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Unpacking the complexities of crisis innovation: a comprehensive review of ecosystem-level responses to exogenous shocks

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Abstract
Innovation in times of crisis has experienced a flood of research in the wake of recent events. These studies are dispersed over a broad range of fields and do not adequately reflect earlier research or prior crises. To encourage the convergence of related literature streams, we define crisis innovation as an ecosystem-level process to meet the needs of—and overcome the resource constraints derived from—an exogenous shock. We then conduct a systematic literature review aided by machine learning techniques, specifically utilizing topic modeling. We derive a taxonomy of crisis innovation, which represents innovation as a response to societal crisis, funding crisis, financial crisis, economic crisis, digitalization, transformation, political crisis, strategy crisis, and organizational crisis. We find that crisis innovation drives digitalization through increased motivation for open and ecosystem innovation, but also that the dynamic network structures required for lasting digital transformation are often not implemented during crisis.

Keywords Crisis innovation · Digital transformation · Innovation management · Innovation ecosystem · Natural language processing · Topic modeling

JEL Classification O32

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1 Introduction

Our society is increasingly influenced by crises, many of which have long-term persistence and impact. Whereas earlier global crises were spanned decades, new crises have begun to emerge nearly every year. For example, we had hardly made it through the COVID-19 pandemic before we were hit with an energy crisis in the wake of Russia's war against Ukraine. To prepare for future crises, it is essential to advance research on crisis response strategies (Puumalainen et al. 2023).

A crisis is a social construction based on an exogenous shock (Abolafia and Kilduff 1988), and this social construction allows powerful actors to direct attention toward themes related to the crisis. For example, crises generate well-defined market needs that help focus ecosystem innovation (Battaglia et al. 2021). In addition, crises typically mean resource constraints that undermine the viability of existing offerings and require new solutions (Corsini et al. 2021). Such foci of attention then align the efforts of innovation ecosystems (Lingens et al. 2021), meaning crises drive the generation of open, ecosystemic mechanisms for innovation (Brem et al. 2021; Lee and Trimi 2021; Liu et al. 2021). Hence, we define crisis innovation as an ecosystem-level process to meet the needs of—and overcome the resource constraints derived from—an exogenous shock.

Firms and nations struggle to develop new technologies, services, and business models to help overcome or adapt to these situations (Brem et al. 2020). While the crisis captures managerial attention, the ability of a firm to deal with a crisis can be reduced by managerial overconfidence, knowledge gaps, lack of independent thinking, or understanding of complexity (Bouncken et al. 2022). Management literature reflects these struggles in ever shorter socio-technical cycles, and much has been written about innovation in relation to specific crises (Paunov 2012). Indeed, innovation was so central to overcoming the pandemic that it yielded a vast amount of scholarly reflection (e.g., Emami et al. 2022; Di Minin et al. 2021; Barragán-Quintero et al. 2020). Earlier literature on innovation in times of crisis largely explored the impact of the 2008 financial crisis (Brem et al. 2020; Filippetti and Archibugi 2011); the economic downturn of the early 1990s (Di Minin et al. 2010) has also been subject to investigation, as have the climate crisis (Averina et al. 2022) and events in the wake of the fall of the Iron Curtain (Meyer-Krahmer 1992).

While innovation under crisis has become the focus of increasing scholarly inquiry, there is not yet a coherent literature stream on crisis innovation. This is unsurprising since research in this field happens in many diverse disciplines. For instance, earlier research indicates that a good relationship of trust and proximity in buyer–seller networks helps to address unexpected shocks (Kranton and Minehart 2001), but this research is not embedded in the innovation management field since the article was published in an economics journal. The dispersed nature of literature related to innovation under crisis means that contributions refer to specific innovation topics e.g., frugal innovation (Corsini et al. 2021) or financial innovation (Daly et al. 2019). However, theory is not consolidated around the concept of crisis innovation. Therefore, recent research does not appropriately

leverage earlier efforts or learning from previous crises that could be applied to future crisis prevention and response (cf. Bruhn et al. 2023; Viardot et al. 2023).

The purpose of this article is therefore to connect the divergent streams of research on crisis innovation so that future work may better draw on these rich foundations. Hence, we conduct a systematic literature review of research to achieve a comprehensive overview of existing work and its interconnections. To this end, we employ topic modeling to identify and map the main strands of research. We then analyze the contributions of each strand and derive a conceptual framework with implications for theory and practice. With this approach, we aim to contribute to a better understanding of crisis events and effective responses to them.

2 Methodology

The study extends topic modelling with an interpretative analysis characteristic of systematic literature reviews (SLRs). The methodology for such an independent literature review needs to be clearly laid out and replicable by future studies (Kraus et al. 2022). We have conducted an SLR using topic modeling to group the findings and results of previous studies on crisis innovation and to provide an overview and classification of the literature in this field. Such algorithmic coding can be more objective than its manual counterpart and also allows for analyzing large sets of articles (Kraus et al. 2020a, b). We thus also extend SLR methodology by including an inductive coding approach (cf, Sauer and Seuring 2023).

2.1 Data sources and retrieval strategy

We used the Web of Science (2022) core collection database to extract articles related to crisis innovation. The use of appropriate databases is crucial for conducting a comprehensive and reliable literature review. The Web of Science (WoS) database was chosen as the main source of data for this study because of its relevance and reliability for the research topic. WoS is one of the most comprehensive and widely used citation databases in the academic community that covers over 13,610 journals across all disciplines (Singh et al. 2021; Falagas et al. 2008). While other databases are available, each has its own strengths and limitations. For example, Scopus has a broader coverage than WoS, but it includes more lower impact journals (Chadegani et al. 2013). In contrast, WoS is known for its rich content of leading and high-impact journals (Kulkarni et al. 2009). The WoS impact classification thus guarantees a higher minimum level of journals (Sauer and Seuring 2017). While combining WoS and Scopus has been recommended (Kraus et al. 2020a, b, 2022), this would thus lower the average quality of the sample. Google Scholar has a larger coverage than both WoS and Scopus, but it also includes non-peer-reviewed sources, such as books, dissertations, patents, and websites (Harzing and Alakangas 2016). To collect the most relevant articles in this field of research, we searched crisis innovation* in the documents' topics (title, abstract, and keywords). Then, we limited the results by language = ("English"), document types = ("article or early access"), and

Web of Science categories = ("business or management or economics"). The resulting sample contained 1773 articles from 1970 to 2022. The study aims to identify cross-disciplinary research on crisis innovation, and the sample was therefore not further screened for fit with a specific field or method. Since the search employed a single database, no duplicates were identified.

2.2 Data processing procedure

To find and analyze logical information from the collection of textual data in this field of research, we used the latent Dirichlet allocation (LDA) technique (Blei et al. 2003). Our research methodology predominantly employs Latent Dirichlet Allocation (LDA) for topic modeling, marking a clear divergence from the generative AI approach (cf. Burger et al. 2023). While LDA identifies patterns and provides topic distributions based on the existing literature, generative AI models like ChatGPT autonomously generate new content, summaries, or explanations. Our methodology maintains an accurate boundary from introducing such generated content, aiming instead for a precise analysis and synthesis of the established patterns in our dataset. In natural language processing and machine learning, a topic model is a statistical method for determining the "topics" in a dataset of documents. Topic modeling is an emerging quantitative method to analyze and extract logical information from a collection of textual data. It has recently been introduced in management research in the context of marketing (Mustak et al. 2021), innovation management (Lee and Kang 2018), open innovation (Bagheri et al. 2022), and management (Hannigan et al. 2019). LDA can uncover hidden semantic structures and topics in a large body of unstructured textual data using natural language processing, machine learning, and statistical algorithms (Blei 2012). While there are various toolkits available for extracting and analyzing topics such as the Stanford Topic Modeling Toolbox (Ramage et al. 2009), Gensim, MALLET (McCallum 2022), and R Packages(Roberts et al. 2019; Grün and Hornik 2011), some of these tools are specifically designed for use in systematic literature review processes. For example, MySLR is a web-based platform that utilizes LDA-based topic modeling for management studies (Ammirato et al. 2022). We used a four-step methodological process to identify and analyze the topics, which is explained in the following paragraphs.

Step 1. Text pre-processing: We used Python programming language v. 3.6.5 to build a topic model, using the article abstracts as an input for the text pre-processing, and employed several techniques to create a dictionary for topic modeling: In this step, we split all of the abstracts into sentences and the sentences into tokens (tokenization). Then, we removed words with fewer than three characters (stop words), deleted all punctuation and email addresses, and extended the stop word list to remove structural words from the abstract e.g., aim, purpose, study, framework, method (Blei 2012). Next, we built word bigrams, such as linking the words "COVID" and "pandemic" as covid_pandemic. We also used the lemmatization algorithm to change the words into their root form (e.g., "took" to "take," "drawing" to "draw") and used the word stemming algorithm to filter such words and reduce

them to their base form (e.g., "strategic"/ "strategy" to "strategi"). Finally, we removed all terms that occurred fewer than five times across all documents or that appeared in more than 70 percent of records. All of these tasks were implemented using gensim v. 3.8.3 (Rehurek and Sojka 2010), NLTK v. 3.7, and spaCy v. 3.0.0. (Honnibal et al. 2020).

Step 2. Topic modeling: In this step, we created a dictionary containing all pre-processed words. Then, we built an LDA model using MALLET, a Java-based software package for statistical natural language processing written by McCallum (2022). A significant problem with the topic modeling technique and fitting the model is finding the optimal number of topics. To address this, we calculated the topic coherence score, which provides a convenient measure to judge how good a given topic model is by computing the degree of semantic similarity between high-scoring terms in the topic. Appendix A provides information about technical details of rendering topics with coherence score.

Step 3. Topic exploration: In this step, we worked to uncover the main topics in crisis innovation research. Using the pyLDAvis library v. 2.1.2 to interpret topics, we analyzed the nine topics identified in the previous step (Sievert and Shirley 2014). This package uses Jensen–Shannon divergence (JSD) to compute the centers of topics in the two-dimensional plane and then uses multidimensional scaling to calculate the distances between topics in two dimensions. Hence, JSD is a method for measuring the similarity of two probability distributions. (See Appendix B for technical aspects of the inter-topic distance map).

Additionally, we used the word_cloud library v. 1.8.1 to visualize topics and their words; the size of each word in a specific topic depends on how frequently it is used in that topic.

Step 4: Topic analysis: In contrast to prior literature reviews using topic modeling (Mustak et al. 2021; Bagheri et al. 2022), we add an interpretive analysis of the identified topics. Based on the identified topics, each article in the sample was classified according to its dominant topic. We then reviewed the articles for each topic to identify, summarize, and connect the most relevant contributions. We first read the abstracts of all the articles for each topic in order to select representative works. The represeantativeness of these articles was verified through a comparison with the topic words. The selected articles were then studied in detail and related to the other key contributions for the same topic.

3 Results

3.1 Descriptive statistics

We collected 1,773 total articles from the Web of Science database from 1970 to 2022. Figure 1 illustrates the growth in scientific articles on crisis innovation in the business, economics, and management literature. The analysis of the data highlights a clear trend in the number of articles on crisis innovation over time. From 1992 to 1999, the number of published articles has remained relatively constant, while a substantial increase has occurred from 2008 onwards. This trend has reached its

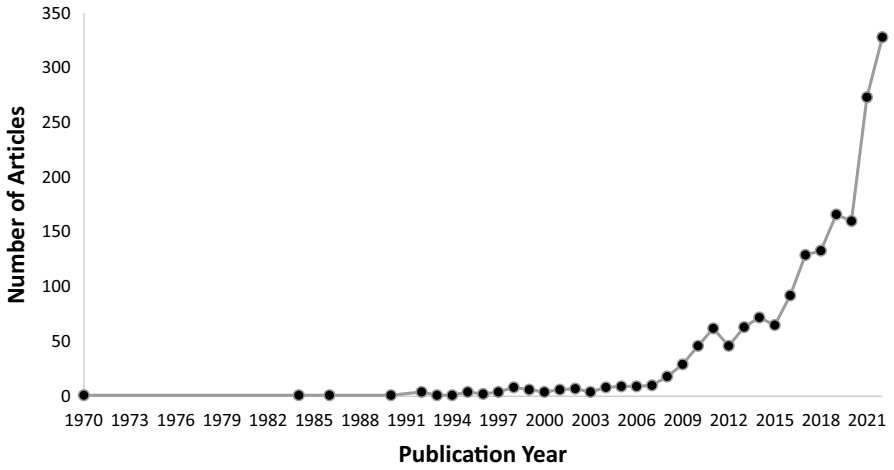

Fig. 1 Number of documents per year

peak in 2022 with a remarkable 328 articles published on this topic, indicating a consistent and growing interest in the area of crisis innovation.

Table 1 shows the most cited journals in this field of research. With 1,803 citations and 32 articles, *Research Policy* is the most relevant source in the field of crisis innovation. *Technological Forecasting and Social Change* ranks second, with 1,296 citations and 46 published papers; the *Journal of Business Research* ranks third, with 1,108 citations and 49 published papers. The managerial relevance of crisis innovation is demonstrated through the presence of the practitioner-oriented journal *Harvard Business Review* in this list.

3.2 Topic modeling and exploration

Using the topic modeling technique, we were able to uncover hidden semantic structures in the unstructured text that we collected. We found that the model with nine topics could demonstrate a broad set of crisis innovation topics and provide a meaningful setting for further analysis. The resulting taxonomy of crisis innovation is reported

Table 1 Most cited journals in crisis innovation research

Rank	Journal	Total citations	Number of publications
1	Research policy	1,803	32
2	Technological forecasting and social change	1,296	46
3	Journal of business research	1,108	49
4	Harvard business review	940	7
5	Cambridge journal of economics	812	13

in Table 2, which lists the most relevant terms for each topic, along with the number of documents and sum of citations. The topics are different types of crises which are responded to by innovation, i.e., societal crisis, funding crisis, financial crisis, economic crisis, digitalization, transformation, political crisis, strategy crisis, and organizational crisis. Digitalization is perhaps not usually considered a crisis, but it is indeed an exogenous shock to the ecosystem which generates new needs and costs that are met by innovation. The taxonomy is illustrated by a word-cloud analysis of the topic modeling results, presented in Fig. 2. In the word clouds, more frequent words are displayed in a larger font, and the illustration thus visualizes the weight of keywords within each topic. Together, these results highlight the variety of topics present in diverse academic disciplines.

We also normalized the weight of each topic per year to analyze the annual changes in crisis innovation research. As Fig. 3 shows, the publication proportion for all the topics fluctuates from 1970 to 2004. Afterward, all the topics experience relatively smooth growth. In the early years, each topic has several amplitudes due to the limited number of studies. However, over time, there is a consistent and growing interest in the area of crisis innovation, resulting in more stable pathways for each topic.

To investigate the structure of topics, we built an inter-topic distance map. This exercise provides an overall view of the topics and how they relate to each other, allowing us to do a deep inspection of the terms highly associated with each individual topic. The topics that are closer on the map have more words in common. Figure 4 illustrates the results of the inter-topic distance plot, showing that the "transformation" and "digitalization" topics overlap. The overlap between these two topics can be explained by the fact that digitalization is often a key driver of transformation during times of crisis. Digital technologies and processes can enable organizations to quickly adapt to changing circumstances, whether that be shifting to remote work or changing business models. Moreover, the "strategy crisis" and "organizational crisis" topics are close to each other, indicating their conceptual closeness. This result implies that these two types of crises may have similar underlying causes and can be tackled through similar solutions. While strategy crisis focuses on developing new strategies to adapt to the crisis context, organizational crisis deals with internal crisis within the organization. Both topics highlight the need for firms to be resilient and adaptable in times of crisis, and to activate dynamic capabilities to improve innovation performance and increase evolutionary fitness. The topics "financial crisis" and "funding crisis" are also very close to each other. While funding crisis is centered on the firm level and relates to a sharp reduction of the funds available for innovation, financial crisis is systemic and refers to the financial aspects of a crisis. Both topics overlap in the sense that financing innovation activities depend on the health of the financial sector. By contrast, "political crisis," "economic crisis," and "societal crisis" are completely separate topics with distinct term distribution.

3.3 Topic analysis

Each of the identified topics represents a main research area in the crisis innovation literature and the topics thus constitute a taxonomy that shapes the conceptual

Table 2 Taxonomy of crisis innovation

	Topic	Keywords	# of documents	Sum of citations
1	Societal crisis	social, COVID, response, pandemic, future, sustainable, network, emerge, organize, global, develop, communal, case, collaborate	218	2,707
2	Funding crisis	firm, product, growth, period, invest, performance, level, export, activity, economy, large, manufacturing, recession, industry, intensity	253	4,122
3	Financial crisis	financial, market, bank, risk, credit, return, price, global, investment, shock, trade, debt, asset	260	4,894
4	Economic crisis	economic, countries, develop, region, policies, growth, global, sector, industries, nation, government, import, European, technology	218	3,334
5	Digitalization	technology, service, product, industries, digitalization, process, sector, adoption, cost, operational, information, transform, manufacture, consumer	132	2,691
6	Transformation	develop, process, economic, activity, integrate, level, enterprise, effect, structure, generate, assess, evaluate, relate, mechanism, complex	117	1,577
7	Political crisis	institutions, policies, public, govern, political, emerge, global, reform, science, economic	228	4,986
8	Strategy crisis	business, management, strategy, market, corporate, value, competitive, sustainable, firm, internal, tourism, explore, environment	159	3,461
9	Organizational crisis	knowledge, performance, SME, resilience, relationship, organize, manage, work, employee, entrepreneurial, capable, small, leadership, entrepreneur	188	2,857

Fig. 2 Word clouds of each topic in the taxonomy of crisis innovation

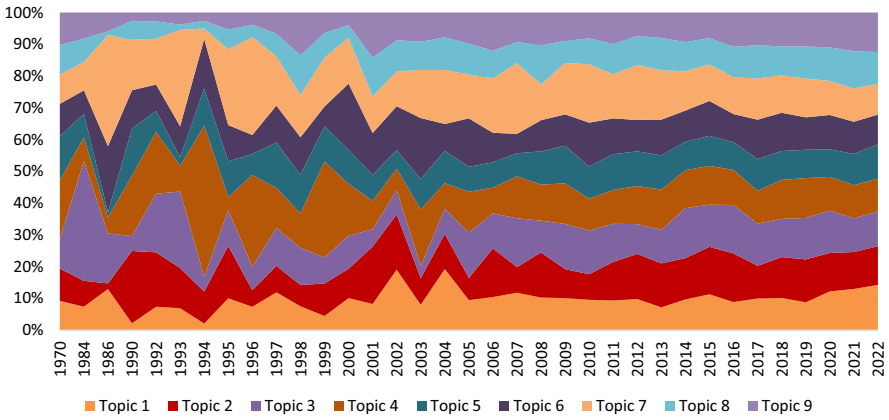

Fig. 3 Research on each crisis innovation topic over time

structure of this field. We therefore reviewed representative articles for each topic in depth. Below, each topic is first defined based on the keywords and the articles of the sample related to the topic. Then, the main findings are reported.

Societal crisis (topic 1) is related to the organization of innovation during society-wide crises such as the COVID-19 pandemic, and centers on forms of open innovation, innovation ecosystems, and other collaborative networks (Temiz and Broo 2020; Brem et al. 2021). For example, the mechanisms for the emergence of new ecosystems have been studied (Radziwon et al. 2022), as have the transformation and restructuring of existing ecosystems (Cosimato et al. 2022). In this context, the urgency rendered by crisis means that self-organized community-based ecosystems can be more efficient than industry- or government-driven initiatives (Dąbrowska

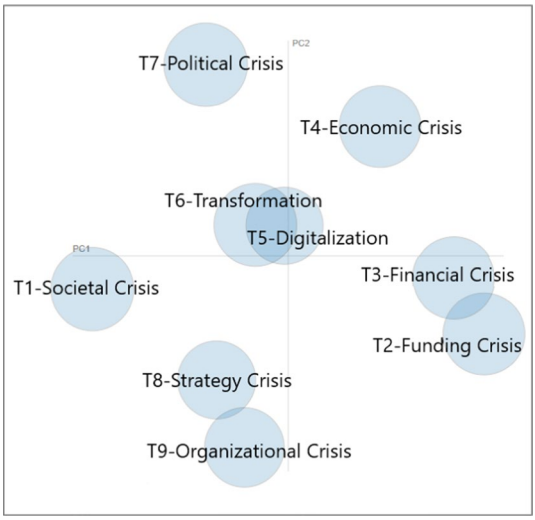

Fig. 4 Inter-topic distance map

et al. 2021). Enabling technologies, (e.g., synthetic biology) can also provide foundations for efficient ecosystem growth in times of crisis if structural, societal, and ethical barriers are overcome (Nylund et al. 2022). The motivations for innovation have also received attention during the pandemic. On the one hand, innovation was destined to save lives and improve health (Brem et al. 2021), including alleviating suffering i.e., through compassion venturing (Majchrzak and Shepherd 2021). On the other hand, innovation improved quality of life under COVID-imposed resource constraints (Brem et al. 2021). These motivations converge when life-saving solutions are needed under resource scarcity, inviting an extension of theory on frugal innovation beyond emerging markets (Corsini et al. 2021; Giones et al. 2020). The time-constrained nature of crisis innovation has also led to research on the timing and life cycle of such organizational forms. To this extent, researchers are considering the durability of initiatives after the peak of the crisis (Kronblad and Pregmark 2021).

Funding crisis (topic 2) relates to a sharp reduction of the funds available for innovation. In the realm of crisis innovation, this topic builds on Filippetti and Archibugi's (2011) seminal contribution identifying the structural characteristics that foment innovation in times of crisis for European firms: stronger national systems of innovation with capacitated human resources, high-tech specialization, and a developed financial system. To this extent, triple-helix interactions involving university, industry, and government, are of increasing importance (Kashani and Roshani 2019). For Latin American firms, access to public funding has been identified as the most important factor (Paunov 2012). Funding is a bottleneck for innovation, although crisis does not hit innovative firms harder in this regard (Lee et al. 2015). When funding is scarce, turning previous profitability into slack resources is key for a firm to keep investing in innovation during crisis (Zona 2012). Therefore, firms that were already innovative before crises keep investing more, as do fast-growing new firms (Archibugi et al. 2013). For emerging markets, the gains from

such investments are contingent on good management under crisis (Nemlioglu and Mallick 2021).

Financial crisis (topic 3) refers to the financial aspects of crisis. As a topic, financial crisis overlaps with funding crisis; however, whereas funding crisis is centered on the firm level, financial crisis appears to be systemic. Financial innovation to obscure risk was largely responsible for the 2008 financial crisis; this innovation's riskiness and radicalness increased abnormal returns before and during this crisis, while its complexity decreased these returns (Schöler et al. 2014). The financing of a firm's innovation activities depends on the financial sector's health, which was restored after the 2008 financial crisis through bailouts and restructuring. Such efforts need to be coordinated on a global scale, since financial shocks tend to spread from one country to another in times of intense financial innovation (Daly et al. 2019). However, the new structures have been unable to overcome the inherent contradiction of the need for long-term commitment to innovation and the financial sector's short-term horizon (Mazzucato 2013). Therefore, new ventures and sectors struggle during financial crisis. Then, startup funding focuses on a few core sectors and the most experienced venture capitalists in a market (Conti et al. 2019). Adding to this effect, firms that are the customers of firms relying on the interbank market may find it more difficult to finance innovation (Giebel and Kraft 2019).

Economic crisis (topic 4) involves macroeconomic crises, such as the recession of the early 1990s. From a macroeconomic perspective, the effects of an economic crisis can be partly overcome by investing in innovative enterprises and by economic policies stimulating entrepreneurial activity (Castaño et al. 2016). Whereas such policy impact was formerly spatially mediated and localized, the recent rapid pace of technological change and global economic integration have made policy development geographically interconnected (Crescenzi and Iammarino 2018). In this increasingly complex context, policymaking should aim for crisis prevention rather than palliative measures (Rizzi et al. 2018). However, public policy adapting to a crisis situation may also make industries more resilient and responsive to future crises (Unger 2000). For example, the European energy industry went through a digital transformation in response to the 2008 financial crisis (Midttun and Piccini 2017). The reformed institutional and industrial landscape has meant that energy providers are emerging strong from the current energy crisis—much to the dismay of customers suffering from the price hikes that keeps the industry in good health.

Digitalization (topic 5) considers the incorporation of digital technology into products, services, and processes. Digitalization in itself can constitute a crisis, as it has for newspapers, which were made obsolete by new media (Rothmann and Koch 2014). Other recent crises have also sparked an increase in digitalization generally—and digitalization-driven retail business model innovation in particular—by increasing the range of technologies as well as the quantity and quality of information employed, leading to a reframing of ecosystem partnerships and strategic alliances (Mostaghel et al. 2022). However, such crisis-driven digitalization is only sustainable in the long run if it avoids drawing exclusively on organizational elasticity and is accompanied by structural, processual, and cultural adaptation (Reuschl et al. 2022).

Transformation (topic 6) refers to such structural changes made by firms and institutions in order to adapt to crisis. External events not only alter the motivations

and desired outcomes of innovation, but also the innovation dynamics and the technology life cycle. Empirical foundations are found in large-scale events, such as the fall of the Iron Curtain (Meyer-Krahmer 1992; Szántó 1994), as well as in regionally limited critical incidents (McAdam and Mitchell 2010). Ryan et al. (2022) discuss the collapse and subsequent transformation of global value chains and the corresponding restructuring of multinational enterprise governance. The flexibility required by crisis, coupled with the opportunities presented by digitalization, requires a transformation toward network structures and network economy rather than the prior hierarchical organizations (Voronkova et al. 2022). Digitalization and transformation's overlapping and central position on the inter-topic distance map (Fig. 4) points to the salience of digital transformation as the lasting structural change that may occur as a result of digitalization.

Political crisis (topic 7) can be a motive for innovation, but innovation can also cause political crisis: for example, a sociopolitical legitimacy crisis is developing due to the regulatory voids generated by platform business model innovation. This means the firms need to shape business opportunity and the business model through a liminal movement in interaction with regulators and other ecosystem participants (Garud et al. 2022). During the pandemic, governments implemented draconian measures limiting the free movement of people and goods, which have led to a reevaluation of proximity and of globalization (Dosi and Soete 2022). In times of crisis, mechanisms of globalization meet with many obstacles—but also become more important for innovation diffusion, such as through the emergence of dominant designs (Brem et al. 2020). Regulatory interventions are however often identified as perpetuators of crisis rather than solutions. While the crisis of the US healthcare system could be remedied by disruptive innovations, for example, transformation of this highly regulated industry is hindered by the efforts of regulators, physicians, and pharmaceutical companies to preserve the existing systems (Christensen et al. 2000). At worst, regulatory responses to crisis can lay the groundwork for future adversity, as in the case of bailouts that allow for even larger financial markets to generate financial crises with greater impact on society (Crotty 2009).

Strategy crisis (topic 8) indicates that prior strategies are no longer adapted to the crisis context and that strategy needs to be developed in accordance with the new situation. Such new strategies can either focus on innovation, particularly business model innovation, perseverance through operational management, or retrenchment through controlled shutdowns (Kraus et al. 2020a, b). For example, open innovation strategies can protect firms' innovation capabilities during resource cuts (Di Minin et al. 2010). Radical and exploratory innovation strategies are generally more effective during crisis and generate better firm performance and variability than exploratory strategies do (Osiyevskyy et al. 2020). However, firms can identify opportunities for exploitative innovation through the analysis of, for example, patent data (Guderian et al. 2021). Firms can endure crises while simultaneously taking advantage of exploratory efficiency by adopting a temporal separation logic and increasing risk-taking in times of crisis (Leppäaho and Ritala 2022). When firms want to generate breakthrough innovations in the absence of external crises, they can also induce critical incidents. Firms can then purposefully construct internal crises to intensify efforts toward organizational learning and innovation (Kim 1998).

Organizational crisis (topic 9) refers to an internal crisis of the firm or organization. While an organizational crisis can lead to firm demise, it can also yield entrepreneurial action that results in new products, processes, or business models, particularly in family firms (Soluk 2022). This action is supported by new alliances, digital platforms, and improved adaptive capacity (Soluk et al. 2021). To generate such a resilient response, firms generally need to activate the dynamic capabilities of sensing, seizing, and transforming on both the firm and ecosystem levels (Khurana et al. 2022). Then, dynamic capabilities lead to better innovation performance, which in turn increases evolutionary fitness (Makkonen et al. 2014; Newey and Zahra 2009). For example, committing to vigilance around threats and opportunities allows firms to act and adapt more quickly to crisis (Schoemaker and Day 2021).

4 Discussion

This discussion is organized as follows: First, we provide a summary of key insights for research. Based on this overview, we then situate the findings within the context of earlier literature and develop a conceptual framework. This serves as the basis for our discussion of managerial implications as well as for the limitations and recommendations for future research.

4.1 Implications for research

For innovation management, this article contributes to our collective understanding of innovation in times of crisis and adds to the literature on the emergence of innovation ecosystems (Giones et al. 2019; Thomas et al. 2022; Nylund et al. 2022). The definition of crisis innovation as an ecosystem-level process may aid both those studying innovation ecosystems under crisis (Brem et al. 2021; Lee and Trimi 2021; Liu et al. 2021), as well as those studying specific underlying processes that need to be placed in a larger context (Voronkova et al. 2022; Garud et al. 2022). The framing of the definition in terms of needs and resource constraints encompass varying motivations generated by a common underlying event and can thus help define different types of initiatives.

We also find that innovation as a crisis response differs according to the type of crisis. The taxonomy of crisis innovation presented in Table 2, delineates innovation as a response to societal crisis, funding crisis, financial crisis, economic crisis, digitalization, transformation, political crisis, strategy crisis, and organizational crisis. This division into different types of crisis innovation helps distinguishing between different strands of research, and also supports cross-disciplinary research since it suggests related lines of theoretical development. Specifically, the inter-topic distance map of Fig. 4 shows which topics are most closely related in the literature. Researchers can venture into an adjacent topic for richness of their analysis, and can also explore more distant topics to explore more complementary perspectives. Conscientious efforts can also be made to bring topics together that may be conceptually related, but that today have distant research approaches, e.g., societal and

economic crisis. However, the taxonomy goes beyond a mere classification since it analyzes how the contributions on each topic have advanced the field of innovation management.

The topics of digitalization and transformation have a central position in the inter-topic distance map and influence research on several other topics. Resource scarcity, coupled with new needs, means crises drive digitalization (Midttun and Piccini 2017; Giones et al. 2020). While crises can prompt new resource allocation behaviors, digital tools enable the firm to convert resource preservation, recombination, or sharing into digital process innovation, product innovation, and business model innovation (Soluk 2022). For example, sharing of intellectual property prompted by crisis can enable digital fabrication that speeds up innovation and side-steps problematic supply chains (Corsini et al. 2021). Open innovation with suppliers is particularly to profit from innovation in such automated contexts (Nylund et al. 2020).

Digital resource sharing includes not only existing resources but also the co-creation of new knowledge and solutions (Cosimato et al. 2022). This co-creation is possible through ecosystemic sensing, seizing, and transforming (Khurana et al. 2022). Here, frugality on an individual and organizational level can contribute to long-term organizational resilience (Giones et al. 2020).

Digitalization-driven retail business model innovation has gained traction to mitigate the negative effects of the COVID-19 pandemic. The rise of digital services and retail platforms has enabled value co-creation with customers and platform owners, leading to models that are much more ecosystemic (Mostaghel et al. 2022). Platform-based business models (e.g., that of Uber) can deepen a sociopolitical legitimacy crisis due to discrepancies between the business model and regulatory frameworks (Garud et al. 2022). Thus, for platform models to lead to successful digital transformation, orchestrators and other actors need to actively engage in building ecosystem legitimacy (Thomas and Ritala 2022).

Kronblad and Pregmark (2021) found that fully digital business models (i.e., digital natives) have thrived in retail and service businesses before, during, and after crisis. Other firms have employed temporary business model innovation to adapt to crisis requirements (Clauss et al. 2022; Kraus et al. 2020a, b). However, firms that were forced toward digital business models under crisis (e.g., educators, restaurants, and retail businesses during COVID-19) have at least partly reverted to analog models (Kronblad and Pregmark 2021) because the new models stretched organizational elasticity without adapting structures, processes, and culture (Reuschl et al. 2022). Thus, much of the digitalization driven by COVID-19 has not been consolidated in the aftermath of the pandemic. However, in some cases (e.g., newspapers), digitalization eliminates the foundation for the previous business model and requires firms to engage in digital business model innovation or yield to digital natives (Rothmann and Koch 2014).

While digital transformation increases industry resilience and helps economies overcome crises, initiatives need to consider those hardest hits by crises. Digital illiteracy and the unaffordability of digital devices are obstacles to widespread innovation diffusion (Misati et al. 2022), as are concerns about data integrity and weakened democracy in light of the corporate power over digital platforms (Boersma et al. 2022; Wu 2018). On the other hand, the impact of compassion gendered by

adverse events can be magnified by crowd-based digital innovations (Majchrzak and Shepherd 2021).

We thus contribute to the literature on innovation management in the context of digital transformation (de Paula et al. 2023; Danuso et al. 2022). Our findings are particularly relevant to the literature examining digital transformation across multiple levels, including that of ecosystems (Lanzolla et al. 2020, 2021; Dąbrowska et al. 2022; Furr et al. 2022). Table 3 summarizes the findings for innovation management and digital transformation for each topic of the taxonomy.

Figure 5 organizes the implications of the findings summarized in Table 3 in a conceptual model. Overall, crises create new needs on the level of the entire ecosystem (Battaglia et al. 2021). These needs must be satisfied under conditions of resource scarcity, especially in terms of time and funding as identified in topics 1, 2, and 8 (e.g., Corsini et al. 2021; Zona 2012; Di Minin et al. 2010). This yields crisis innovation, which due to the shared motivations for innovation in crisis, is also organized in sharing ecosystems with the need for co-creation as formulated in topics 1 and 9 (Cosimato et al. 2022; Khurana et al. 2022). Such sharing behaviors, in turn, drive the digitalization of topic 5 (Mostaghel et al. 2022). For digitalization to turn into digital transformation, there must be changes in policy, structure, processes, culture, business models, and legitimacy as exposed in topics 4, 6 and 7 (Unger 2000; Voronkova et al. 2022; Garud et al. 2022). However, the contradiction between long-term structure and short-term urgency is only temporarily overcome by crisis as mentioned in topic 3 (Mazzucato 2013). Due to this ephemeral increase in organizational elasticity, the digitalization that happens during crisis does not always prompt the structural changes required for digital transformation as expressed by in topic 5 (Reuschl et al. 2022). The conceptual model thus highlights specific and sequential mechanisms of crisis innovation. It allows researchers to situate specific contributions within a wider theoretical context, and therefore furthers our understanding of crisis innovation as a whole.

4.2 Implications for practice

This conceptual framing offers also several starting points to explore managerial implications. A crisis event inevitably creates short-term changes to corporate management. New needs must be addressed in the short term, which calls for constraint-based solutions and flexible organizational answers. Additionally, as opposed to normal circumstances, crisis is a time when managers might need to rely even more on their gut feeling (Scheiner et al. 2015). In this regard, concepts like VUCA can help managers develop responses to the volatility, uncertainty, complexity, and ambiguity appearing in their industry. Since some sectors (e.g., energy) have been through such crisis-initiated events, learning can also be drawn from these sectors without reinventing the wheel (Giones et al. 2019). This also touches on the organizational culture, process, and structure, as well as the business model and overall legitimacy of corporate management.

Managers can also prepare for future crises by increasing the degree to which they engage in sharing behaviors, ecosystems, and co-creation. More flexible

Table 3 Summary of findings for innovation management and digital transformation for each topic of the taxonomy of crisis innovation

Topic	Findings for innovation management	Findings for digital transformation
1 Societal crisis	Crisis drives self-organized and collaborative organizational forms Resource and time constraints call for frugal innovations and related approaches	Crisis-driven digitalization is temporal due to a lack of transformation Compassion drives effort in crisis and is amplified by digitalization
2 Funding crisis	Strong innovation systems providing funding is crucial in crisis. High-tech specialization, slack resources, and good management mitigate the impact of reduced funding during crisis	
3 Financial crisis	Crises amplify the contradiction between long-term innovation needs and the short-term financial horizon Innovation is financed in line with venture capitalist experience	
4 Economic crisis	Innovation policy is becoming more geographically interconnected Former crises build system resilience for future shocks	Digitalization efforts must be supported by innovation policy. Once the crisis arrives, any investment in infrastructure is too late
5 Digitalization	Recent crises have driven digitalization Digitalization, as any crisis, drives structural adaptation	Digitalization does not yield transformation due to organizational elasticity during crisis. Crises can drive transformation through business model innovation
6 Transformation	Transformation is the structural adaptation required by a crisis Dynamic networks adapt better to crisis than hierarchical structures do	Structural adaptation toward dynamic network structures is required for lasting digital transformation
7 Political crisis	Globalization is less viable in times of crisis. Regulatory responses tend to perpetuate the dynamics of crisis by supporting incumbent systems	Regulatory voids concerning digitalization create crises and require ecosystem legitimacy
8 Strategy crisis	Firms do better when adapting strategy to the cycles of external events. Crises require exploratory innovation strategies	Digitalization enables innovation under conditions of resource scarcity. Digital transformation is driven by strategic decisions
9 Organizational crisis	Exogenous shocks can lead to internal organizational crisis Dynamic capabilities help firms predict and adapt to crisis	Digitalization supports ecosystemic dynamic capabilities. Long-term effects are achieved through organizational learning

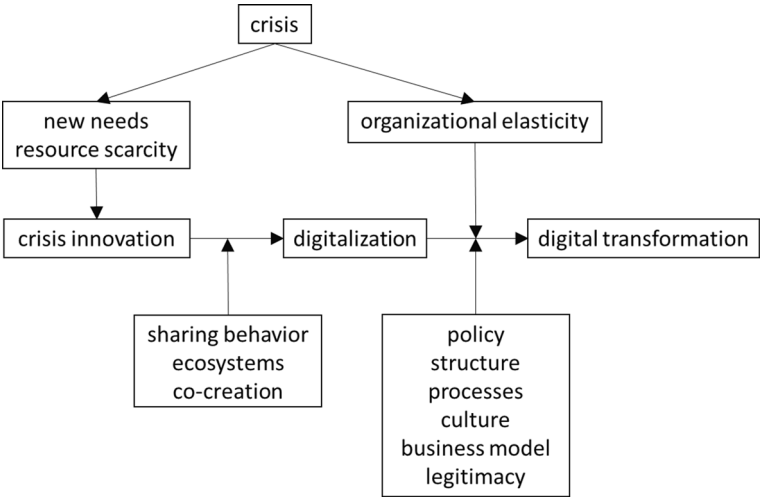

Fig. 5 Conceptual model of crisis innovation

structures and business models will help the organization adapt more rapidly to crisis and facilitate the structural adaptation necessary for digitalization to yield sustained digital transformation. Thus, crisis innovation calls for active management of the tension between stability and evolvability (Tilson et al. 2010; Wareham et al. 2014). This requires rapid evolution and thus flexible prior structures. However, the perdurance of crisis innovation requires the generation of structures that bring stability to the ecosystem. Resilience is hence aided by diversification strategies e.g., geographical diversification, that generate structures allowing multiple responses to crisis (Caloghirou et al. 2022).

Additionally, it is important to distinguish between company size and industry. Large firms have many more resources but must follow long internal coordination processes, implying time constraints. By contrast, small and medium-sized companies can react much more quickly than large organizations can, but they typically face resource constraints. Entrepreneurial orientation let firms pivot to cope with such constraints (Puumalainen et al. 2023). For both small/medium and large enterprises, digitalization can help address these constraints to allow for the more rapid responses that are necessary in crisis situations.

4.3 Limitations and directions for future research

The presented research is not free from limitations, which creates potential avenues of exploration for future researchers. For example, our research has uncovered a relationship between crisis innovation and digital transformation. Future research can extend this by considering the impact of the next generation of enabling technologies, such as artificial intelligence (Ferras-Hernandez et al. 2022), or related managerial concepts, such as frugality (Giones et al. 2020). Another aspect that future research could consider is the role of tools that could be applied in crisis situations;

earlier research suggests several, including hackathons (Yokoi 2023) and TRIZ (Münzberg et al. 2016). Moreover, future studies could collect and analyze quantitative data to identify patterns in crisis situations, which could help develop even better managerial responses to crises.

The methodology herein presented also has limitations. We read the abstracts of the 1,772 articles in the sample, and the capacity for this manual process sets the limits for the applicability of the methodology to larger literature streams. Future applications of artificial intelligence may handle also this step of the process to enable even larger literature reviews. Additionally, as with all literature reviews, this research may suffer from selection biases: Since a crisis is a social construction, we rely on authors to identify a crisis as such (Abolafia and Kilduff 1988). For instance, relatively little has been written on innovation in the context of climate crisis, but using wording such as "climate change" or "global warming" might uncover relevant work. Innovation-related findings may also be known by "R&D" or "technological change," and while we have verified that such literature is represented in the sample, future research could consider additional related areas. However, while this article could have been expanded to related literature streams, the current delineation corresponds to our aim of representing and consolidating crisis innovation research.

Appendix A: Rendering topics with coherence score

We used the "c_v" measure to calculate the coherence score of the topic. Based on previous studies exploring topic coherence scores (e.g., Röder et al. 2015), we computed the coherence of a set of models through different numbers of topics. To identify the number of topics, we combined the quantitative (objective) and qualitative (subjective) approaches, which is suitable for LDA model assessment. After conformational analysis of each model's topic coherence score, we evaluated its validity. Figure 6 demonstrates the models' coherence score by the number of topics. The results show that the highest coherence score (0.4068) occurs when the number of topics is nine. After topic number 32, the coherence score decreases to a value below the average of all coherence scores (0.3587).

Appendix B: Technical aspects of inter-topic distance map

As we discussed earlier, in order to illustrate inter-topic distance map, we used pyLDAvis library to map the inter-topic distance map between topics. These library use Jensen–Shannon divergence (JSD) as a metrics for calculating the distance between topics. JSD is defined as follows (Aletras 2014):

$$\mathrm{JSD}(\mathrm{P}||\mathrm{Q}) = \frac{1}{2}\mathrm{D}_{\mathrm{KL}}(\mathrm{P}||\mathrm{M}) + \frac{1}{2}\mathrm{D}_{\mathrm{KL}}(\mathrm{Q}||\mathrm{M}) \quad (1)$$

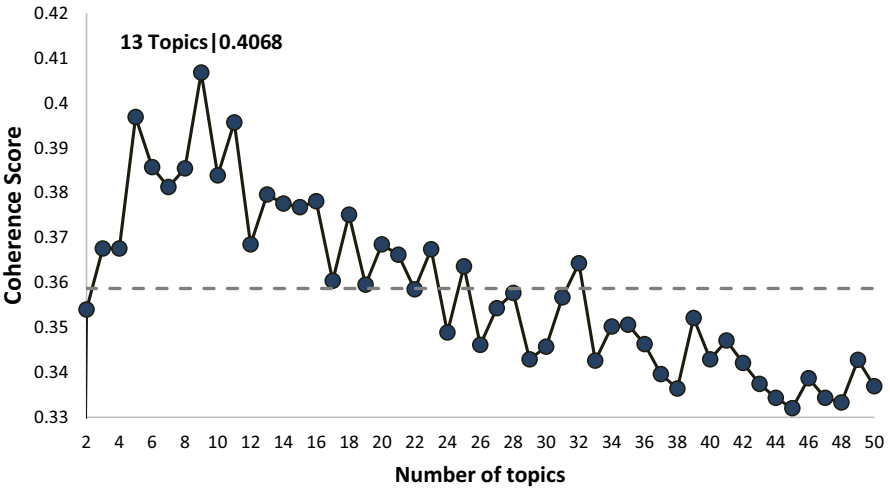

Fig. 6 Topic coherence score by number of topics, with a sliding window size of 50

where D_{KL} stands for Kullback–Leibler (KL) divergence and $M = \frac{P+Q}{2}$. KL is a common measure to calculate the differences between two probability distributions (i.e., P and Q). Additionally, KL is asymmetric and can be calculated as follows:

$$D_{KL}(P||Q) = \sum_{i} P(i)\log_2\left(\frac{P(i)}{Q(i)}\right) \tag{2}$$

Thus, JSD is a symmetric version of KL that computes the distance between two probability distributions. To identify the distances between topics, we set the parameter "mds" to principal coordinate analysis (PCoA). PCoA is a method to explore and visualize the similarity of data according to their distances. The output of the PCoA function approximates the distance between topics. Regarding the contextual issues, we explored the main topics by looking at different aspects, such as the intellectual structure of topics (e.g., labeling of topics).

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References

Abolafia MY, Kilduff M (1988) Enacting market crisis: the social construction of a speculative bubble. Adm Sci Q 33:177. https://doi.org/10.2307/2393054

Aletras N (2014) Interpreting document collections with topic models. Dissertation, University of Sheffield

Ammirato S, Felicetti AM, Rogano D, Linzalone R, Corvello V (2022) Digitalising the systematic literature review process: the MySLR platform. Knowl Manag Res Pract. https://doi.org/10.1080/14778238.2022.2041375

Archibugi D, Filippetti A, Frenz M (2013) Economic crisis and innovation: is destruction prevailing over accumulation? Res Policy 42:303–314. https://doi.org/10.1016/j.respol.2012.07.002

Averina E, Frishammar J, Parida V (2022) Assessing sustainability opportunities for circular business models. Bus Strat Environ 31:1464–1487. https://doi.org/10.1002/bse.2964

Bagheri SK, Roshani S, Piccaluga A, Di Minin A (2022) A bird's-eye view of the open innovation research and its evolution. R&D Management Conference, Trento

Barragan-Quintero RV, Barragan-Quintero F, Ahumada-Tello E (2020) The impact of COVID-19 on innovation: Old projections or new expectations after the pandemic? IEEE Eng Manag Rev 48:197–201. https://doi.org/10.1109/EMR.2020.3016043

Battaglia D, Paolucci E, Ughetto E (2021) The fast response of academic spinoffs to unexpected societal and economic challenges. Lessons from the COVID-19 pandemic crisis. R&D Manag 51:169–182. https://doi.org/10.1111/radm.12444

Blei DM (2012) Probabilistic topic models. Commun ACM 55:77–84. https://doi.org/10.1145/2133806.2133826

Blei DM, Ng AY, Jordan MI (2003) Latent Dirichlet allocation. J Mach Learn Res 3:993–1022

Boersma K, Büscher M, Fonio C (2022) Crisis management, surveillance, and digital ethics in the COVID-19 era. J Conting Crisis Manage 30:2–9. https://doi.org/10.1111/1468-5973.12398

Bouncken RB, Kraus S, de Lucas AA (2022) Management in times of crises: reflections on characteristics, avoiding pitfalls, and pathways out. Rev Manag Sci 16:2035–2046. https://doi.org/10.1007/s11846-022-00580-2

Brem A, Nylund P, Viardot E (2020) The impact of the 2008 financial crisis on innovation: a dominant design perspective. J Bus Res 110:360–369. https://doi.org/10.1016/j.jbusres.2020.01.048

Brem A, Viardot E, Nylund PA (2021) Implications of the coronavirus (COVID-19) outbreak for innovation: which technologies will improve our lives? Technol Forecast Soc Change 163:120451. https://doi.org/10.1016/j.techfore.2020.120451

Bruhn M, Demirguc-Kunt A, Singer D (2023) Competition and firm recovery post-COVID-19. Small Bus Econ. https://doi.org/10.1007/s11187-023-00750-w

Burger B, Kanbach DK, Kraus S, Breier M, Corvello V (2023) On the use of AI-based tools like ChatGPT to support management research. Eur J Innov Manag 26:233–241. https://doi.org/10.1108/EJIM-02-2023-0156

Caloghirou Y, Giotopoulos I, Kontolaimou A, Tsakanikas A (2022) Inside the black box of high-growth firms in a crisis-hit economy: corporate strategy, employee human capital and R&D capabilities. Int Entrep Manag J 18:1319–1345. https://doi.org/10.1007/s11365-020-00674-x

Castaño MS, Méndez MT, Galindo MÁ (2016) The effect of public policies on entrepreneurial activity and economic growth. J Bus Res 69:5280–5285. https://doi.org/10.1016/j.jbusres.2016.04.125

Chadegani A, Salehi H, Md Yunus MM, Farhadi H, Fooladi M, Farhadi M, Ale Ebrahim N (2013) A comparison between two main academic literature collections: web of science and scopus databases. Asian Soc Sci 9:18–26. https://doi.org/10.5539/ass.v9n5p18

Christensen CM, Bohmer R, Kenagy J (2000) Will disruptive innovations cure health care? Harv Bus Rev 78:102–112

Clauss T, Breier M, Kraus S, Durst S, Mahto RV (2022) Temporary business model innovation – SMEs' innovation response to the Covid-19 crisis. R&D Manag 52:294–312. https://doi.org/10.1111/radm.12498

Conti A, Dass N, Di Lorenzo F, Graham SJH (2019) Venture capital investment strategies under financing constraints: evidence from the 2008 financial crisis. Res Policy 48:799–812. https://doi.org/10.1016/j.respol.2018.11.009

Corsini L, Dammicco V, Moultrie J (2021) Frugal innovation in a crisis: the digital fabrication maker response to COVID-19. R&D Manag 51:195–210. https://doi.org/10.1111/radm.12446

Cosimato S, Di Paola N, Vona R (2022) Digital social innovation: how healthcare ecosystems face Covid-19 challenges. Technol Anal Strateg Manag. https://doi.org/10.1080/09537325.2022.2111117

Crescenzi R, Iammarino S (2018) Global investments and regional development trajectories: the missing links. In: Turok I et al (eds) Transitions in regional economic development. Routledge, Milton Park, UK, pp 171–203

Crotty J (2009) Structural causes of the global financial crisis: a critical assessment of the "new financial architecture." Cambridge J Econ 33:563–580. https://doi.org/10.1093/cje/bep023

Dąbrowska J, Keränen J, Mention A-L (2021) The emergence of community-driven platforms in response to COVID-19. Res-Technol Manag 64:31–38. https://doi.org/10.1080/08956308.2021.1945347

Dąbrowska J, Almpanopoulou A, Brem A, Chesbrough H, Cucino V, Di Minin A, Giones F, Hakala H, Marullo C, Mention AL, Mortara L, Nørskov S, Nylund PA, Oddo CM, Radziwon A, Ritala P (2022) Digital transformation, for better or worse: a critical multi-level research agenda. R&D Manag 52:930–954. https://doi.org/10.1111/radm.12531

Daly K, Batten JA, Mishra AV, Choudhury T (2019) Contagion risk in global banking sector. J Int Financ Markets Instit Money 63:101136. https://doi.org/10.1016/j.intfin.2019.101136

Danuso A, Giones F, Ribeiro Da Silva E (2022) The digital transformation of industrial players. Bus Horizons 65:341–349. https://doi.org/10.1016/j.bushor.2021.04.001

de Paula D, Marx C, Wolf E, Dremel C, Cormican K, Uebernickel F (2023) A managerial mental model to drive innovation in the context of digital transformation. Ind Innov 30:42–66. https://doi.org/10.1080/13662716.2022.2072711

Di Minin A, Frattini F, Piccaluga A (2010) Fiat: open innovation in a downturn (1993–2003). Calif Manag Rev 52:132–159. https://doi.org/10.1525/cmr.2010.52.3.132

Di Minin A, Dooley L, Lazzarotti V, Manzini R, Mortara L, Piccaluga A (2021) R&D Management at a time of crisis: what are we learning from the response to the COVID-19 pandemic? R&D Manag 51:165–168. https://doi.org/10.1111/radm.12454

Dosi G, Soete L (2022) On the syndemic nature of crises: a freeman perspective. Res Policy 51:104393. https://doi.org/10.1016/j.respol.2021.104393

Emami A, Ashourizadeh S, Sheikhi S, Rexhepi G (2022) Entrepreneurial propensity for market analysis in the time of COVID-19: benefits from individual entrepreneurial orientation and opportunity confidence. Rev Manag Sci 16:2413–2439

Falagas ME, Pitsouni EI, Malietzis GA, Pappas G (2008) Comparison of pubmed, scopus, web of science, and google scholar: strengths and weaknesses. FASEB J 22:338–342. https://doi.org/10.1096/fj.07-9492LSF

Ferras-Hernandez X, Nylund PA, Brem A (2022) Strategy follows the structure of artificial intelligence. IEEE Eng Manag Rev 50:17–19. https://doi.org/10.1109/EMR.2022.3188996

Filippetti A, Archibugi D (2011) Innovation in times of crisis: national systems of innovation, structure, and demand. Res Policy 40:179–192. https://doi.org/10.1016/j.respol.2010.09.001

Furr N, Ozcan P, Eisenhardt KM (2022) What is digital transformation? Core tensions facing established companies on the global stage. Global Strategy J 12:595–618. https://doi.org/10.1002/gsj.1442

Garud R, Kumaraswamy A, Roberts A, Xu L (2022) Liminal movement by digital platform-based sharing economy ventures: the case of Uber technologies. Strat Manag J 43:447–475. https://doi.org/10.1002/smj.3148

Giebel M, Kraft K (2019) External financing constraints and firm innovation. J Ind Econ 67:91–126. https://doi.org/10.1111/joie.12197

Giones F, Brem A, Berger A (2019) Strategic decisions in turbulent times: lessons from the energy industry. Bus Horizons 62:215–225. https://doi.org/10.1016/j.bushor.2018.11.003

Giones F, Brem A, Pollack JM et al (2020) Revising entrepreneurial action in response to exogenous shocks: Considering the COVID-19 pandemic. J Bus Venturing Insights 14:e00186. https://doi.org/10.1016/j.jbvi.2020.e00186

Grün B, Hornik K (2011) Topicmodels: an R package for fitting topic models. J Stat Soft. https://doi.org/10.18637/jss.v040.i13

Guderian CC, Bican PM, Riar FJ, Chattopadhyay S (2021) Innovation management in crisis: patent analytics as a response to the COVID-19 pandemic. R&D Manag 51:223–239. https://doi.org/10.1111/radm.12447

Hannigan TR, Haans RFJ, Vakili K, Tchalian H, Glaser VL, Wang MS, Kaplan S, Jennings PD (2019) Topic modeling in management research: rendering new theory from textual data. Acad Manag Ann 13:586–632. https://doi.org/10.5465/annals.2017.0099

Harzing A-W, Alakangas S (2016) Google scholar, scopus and the web of science: a longitudinal and cross-disciplinary comparison. Scientometrics 106:787–804. https://doi.org/10.1007/s11192-015-1798-9

Honnibal M, Montani I, Van Landeghem S, Boyd A (2020) spaCy: industrial-strength natural language processing in python. https://doi.org/10.5281/zenodo

Kashani ES, Roshani S (2019) Evolution of innovation system literature: Intellectual bases and emerging trends. Technol Forecast Soc Change 146:68–80. https://doi.org/10.1016/j.techfore.2019.05.010

Khurana I, Dutta DK, Ghura AS (2022) SMEs and digital transformation during a crisis: The emergence of resilience as a second-order dynamic capability in an entrepreneurial ecosystem. J Bus Res 150:623–641. https://doi.org/10.1016/j.jbusres.2022.06.048

Kim L (1998) Crisis construction and organizational learning: capability building in catching-up at Hyundai motor. Organ Sci 9:506–521. https://doi.org/10.1287/orsc.9.4.506

Kranton RE, Minehart DF (2001) A theory of buyer-seller networks. Am Econ Rev 91:485–508. https://doi.org/10.1257/aer.91.3.485

Kraus S, Breier M, Dasí-Rodríguez S (2020a) The art of crafting a systematic literature review in entrepreneurship research. Int Entrep Manag J 16:1023–1042. https://doi.org/10.1007/s11365-020-00635-4

Kraus S, Clauss T, Breier M, Gast J, Zardini A, Tiberius V (2020b) The economics of COVID-19: initial empirical evidence on how family firms in five European countries cope with the corona crisis. Int J Entrep Behav Res 26:1067–1092. https://doi.org/10.1108/IJEBR-04-2020-0214

Kraus S, Breier M, Lim WM, Dabić M, Kumar S, Kanbach D, Mukherjee D, Corvello V, Piñeiro-Chousa J, Liguori E, Palacios-Marqués D, Schiavone F, Ferraris A, Fernandes C, Ferreira JJ (2022) Literature reviews as independent studies: guidelines for academic practice. Rev Manag Sci 16:2577–2595. https://doi.org/10.1007/s11846-022-00588-8

Kronblad C, Pregmark JE (2021) Responding to the COVID-19 crisis: the rapid turn toward digital business models. J Sci Technol Policy Manag Early View. https://doi.org/10.1108/JSTPM-10-2020-0155

Kulkarni AV, Aziz B, Shams I, Busse JW (2009) Comparisons of citations in web of science, scopus, and google scholar for articles published in general medical journals. JAMA 302:1092–1096. https://doi.org/10.1001/jama.2009.1307

Lanzolla G, Lorenz A, Miron-Spektor E, Schilling M, Solinas G, Tucci CL (2020) Digital transformation: what is new if anything? Emerging patterns and management research. Acad Manag Discov 6:341–350. https://doi.org/10.5465/amd.2020.0144

Lanzolla G, Pesce D, Tucci CL (2021) The digital transformation of search and recombination in the innovation function: tensions and an integrative framework. J Prod Innov Manag 38:90–113. https://doi.org/10.1111/jpim.12546

Lee SM, Trimi S (2021) Convergence innovation in the digital age and in the COVID-19 pandemic crisis. J Bus Res 123:14–22. https://doi.org/10.1016/j.jbusres.2020.09.041

Lee N, Sameen H, Cowling M (2015) Access to finance for innovative SMEs since the financial crisis. Res Policy 44:370–380. https://doi.org/10.1016/j.respol.2014.09.008

Leppääho T, Ritala P (2022) Surviving the coronavirus pandemic and beyond: Unlocking family firms' innovation potential across crises. J Fam Bus Strat 13:100440. https://doi.org/10.1016/j.jfbs.2021.100440

Lingens B, Miehé L, Gassmann O (2021) The ecosystem blueprint: How firms shape the design of an ecosystem according to the surrounding conditions. Long Range Plann 54:102043. https://doi.org/10.1016/j.lrp.2020.102043

Liu W, Beltagui A, Ye S (2021) Accelerated innovation through repurposing: exaptation of design and manufacturing in response to COVID-19. R&D Manag 51:410–426. https://doi.org/10.1111/radm.12460

Majchrzak A, Shepherd DA (2021) Can digital innovations help reduce suffering? A crowd-based digital innovation framework of compassion venturing. Inf Organ 31:100338. https://doi.org/10.1016/j.infoandorg.2021.100338

Makkonen H, Pohjola M, Olkkonen R, Koponen A (2014) Dynamic capabilities and firm performance in a financial crisis. J Bus Res 67:2707–2719. https://doi.org/10.1016/j.jbusres.2013.03.020

Mazzucato M (2013) Financing innovation: creative destruction vs. destructive creation. Ind Corp Change 22:851–867. https://doi.org/10.1093/icc/dtt025

McAdam R, Mitchell N (2010) The influences of critical incidents and lifecycle dynamics on innovation implementation constructs in SMEs: a longitudinal study. Int J Technol Manag 52:189–212. https://doi.org/10.1504/IJTM.2010.035862

McCallum AK (2022) Mallet: a machine learning for language toolkit. http://mallet.cs.umass.edu.
Meyer-Krahmer F (1992) The German R&D system in transition: empirical results and prospects of future development. Res Policy 21:423–436. https://doi.org/10.1016/0048-7333(92)90003-M
Midttun A, Piccini PB (2017) Facing the climate and digital challenge: European energy industry from boom to crisis and transformation. Energy Policy 108:330–343. https://doi.org/10.1016/j.enpol.2017.05.046
Misati R, Osoro J, Odongo M, Abdul F (2022) Does digital financial innovation enhance financial deepening and growth in Kenya? Int J Emerg Mark Early View. https://doi.org/10.1108/IJOEM-09-2021-1389
Mostaghel R, Oghazi P, Parida V, Sohrabpour V (2022) Digitalization driven retail business model innovation: Evaluation of past and avenues for future research trends. J Bus Res 146:134–145. https://doi.org/10.1016/j.jbusres.2022.03.072
Münzberg C, Hammer J, Brem A, Lindemann U (2016) Crisis situations in engineering product development: a TRIZ based approach. Procedia CIRP 39:144–149. https://doi.org/10.1016/j.procir.2016.01.180
Mustak M, Salminen J, Plé L, Wirtz J (2021) Artificial intelligence in marketing: Topic modeling, scientometric analysis, and research agenda. J Bus Res 124:389–404. https://doi.org/10.1016/j.jbusres.2020.10.044
Nemlioglu I, Mallick S (2021) Effective innovation via better management of firms: the role of leverage in times of crisis. Res Policy 50:104259. https://doi.org/10.1016/j.respol.2021.104259
Newey LR, Zahra SA (2009) The evolving firm: how dynamic and operating capabilities interact to enable entrepreneurship. Br J Manag 20:S81–S100. https://doi.org/10.1111/j.1467-8551.2008.00614.x
Nylund PA, Ferras-Hernandez X, Brem A (2020) Automating profitably together: is there an impact of open innovation and automation on firm turnover? Rev Manag Sci 14:269–285. https://doi.org/10.1007/s11846-018-0294-z
Nylund PA, Ferràs-Hernández X, Pareras L, Brem A (2022) The emergence of entrepreneurial ecosystems based on enabling technologies: evidence from synthetic biology. J Bus Res 149:728–735. https://doi.org/10.1016/j.jbusres.2022.05.071
Osiyevskyy O, Shirokova G, Ritala P (2020) Exploration and exploitation in a crisis environment: implications for level and variability of firm performance. J Bus Res 114:227–239. https://doi.org/10.1016/j.jbusres.2020.04.015
Paunov C (2012) The global crisis and firms' investments in innovation. Res Policy 41:24–35. https://doi.org/10.1016/j.respol.2011.07.007
Puumalainen K, Sjögrén H, Soininen J, Syrjä P, Kraus S (2023) Crisis response strategies and entrepreneurial orientation of SMEs: a configurational analysis on performance impacts. Int Entrep Manag J Early View. https://doi.org/10.1007/s11365-023-00847-4
Radziwon A, Bogers ML, Chesbrough H, Minssen T (2022) Ecosystem effectuation: creating new value through open innovation during a pandemic. R&D Manag 52(2):376–390
Ramage D, Rosen E, Chuang J, Manning C, McFarland DA (2009) Topic modeling for the social sciences. NIPS 2009 Workshop Appl Topic Models Text beyond 5:1–4
Rehurek R, Sojka P (2010) Software framework for topic modelling with large corpora. In: Proceedings of the LREC 2010 workshop on new challenges for NLP frameworks
Reuschl AJ, Deist MK, Maalaoui A (2022) Digital transformation during a pandemic: stretching the organizational elasticity. J Bus Res 144:1320–1332. https://doi.org/10.1016/j.jbusres.2022.01.088
Rizzi P, Graziano P, Dallara A (2018) A capacity approach to territorial resilience: the case of European regions. Ann Reg Sci 60:285–328. https://doi.org/10.1007/s00168-017-0854-1
Roberts ME, Stewart BM, Tingley D (2019) stm: an R package for structural topic models. J Stat Soft 91:1–40. https://doi.org/10.18637/jss.v091.i02
Röder M, Both A, Hinneburg A (2015) Exploring the space of topic coherence measures. In: Proceedings of the eighth ACM international conference on web search and data mining
Rothmann W, Koch J (2014) Creativity in strategic lock-ins: the newspaper industry and the digital revolution. Technol Forecast Soc Change 83:66–83. https://doi.org/10.1016/j.techfore.2013.03.005
Ryan P, Buciuni G, Giblin M, Andersson U (2022) Global value chain governance in the MNE: A dynamic hierarchy perspective. Calif Manag Rev 64:97–118. https://doi.org/10.1177/00081256211068544

Sauer PC, Seuring S (2017) Sustainable supply chain management for minerals. J Clean Prod 151:235–249. https://doi.org/10.1016/j.jclepro.2017.03.049
Sauer PC, Seuring S (2023) How to conduct systematic literature reviews in management research: a guide in 6 steps and 14 decisions. Rev Manag Sci 17:1899–1933. https://doi.org/10.1007/s11846-023-00668-3
Scheiner CW, Baccarella CV, Bessant J, Voigt K-I (2015) Thinking patterns and gut feeling in technology identification and evaluation. Technol Forecast Soc Change 101:112–123. https://doi.org/10.1016/j.techfore.2013.12.003
Schoemaker PJH, Day G (2021) Preparing organizations for greater turbulence. Calif Manage Rev 63:66–88. https://doi.org/10.1177/00081256211022039
Schöler L, Skiera B, Tellis GJ (2014) Stock market returns to financial innovations before and during the financial crisis in the United States and Europe: stock market returns to financial innovations. J Prod Innov Manag 31:973–986. https://doi.org/10.1111/jpim.12138
Sievert C, Shirley K (2014) LDAvis: a method for visualizing and interpreting topics. In: Proceedings of the workshop on interactive language learning, visualization, and interfaces
Singh VK, Singh P, Karmakar M, Leta J, Mayr P (2021) The journal coverage of web of science, scopus and dimensions: a comparative analysis. Scientometrics 126:5113–5142. https://doi.org/10.1007/s11192-021-03948-5
Soluk J (2022) organisations' resources and external shocks: Exploring digital innovation in family firms. Ind Innov 29:792–824. https://doi.org/10.1080/13662716.2022.2065971
Soluk J, Kammerlander N, De Massis A (2021) Exogenous shocks and the adaptive capacity of family firms: exploring behavioral changes and digital technologies in the COVID-19 pandemic. R&D Manag 51:364–380. https://doi.org/10.1111/radm.12471
Szántó B (1994) Innovation in crisis: hungary before and after the watershed of 1989. Technovation 14:601–611. https://doi.org/10.1016/0166-4972(94)90042-6
Temiz S, Broo DG (2020) Open innovation initiatives to tackle COVID-19 crises: imposter open innovation and openness in data. IEEE Eng Manag Rev 48:46–54. https://doi.org/10.1109/EMR.2020.3033991
Thomas LDW, Ritala P (2022) Ecosystem legitimacy emergence: a collective action view. J Manag 48:515–541. https://doi.org/10.1177/0149206320986617
Thomas LDW, Autio E, Gann DM (2022) Processes of ecosystem emergence. Technovation 115:102441. https://doi.org/10.1016/j.technovation.2021.102441
Tilson D, Lyytinen K, Sørensen C (2010) Digital infrastructures: the missing IS research agenda. Inf Syst Res 21:748–759. https://doi.org/10.1287/isre.1100.0318
Unger B (2000) Innovation systems and innovative performance: voice systems. Organ Stud 21:941–969. https://doi.org/10.1177/0170840600215005
Viardot E, Brem A, Nylund PA (2023) Post-pandemic implications for crisis innovation: a technological innovation view. Technol Forecast Soc Change 194:122680. https://doi.org/10.1016/j.techfore.2023.122680
Voronkova V, Nikitenko V, Metelenko N (2022) Agile-economy as a factor in improving the digital society. Balt J Econ Stud 8:51–58. https://doi.org/10.30525/2256-0742/2022-8-2-51-58
Wareham J, Fox PB, Cano Giner JL (2014) Technology ecosystem governance. Organ Sci 25:1195–1215. https://doi.org/10.1287/orsc.2014.0895
Wu T (2018) The curse of bigness: antitrust in the new gilded age. Columbia Global Reports, New York
Yokoi T, Obwegeser N, Beretta M (2023) Crisis innovation: leveraging virtual hackathons for rapid ideation. IEEE Trans Eng Manage. https://doi.org/10.1109/TEM.2021.3097238
Zona F (2012) Corporate investing as a response to economic downturn: prospect theory, the behavioral agency model and the role of financial slack. Brit J Manage 23:S42–S57. https://doi.org/10.1111/j.1467-8551.2012.00818.x