics related to the innovation mind, including education and

knowledge spillover (Acs & Sanders, 2012; Baumol, 1996, 2005) and supporting ecosystems (Beltagui et al., 2020). Acs & Sanders (2012) argued that new knowledge will positively impact innovation and growth. Relevantly, Baumol (2005) argued that entrepreneurs need strong education to master scientific knowledge and methods to generate innovation and growth.

Referring to Markey-Towler (2018), we argue that the innovation mind arises from a positive psychology process, while the ingredients are strong education and knowledge spillover in the organization. Strong education has the role of a knowledge basis, while knowledge spillover is the dynamics to produce new knowledge continuously that transforms uncertainty into innovation. At the same time, Beltagui et al. (2020) required the healthy business ecosystem to deal with the disruption and the exaptation of the latent function of pre-existing technology. Similarly to Markey-Towler's (2018) view, in business ecosystems, the new entrant will bring a new challenge for the business incumbent to innovate their business to maintain their competitiveness while at the same time, the collaboration option is open to developing mutual competitive advantage (Beltagui et al., 2020). Furthermore, exaptation-driven innovation focuses on the optimation of existing artefacts to deliver new value in specific or general business processes (manufacturing, business and information systems, marketing, or selling) (Beltagui et al., 2020).

Cooperative Diversity and Transformative Organization

Consistently, several co-citation articles explained the organization's transformation or failure from the theory of complexity point of view (Chiles et al., 2004; Cilliers, 2016; Dekker et al., 2011). Chiles et al. (2004) argued that transformative or revolutionary organizations are born from increasing diversity while the organization maintains its perpetual equilibrium. In a complex model, there is a dynamic mechanism of emergent self-organization, which improves local knowledge through continuous feedback about innovative action (Chiles et al., 2004). The dynamic equilibrium includes 1) spontaneous fluctuation; 2) autocatalytic feedback; 3) coordinating mechanism; and 4) recombinating preexisting resources (Chiles et al., 2004). Related to that view, Fortunato (2017) argued that antifragile organization needs diverse knowledge. Fortunato (2017) found that standardized knowledge would barrier transformative ideas in organizations. In contrast, diverse knowledge is defined as a contrary idea, viewpoint, or skill set that aims to facilitate meaningful discussion and build understanding in crafting meta-level goals and system-level design (Fortunato, 2017).

In a more concrete description, Elert and Henrekson (2019) stated that organizations need actors from several skill pools to identify and exploit new opportunities together. The different pools of skills that complement each other would help the company to provide a substantial effect on innovation and growth compared to the analysis from a single skills actor (Elert & Henrekson, 2019; Phelps, 2007). In this case, those diverse actors are expected to work in a cooperative environment instead of competition to collaborate for an innovation-based venture to gain a higher probability of success (Elert & Henrekson, 2019; Rubin, 2014). Elert and Henrekson (2019) described this dynamic as "the collaborative innovation bloc". If we connect this concept to failure management, the chaotic event brings an emergent challenge to the company that is ideally responded to it by a diverse knowledge and complex model in the frame of a collaborative innovation bloc. How a company responds to chaotic events will determine its failure, survival, or even growth; it is a choice (Eberhart et al., 2017).

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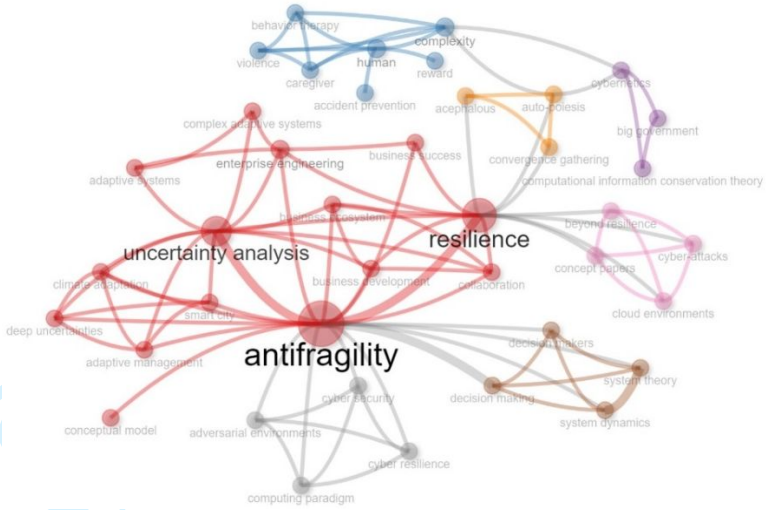


Figure 2. Thematic Network

Autopoiesis, Cybernetics, and System Dynamics

In the thematic analysis, Cluster 4 presents cybernetics, and Cluster 5 presents autopoiesis as the single topic detected. Furthermore, Cluster 6 represents system dynamics as one of the discussed themes in the antifragility field. It indicates that antifragile business needs credible systems to help the company make transformative decisions during randomness. Therefore, firstly, we must understand how autopoiesis and cybernetics work to generate credible system dynamics.

Autopoiesis is the concept first proposed by Maturana and Verela (1980). It describes a living system in which the system is capable of self-sustaining owing to an inner network reaction and regenerating all the system's components (Dinga et al., 2022; Luisi, 2003; Maturana & Varela, 1980). Autopoiesis captures how components organize themselves (self-organization) in the bounded system by generating a metabolic reaction network to produce new features to maintain, repair, and make better systems for themselves (Luisi, 2003; Maturana & Varela, 1980). Maturana and Verela (1980) mentioned the bounded system in the autopoiesis concept of self-organization. It was interesting because we previously understood from Elert and Henrekson (2019) the importance of cooperation from diverse knowledge and skill pools to generate new insight for innovation. Luisi (2003) mentioned that the nutrients and energy that are exploited to generate autopoiesis in bounded systems come from the medium or open systems as the dissipative cell. On the other perspective, Dinga et al. (2022) argued that self-organization in the autopoiesis concept has a certain threshold. The idea of self-organization needs to be validated by a certain environment and proposed as an intermediate stage between mutation and selection (Dinga et al., 2022). Cooperation, competition, and mutation exist in the market as an open system (Dinga et al., 2022; Luisi, 2003). How a company or individual responds to it, represents their self-organization and determines whether they will mutate and produce co-evolution (transformation) or fail in the selection (Dinga et al., 2022).

Relating to the strategy to generate self-organization, Cutler and von Lingen (2019) proposed three phases in emergent autopoietic coherence (EAC), including 1) information and communication emerge, manifested as cognitive and organizational hierarchies (emergence); 2) motivation changes and stabilizes, manifested as sustained goal definition and goal realization (auto-poiesis); and 3) competence self-organizes, manifested and cohered as systems for response to threat (coherence). Cutler and von Lingen (2019) developed EAC based on the cybernetic learning paradigm. Cybernetics is a science that studies the abstract

principles of organization in complex systems, which focuses on how the systems use information, models, and control actions to help management or individuals act to maintain goals and counteract various disturbances (Heylighen & Joslyn, 2003). In the cybernetics context, self-organization is described as the principle of dynamic systems. Ashby (1956) argued that systems consist of various sub-systems that are mutually dependent and mutually adapted, which will be aligned in a similar direction. Those dynamics would be enhanced by random perturbation of the system's state and speed up the improvement of the system itself (Heylighen & Joslyn, 2003). Autopoiesis and cybernetics describe a similar concept of the organizational system dynamics in response to perturbation. The natural response of the organization or individual in response to perturbation is counteracted through learning. However, the dynamics of interaction in the internal network of subsystems, components, skills, and knowledge are needed to construct new knowledge to improve existing systems facing perturbation. Therefore, a collaboration network at the relative level of the system or ecosystem would become a crucial dynamic to earn antifragility.

Table 3. Thematic Network

Occur-rences	Words	Cluster	Cluster_Label	btw_ centrality	clos_ centrality	pagerank_ centrality
8	antifragility	1	antifragility	308,75	0,010204082	0,077564621
4	resilience	1	antifragility	429	0,011764706	0,053575409
3	uncertainty analysis	1	antifragility	113	0,010309278	0,043483593
2	enterprise engineering	1	antifragility	71,61111111	0,010752688	0,022427589
3	human	2	human	75	0,006451613	0,034434776
2	complexity	2	human	198	0,008064516	0,030374917
2	urban area	3	urban area	2	0,333333333	0,029937622
2	cybernetics	4	cybernetics	74	0,0078125	0,02309934
2	auto-poiesis	5	auto-poiesis	290	0,00990099	0,023255931
2	system dynamics	6	system dynamics	9	0,007518797	0,018690159
2	decision making	6	system dynamics	0,25	0,005952381	0,01842451
2	system theory	6	system dynamics	9	0,007518797	0,018690159

Systematic Literature Review

The results of the systematic literature review were processed with different techniques. We reviewed the collected articles, resumed the main findings, and ordered the relevant information based on the research objective. After that, we presented the findings with a similar form of the co-citation and thematic analysis result to maintain the pattern of the discussion. We offer three related topics in this section, including 1) Antifragility and Resilience, 2) Antifragility and Collaborative Networks Strategy, and 3) Antifragile SME. The review matrix of those three topics is presented in Table 4, Table 5, and Table 6.

Antifragility and Resilience

Scholars still have an inconsistent argument about positioning antifragility and resilience to describe how companies face or pass adversity or perturbance. Some scholars argue that resilience is part of antifragility (Botjes et al., 2021), others argue that antifragility is part of resilience (Nieuwborg et al., 2023), and others argue that antifragility is a different level of response or counteract to pass the perturbances (Corvello, Felicetti, et al., 2023; Jaaron & Backhouse, 2014; Munoz et al., 2022). If resilience only allows the company to manage adversity and sustain, then antifragility is beyond. The antifragile company can gain opportunity and make valuable investments in the unfortunate event, and they can generate advantage or revenue growth from it (Corvello, Felicetti, et al., 2023; Jaaron & Backhouse,

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2014; Munoz et al., 2022). Antifragility and resilience are the intersections, and the company's main characteristics needed to be resilience and antifragile are similar, that is, learning (Botjes et al., 2021; Corvello, Felicetti, et al., 2023; Jaaron & Backhouse, 2014; Uzunov et al., 2019).

A resilient business can accept adversity and then absorb energy from it to adapt its business system to the new situation (Bostock & Breese, 2021; Carpenter et al., 2001; Chowdhury et al., 2019; Corvello, Felicetti, et al., 2023; Martin, 2012). That ability allows the company to return to its state of equilibrium, even though it may not be in the same as the previous state, the business is still sustainable (Chowdhury et al., 2019). On the other hand, antifragility shares common points with resilience (Corvello, Felicetti, et al., 2023; Ramezani & Camarinha-Matos, 2020). Antifragility also talks about how someone or a company can deal with randomness, which represents uncertainty, catastrophe, adversity, perturbation, and shock, by reconfiguring the current system into a new and more capable system (Blečić & Cecchini, 2017; Markey-Towler, 2018; Nikookar et al., 2021). However, antifragility expects more than just sustainability or gaining back the equilibrium. The critical goal of antifragility is obtaining an advantage to getting benefits from the shock (Munoz et al., 2022; Ramezani & Camarinha-Matos, 2020). Antifragile companies exploit the unique opportunity of the shock as the momentum to transform the business into a new form, which helps them generate more competitive advantage (Blečić & Cecchini, 2017; Corvello, Felicetti, et al., 2023; Munoz et al., 2022). More specifically, Ramezani & Camarinha-Matos (2020) elaborated the conception of resilience and antifragility into three levels in a continuum line: resilience, transformative resilience, and antifragility. Resilient businesses would achieve stability during adversity, while transformative resilience would gain dynamic stability, which is more elastic and adaptive, and antifragile businesses would gain improvement through business transformation (Ramezani & Camarinha-Matos, 2020). That view has given insight into the gradation between resilience and antifragility.

Interestingly, based on the findings of primary articles, both resilience, and antifragility have a similar character that is required to exist in business companies, that is a learning-centered organization (Botjes et al., 2021; Jaaron & Backhouse, 2014; Uzunov et al., 2019). The learning process is the core antecedent that enables the company to understand perturbation, develop categorization, generate ideas, determine the strategy to execute the idea, reconfigure the system, and self-organize. The whole phase of pursuing resilience and antifragility depends on how the company learns its internal and external business circumstances and adopts them to make decisions (Chiles et al., 2004). Besides, the existing knowledge (cognitive) also becomes a strategic issue in determining the level of resilience or antifragility (Markey-Towler, 2018). Botjes et al. (2021) indicated learning as a mental model that becomes a fundamental ingredient of resilience and antifragility.

Table 4. Review Matrix of Antifragility and Resilience

No.	First order sources	Purpose	Sample	Key Findings
Antifragility and resilience				
1.	Corvello, Felicetti, Troise, & Tani (2023)	Investigate the relationship between antifragility and intangible resources, tangible surplus resources, and absorptive capacity.	Italian start-ups	A combination of tangible (slack resources) and intangible (intellectual capital and absorptive capacity) resources can help start-ups to thrive and support their antifragility.
2.	Razemani & Camarinha-Matos (2020)	Perform a survey and analysis of relevant literature on resilience and antifragility, focusing on collaborative business ecosystems.	Literature in ISI Web of Science, Google Scholar, and Scopus (Literature Survey).	Resilience and antifragility are mainly related. Considering the internal capabilities and understanding disruption sources and drivers to activate strategy in response to disruption, then improve the strategy through learning mechanisms.

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3.	Nikookar, Varsei, & Wieland (2021)	Introduce antifragility to the purchasing and supply chain management literature as an approach to disorder and randomness.	Literature	Experimental approaches within supply chains would help managers detect vulnerability earlier, learn quickly, and gain from disorder.
4.	Munoz, Billsberry, & Ambrosini (2022)	Conceptually contrast resilience with robustness and antifragility so that future research might craft a more nuanced understanding of the presence of all three concepts in management research, which is currently dominated by resilience.	Literature	*Robustness* is the ability to resist and avoid the negative impact of adversity on company performance through slack resources. *Resilience* is the ability to act toward recovery by passing the adversity through procuring resources. *Antifragility* is the ability to exploit unexpected opportunities during adversity and then make strategic investments to minimize downside risk and maximize upside opportunity.
5.	Nieuwborg, Mastrigt, Melles, Zekveld, & Santema (2023)	Create concept clarity regarding resilience by proposing a categorization of resilience.	Literature (Scoping Review)	Resilience is categorized into four reoccurring aspects: fragility, robustness, adaptation, and transformation.
6.	Bostock & Breese (2021)	Provide firm foundations for conceptualizing organizational resilience in sports management.	Literature	Organizational resilience is conceptualized as a strategy to achieve externally generated goals, emphasizing its dynamic and temporal nature.
7.	Jaaron & Backhouse (2014)	Explore the benefits of applying a systems approach to service delivery design to build an 'antifragile' organization that can learn from disruptions.	UK insurance sector	The systems approach will likely enhance organizational 'antifragility' by promoting a multilevel driver for learning from stressors (Macro level: continuous consumer analysis; Meso level: development of learning-centered teams and organic structure; Micro level: employees' engagement and readiness to learn).
8.	Botjes, van den Berg, van Gills, & Mulder (2021)	Find relevant attributes for an organization to become antifragile.	Literature (literature survey); Experts and various organization leaders	EAAL: *Attenuate Variety* (Engineering Resilience & System Resilience); *Amplify Variety* (Complex Adaptive System Resilience & Antifragile) *Fundamentals*: Learning organization, personal mastery, shared mental model, building shared vision, team learning, system thinking.
9.	Uzunov, Nepal, & Chhetri (2019)	Propose a conceptualization of a proactive antifragility, and then outline associated challenges and research directions indicating which existing approaches can be re-used or advanced/developed further for proactive antifragility to be achieved "at the edge".	Literature	Five ingredients of proactive antifragility: 1) distributed intelligence via self-generating policies; 2) coordination and self-organization; 3) proactivity in decision-making; 4) stateful service, resource, and link management; and 5) self-testing for self-improvement.

Antifragility and Collaborative Network Strategy

Most of the primary articles on antifragility and CNs indicate that CNs are a critical ingredient of antifragility (Cucino et al., 2023; Priyadarshini et al., 2022; Ramezani & Camarinha-Matos, 2020). CNs are a condition when members can confront their ideas and practices, combine their idiosyncratic knowledge, resources, and technologies, and create synergies to achieve common goals (Camarinha-matos & Afsarmanesh, 2006). If we refer to the dynamic mechanism (Chiles et al., 2004), diverse knowledge (Fortunato, 2017), collaborative innovation bloc (Elert & Henrekson, 2019), and autopoiesis (Maturana & Varela, 1980), all of those concepts are disembogued to a similar value with CNs. However, in CNs, collaborative work is more formal and well-organized to deliver proportional mutual advantages and predictable mutual benefits (Camarinha-matos & Afsarmanesh, 2006). The collaborative networked organization expectedly identifies the advantage specialty, the valuable and relevant idiosyncratic knowledge, and the market specification and defines the role of each member and the rules of the collaboration agreements (Camarinha-matos &

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Afsarmanesh, 2006). That schema is crucial to maintaining sustainable CNs, which directly affects the company's antifragility.

The diverse knowledge, skills, and characteristics of the business actors, which meet in mutual advantage goal, could enable the company to create new value or a new system to gain an advantage in the perturbance. These dynamics provoked the company to be antifragile. The perturbance event would be defined as challenges and stimulating collaboration between companies to counteract through companies' network interaction, confront their expertise, and reconfigure their collective goal and business process that represent self-organization, which brings them to antifragility. This CNs strategy is exceptionally fit for SMEs with various limitations and vulnerabilities in the highly competitive market. Therefore, the SME actors must consider the specific practical strategy for effective CNs strategy in a current volatile business environment.

Table 5. Review Matrix of Antifragility and Collaborative Network Strategy

No.	First order sources	Purpose	Sample	Key Findings
Antifragility and Collaborative Networks Strategy				
1.	Priyadarshini, Singh, Mishra, & Bag (2022)	Move beyond robustness and resilience and shift to an antifragile supply chain that sees disorder as an opportunity to learn and grow.	Literature in Scopus and 7 experts across industries	Top management, collaboration, and innovation strategy are essential driving power of antifragility besides technology adoption and resource allocation for digitalization.
2.	Ramezani & Camarinha-Matos (2019)	Identify several strategies that contribute to the business ecosystem's resilience or antifragility.	Literature	Several capabilities are proposed to overcome disruptions (flexibility, redundancy, convexity, agility, simplicity, visibility, creativity, and financial strength), and specific strategies are needed.
3.	Ramezani & Camarinha-Matos (2019)	Find how organizations can strive and improve or gain benefits in disruptive environments.	Literature	Collaboration in business ecosystems is a promising approach to cope with disruptions.
4.	Tartaglione, Cavacece, Carrubo, & Megaro (2023)	Understand if augmented intelligence may be considered as a driver of antifragility that can be allegorically represented by the Japanese art of Kintsugi, which consists of the use of gold or silver to repair broken objects in ceramic to get a better aesthetic form.	Italian companies	Efficient resource management, endless orientation towards results, and new synergies in increased networks, collaborations, and new forms of business culture (remote smart working, profitable relationships, trust, and work-life balance opportunities) are essential drivers of antifragility.
5.	Cucino, Botti, Celenta, & Baldegger (2023)	Examine which interactions between the internal capabilities affect the survival of innovative start-ups.	Start-ups in Italy	Creativity, flexibility, and collaboration are the main antecedents of antifragility. Interaction between these capabilities enables start-ups to survive during a crisis.

Antifragile SME

The paper by Corvello et al. (2022) was included both in the search results of antifragility & collaboration networks strategy and antifragility in SMEs. However, we included it in the "antifragility in SMEs" group as Corvello et al. (2022) consistently discussed antifragility in SMEs, and the paper had a strong relation to the other Corvello's publications in Corvello, Straffalaci, et al. (2022), and Corvello, Verteramo, et al. (2023). According to Corvello et al. (2023) and Branicki et al. (2018), SMEs have more flexibility and adaptability than big companies due to their simple business model, organizational structure, and human resources, which make them able to make decisions faster. Besides, the entrepreneurial attitude that usually works in the uncertain business environment due to limited human and financial resources has developed agility and advantage for SMEs to be comfortable with randomness compared to a big company (Corvello, Verteramo, et al., 2022, 2023). These advantages enable SMEs to improve their strategic position in facing crisis and increase their competitiveness to

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exploit disruption strategically (Branicki et al., 2018; Corvello, Verteramo, et al., 2023; Tavoletti et al., 2022).

However, SMEs need strategic action to optimize their advantages to gain antifragility. Based on the primary articles' findings, we collected three main antecedents of SME antifragility that is 1) Entrepreneurial attitude and knowledge; 2) collaborative networks; and 3) digital transformation. SMEs with good entrepreneurial attitudes and knowledge tend to grab new occasions, irrespecting crises, operate crises as opportunities, and have a good level of preparedness to make changes (Branicki et al., 2018; Corvello, Verteramo, et al., 2023). Entrepreneurial attitudes and knowledge are the ability of SMEs to understand the business circumstances comprehensively, determine their positive response and goal in facing adversity, and then decide on relevant action to take advantage of the adversity (Corvello, Verteramo, et al., 2023).

The second antecedent is CNs. Corvello, Verteramo, et al. (2022), Corvello, Straffalaci, et al. (2022), and Corvello, Verteramo, et al. (2023) indicated that collaboration is the gateway for SMEs to manage their limitation of knowledge, human and financial resources. Corvello et al. (2022) mentioned specifically that SMEs should initiate CNs strategy with research institutions to help SMEs do accurate business analysis, need assessment, technology transfer, and research-based decisions. However, in the broader context, CNs also potentially develop between partners in the business ecosystems or multisector industry, which can help SMEs fill the limitations of each other (Corvello, Verteramo, et al., 2023; Elert & Henrekson, 2019).

Finally, the third antecedent is digital transformation. Digital technology helps SMEs interact with business partners and consumers, detect changes promptly, gain visibility for initiatives, flexibly coordinate with employees, and automate some business processes (Corvello, Verteramo, et al., 2022). Furthermore, digital transformation could improve SMEs' flexibility in collaborative work through collaborative platforms, flexible data sharing, remote working, and continuous interaction. Corvello et al. (2022) argue that digital competence would escalate the level of antifragility of SMEs. Digital technology would improve SMEs' agility due to the accessibility of information, reliable connectivity to business networks, and the mediation of internal and external collaborative work, which are all related to antifragility efforts.

Table 6. Review Matrix of Antifragility in SMEs

No.	First order sources	Purpose	Sample	Key Findings
Antifragility in SMEs				
1.	Corvello, Verteramo, Nocella, & Ammirato (2022)	Study how digital technologies can contribute to the development of antifragility in SMEs.	SMEs in Italy	The primary antecedents of antifragility are slack financial resources, strategic agility, and networking with research institutions (collaboration), while digital technology helps the company to manage it in a better way.
2.	Corvello, Straffalaci, & Filice (2022)	Identify the dynamic capabilities implemented by the three companies and the levers used to develop these capabilities.	SMEs in Italy	Collaboration with research institutions in research and innovation processes has proved essential in building antifragility.
3.	Corvello, Verteramo, & Giglio (2023)	Investigate the variables that foster antifragility in the context of service SMEs.	Service SMEs in Italy	Entrepreneurial orientation, context insightfulness, and operational dexterity (agility) are the main ingredients of antifragility.
4.	Geldenhuys, Gobbelaar, & Kennon (2020)	Identify a new strategic approach to guide organizations and enterprises to adapt structural and strategic inadequacies to better handle disruption.	Literature	Complex adaptive systems are valuable and relevant perspectives to understand organizations, change and volatility, and antifragile responses and principles.

Conceptual Framework of Antifragile SMEs and Implications

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Based on the co-citation analysis, thematic analysis, and systematic literature review, we proposed a conceptual framework for explaining antifragile SMEs. We used the co-citation results to identify the root concept of antifragility from a retrospective view to see the critical characteristics and theoretical foundation of antifragility (Bandara et al., 2011; Boyack & Klavans, 2010; Small, 1973; Webster & Watson, 2002). It is important to understand the key characteristics, capture the related concepts, and assist in defining them clearly (Bandara et al., 2011). Furthermore, we used the results of the literature review to define the critical points and confirm a common understanding of resilience, antifragility, and collaboration in the SME context. This approach was helpful for the information systems field as most topics are constantly growing, especially antifragility in SMEs, and there is little consensus about the core concepts (Bandara et al., 2011; Okoli, 2015; Webster & Watson, 2002). We connected the results of the co-citation analysis as the theoretical foundation and the literature review as the operational concept to construct a complete understanding. After all, we restructured the knowledge to propose a comprehensive framework for SME's antifragility (Okoli, 2015; Tranfield et al., 2003). The mind map of that framework is presented in Figure 3.

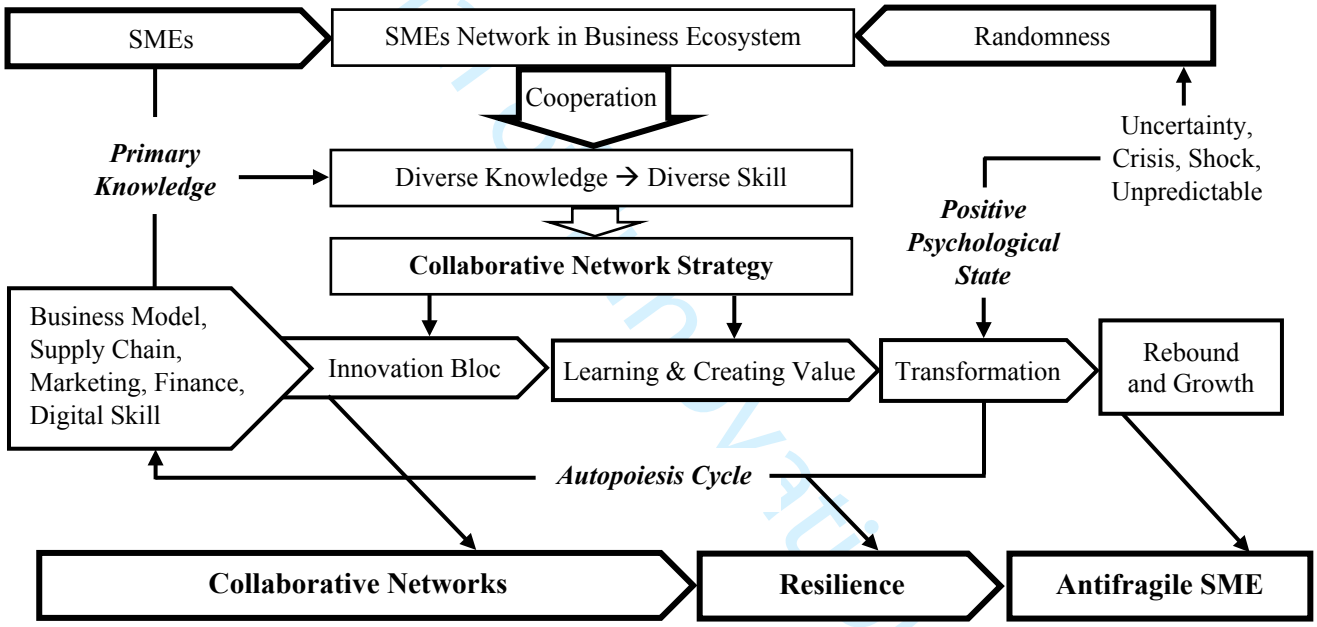


Figure 3. Proposed Framework of Antifragile SMEs

We argue that a positive psychological state and strong primary knowledge (cognitive) are the pillars of antifragility in SMEs, which is observable through entrepreneurial attitude. Previous studies have investigated those characteristics separately as the antecedent of resilience among SMEs, yet have not explored more on antifragility levels (Corvello, Verteramo, et al., 2022, 2023). Whereas, in randomness, SMEs need positive psychology to accept adversity and think about potential opportunities to face it (Blečić & Cecchini, 2017; Markey-Towler, 2018). With positive psychology, SMEs could define adversity as an opportunity to grow instead of a threat, which could activate their innovation mind. At the same time, it requires primary knowledge. SME actors need primary knowledge about their business and then connect it to the current trends to understand the critical part of their business state. After that, they can define the appropriate strategy to deal with the targeted problem. Strong and diverse knowledge about their business is critical to develop an appropriate strategy to execute the business transformation (Fortunato, 2017). Therefore, positive psychology extended with experience, business knowledge, product and market competition knowledge,

and digital skills are the combinations that generate an innovation mind that enables SMEs to be agile in doing business and antifragile in facing randomness.

Furthermore, remind that SMEs commonly have limitations of resources, CNs would be a core aspect that SMEs should deal with both internally and externally. Knowledge diversity should be managed under collaborative works to complement each other and stimulate ideas of innovation. Internal collaboration would help SMEs engage all of the diverse resources in the company to produce practical innovation in their idiosyncratic business (Camarinha-matos & Afsarmanesh, 2006; Tartaglione et al., 2023). In contrast, external collaboration would help SMEs substitute their specific limitation to their partner's advantage to get broader benefits for their competitiveness (Elert & Henrekson, 2019; Ramezani & Camarinha-Matos, 2019b). Collaboration with a heterogeneous business partner would help SMEs transform their limitations into opportunities (Cucino et al., 2023; Ramezani & Camarinha-Matos, 2019a). In this case, SMEs could explore collaboration opportunities inside their business ecosystem or existing partnerships with more productive cooperation or widen the opportunity by joining a new business ecosystem in different geographical areas or business sectors. CNs concept was already proposed by Ramezani & Camarinha-Matos (2020) to generate antifragility in business ecosystems. We adapted that idea to the SME context. In the proposed framework, we included CNs in the model as the leverage of innovation as it is tightly suitable to accommodate SMEs' resource limitations.

In the proposed framework, we adapt the autopoiesis concept as a cycle that underlies the antifragility construction (Luisi, 2003). We argue that autopoiesis is an iterative process of generating innovative ideas, learning, relearning, and acting for transformation. SMEs that consistently do autopoiesis cycles would be able to develop their competitive advantage in their DNA and would be agile in facing uncertainty. In the autopoiesis cycle, SMEs would stimulate their innovation mind, which is the principal capital of network interaction in the innovation bloc (Cutler & von Lingen, 2019; Elert & Henrekson, 2019; Luisi, 2003). Furthermore, we propose learning and value creation as the main ingredients of autopoiesis and products of the CNs, which implies SME transformation. Autopoiesis is the core cycle that SMEs should engage in to pursue transformation which is the strategic action to achieve rebound and growth. This concept integrates valuable insights that were only separately stated from primary studies (Botjes et al., 2021; Elert & Henrekson, 2019; Nieuwborg et al., 2023; Ramezani & Camarinha-Matos, 2020).

We consider both digital and business transformation as an intersection in gaining advantages from randomness represented by crisis and a highly competitive environment (Corvello, Verteramo, et al., 2023; Troise et al., 2022). Transformation is the consequence of autopoiesis, innovation minds, and CNs. Innovation ideas will give an advantage only if they are executed in business transformation. In other cases, massive IT innovation and COVID-19 have become the momentum of SMEs' digital transformation, where digital technology has become an exit door for SMEs to pass the crisis. However, SMEs cannot deal with randomness with simply digital investment. A comprehensive view of digital and business transformation is inevitable. Digital technology expectedly could make business operations more agile. But it requires a new way of business works. SMEs must continuously adjust their business, aligning the digital technology and transforming the company until they find the fittest business model. That new business model will simultaneously shift SMEs into a new equilibrium.

Finally, the indicator of successful antifragile SMEs is that they can rebound from adversity and have even better equilibrium than their previous state (Corvello, Straffalaci, et al., 2022). Antifragile SMEs can be resilient in the randomness while improving their business efficiency and profitability. Antifragile SMEs can find a better business model for their specific business case, find a new market, and create a new competitive advantage. That is a unique skill that is possible for SMEs due to their characteristics. A simple business structure, simple

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business model, and low assets give SMEs more flexibility to be agile in transforming business and, in turn, to be antifragile in a random business environment. However, antifragility needs to be developed as it is not a gift. In this case, SMEs could use the proposed framework as a thinking foundation to construct their antifragility development strategy.

Conclusion and Future Research Agenda

This study aimed to develop a complete understanding regarding 1) the emerging knowledge which is critical in explaining antifragility in the business sector based on co-citation and thematic analysis; 2) the relation between resilience and antifragility in emerging business research; 3) the relation between CNs and antifragility in emerging business research; and 4) a framework of antifragility in the SME context. The co-citation analysis and literature review results have explained the emerging knowledge regarding antifragility, resilience, and CNs in business research and their interrelation. Furthermore, the theoretical and practical implications of the SME context have been presented in the proposed SME's antifragile framework.

Antifragile SMEs can exploit uncertainty, beyond resilience. Antifragility exists in the entrepreneur's DNA and it needs to be activated. To activate it, the company must actively learn, generate ideas, create value through diverse skill teams, and execute new systems to get unique advantages in a changing environment. SMEs should transform randomness into opportunities to gain new competitive advantage. Furthermore, CNs are the critical gateway for SMEs to substitute their limitation with collaborative partner skills and resources. CNs would work effectively if collaborative partners meet their mutual business expectations through skill and resource exchange. Besides, the flexibility and adaptability of SMEs give them more chances to be antifragile than big companies (Corvello, Straffalaci, et al., 2022).

Finally, the proposed framework has a comprehensive view that bridges the ideas from previous studies with a solid theoretical foundation. This theoretical stance on SMEs' antifragility is helpful for further field study or empirical research for business scholars and practical experimentation for business practitioners. SME actors could use this framework to guide their pathway to transform their business when facing randomness in the market. They can focus on developing their autopoiesis cycle to achieve an innovation mind, initiating CNs to substitute the limitations with the advantages of the collaboration partner, and acting for transformation with continuous experimentation to find the fittest business model. The successful transformation could bring SMEs into business growth both individually and collectively. When SMEs succeed in transforming their business in the randomness market, they are antifragile SMEs. For business researchers, the proposed framework is valuable for theoretical foundation and a baseline for further empirical analysis. Practical research regarding 1) the autopoiesis cycle in the business entity, 2) positive psychological development during randomness, and 3) CNs strategy among SMEs are critical for further investigation to provide practical guidance for SMEs' antifragility.

As a limitation, empirical evidence of the practical strategy of SMEs' antifragility CNs strategy is scarce. There is no empirical research yet exploring the appropriate mechanism of CNs in SME ecosystems. More profoundly, the mechanism of autopoiesis in CNs interaction has not yet been discussed in previous studies. Therefore, the literature review in this study does not yet deliver practical implications in specific strategic issues and micro foundation aspects. Regarding this issue, applied research could focus on three agendas. Firstly, reinvent the framework with specific problems, such as autopoiesis dynamics or positive psychology development, on the CNs in SME ecosystems. An experiment or a case study would give scholars and SME actors more practical insight. Secondly, identify how SMEs practice CNs strategy and gain antifragility through collaboration. The phenomenology or case study on the SME ecosystem, which earned success during the crisis or current business dynamics, would

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significantly deliver insight into the related topic. Thirdly, empirically examining the antifragile SME framework through survey method and quantitative analysis could provide external validation of the proposed framework.

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