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## Editorial to the special issue on applications of complexity for resilient organizations, management and innovation systems

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## Editorial to the special issue on applications of complexity for resilient organizations, management and innovation systems

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### Abstract

Welcome to the Special Issue on Applications of Complexity for Resilient Organizations, Management, and Innovation Systems. This Special Issue includes six articles highlighting how complexity science and complex systems approaches can be employed to study resilient aspects in organizations, management and innovation systems. Nowadays, governments, policy-makers, managers, firms, and organizations are requested to face challenges with possible and unpredictable disruptive events always more and more interconnected. Complexity science and complex systems approaches applied to economic and managerial systems allow to model the endogenous dynamics of a system as a whole and composed of heterogeneous interacting agents from the bottom up. Such models open the opportunity for a dynamic and systemic approach to investigate and improve the resilience of organizations and innovation systems. It is crucial to remark that both scholars and decision-makers collaborated on the Special Issue to better understand the advantages of using a systemic approach (i.e., complexity science and complex systems approaches) in areas where such methodologies have not been considered so far, i.e., organization, innovation, and management. To aid in this endeavor, the papers included in the Special Issue investigate different conceptual and methodological aspects applied in different contexts and open a new vista on the opportunity offered by complexity science and complex systems approaches to face research and professional questions in the areas of organization, management, and innovation.

**Keywords** Complexity · Resilience · Organization · Management · Innovation systems

## 1 Introduction

In this world full of challenges and unpredictable and disruptive events such as the COVID-19 pandemic, complexity theory and complex systems approaches are very useful in supporting decision-making processes of governments, policymakers, managers, companies, and organizations (Cincotti et al. 2022; Teglio et al. 2019; Ponta et al. 2018a; Riccetti et al. 2022). Moreover, they permit the modelling of complex system behaviours, reproducing the internal dynamics of the whole system from the bottom-up, focusing on its microelements such as the agents, their attributes, actions, goals, and the network structure (and type of relationships) that connect them. Furthermore, they can deal with uncertainty and resilience including the ability to learn and adapt (Cincotti et al. 2010; Ponta et al. 2011; Cruciani et al. 2017).

Complex systems can be found everywhere in organizations, management, and innovation systems (see Ping et al. 2024). They include multiple scales, from the macro level, referring to industries, markets, and countries, to the micro level, involving firms, work teams, and individuals (Farmer et al. 2012, Villani et al. 2022). Thus, the application of complexity theory spans multiple contexts and areas (Khan et al. 2019; Clementis et al. 2019; Green 2023; Holcombe et al. 2013; Guerri et al. 2005; Petrović et al. 2020).

From a methodological point of view, the study of complexity in modern organizations requires dynamic and systemic approaches. In this regard, methodologies based on agent-based modelling and networks are very suitable (Ponta and Cincotti 2018; Raberto et al. 2012; Mazzocchi et al. 2020). The agent-based simulations are particularly flexible, allowing for studying—in a well-controlled way—both the consequences of agents' behaviour, as well as the behaviour of the entire system. Agent-based models are typical tools for studying complex systems and, so far, have mainly been used in economics and finance (Ozel et al. 2019; Raberto et al. 2001, 2019; Teglio et al. 2019; Pastore et al. 2010; Ponta et al. 2018b; Samanidou et al. 2007; Kirman 1997; Caiani et al. 2016; Gatti et al. 2010; Ahrweiler et al. 2011; Gilbert et al. 2014). Recently, they have also been used in many different fields, such as management and organization (Ponsiglione et al. 2021; Giannoccaro 2011; Herrera-Restrepo and Triantis 2019; Ponta et al. 2020, 2023; Jiang et al. 2016; Rand and Stummer 2021; Ma and Nakamori 2005; Amini et al. 2012). However, as noted by Phillips and Ritala (2019), mixed methods with a combination of qualitative and quantitative approaches can be also useful in investigating organizations, management, and innovation systems in light of the complex adaptive systems approach. Thus, the main research questions outlined in the special issue address the use of complexity in various economic and management settings.

This special issue collects six papers investigating different conceptual and methodological aspects related to the use of complex systems. Sabol (2024) analyzes the relationship between complexity and innovation. Guida et al. (2024), Morone et al. (2023), and Passavanti et al. (2024), focus on advancing knowledge on methodological aspects suitable to model the complexity of organizations,

management, and innovation systems. Cicerelli and Ravetti (2023), and Butkus et al. (2024) explore the relationships between complexity and resilience.

## 2 The contributions to the special issue

All the papers included in this special issue deal with several innovation topics in management research. In particular, Sabol (2024) investigates innovation dynamics in the context of municipal ecosystems; Guida et al. (2024) study the role of imitation, a less costly alternative to experimentation, with respect to the exploration, exploitation, and organizational learning; Morone et al. (2023) analyze the resilience of socioeconomic systems under conditions of crises and external shocks, considering the impact of social/behavioral rules and social networks structure on the process of knowledge diffusion. Passavanti et al. (2024) investigate the role of information asymmetries and moral hazards in the financing system of New Technology-Based Firms (NTBFs); Cicerelli and Ravetti (2023) investigate the relationship among sustainability, complexity, and organizational resilience in the electrical and electronic equipment industry; Butkus et al. (2024) address the topic of resilience in public sector organizations.

Methodologies and scopes may differ across papers but they all share the idea that complexity theory and the complex systems approach are needed to better understand organizational and innovation systems and to support the design of policy measures and interventions toward resilience.

Sabol (2024) uses a mixed methods approach to build a novel framework supporting the understanding of the innovative behaviors in a Municipal Innovation Ecosystem. Firstly, qualitative data were collected by person-to-person semi-structured interviews to better inform the second stage of quantitative data collection through a survey. The structural model obtained was tested using PLS-Sem Method. Guida et al. (2024) use an agent-based model to perform what-if analyses to explore how two distinct agent types, i.e. those who imitate and those who experiment, interact and influence each other. Morone et al. (2023) adopt an agent-based modelling approach to investigate the impact of different behavioral/sociological rules and social interaction structures on the knowledge diffusion process and economic performances of the system. The study incorporates social network analysis to examine the effects of different social network structures on efficiency, equity, and sustainability-resilience in knowledge diffusion. Passavanti et al. (2024) employ a configurative approach built on five accessible signals in the context of Qualitative Comparative Analysis (QCA). Cicerelli and Ravetto employ an in-depth longitudinal case study to build a conceptual framework useful to relate sustainability and complexity management to organizational resilience and competitiveness issues in the electrical and electronics industry. Butkus et al. (2024) propose an empirical analysis to present a resilience framework consisting of Planning, Adaptation, and Enhanced learning, which is validated empirically by surveying 401 public sector organizations that can be used as the basis for future simulations.

This Special Issue, therefore, reflects the heterogeneity in terms of analyzed topics and used methodologies that characterize the current state of the art in the field of complexity approach to management, organization, and innovation systems. In the following, we provide a short description of each work included in this publication.

Sabol (2024) analyzes municipal innovation ecosystems focusing on intrapersonal and interpersonal resources. The paper aims to develop a framework and novel constructs to be adopted to assess the innovation behaviours of heterogeneous individuals in the analyzed context of a city ecosystem. A mixed-method methodological approach is adopted, employing qualitative and quantitative data and techniques, to answer the research question. The field research is performed using a specific setting: Mobile, a port city on Alabama's Gulf Coast. The main results concern the development of a novel framework and related constructs to analyze how moving from an individual level, innovative behaviors can be induced and strengthened in a municipal ecosystem. In particular, findings suggest that the intrapersonal resources of individuals and intense social interactions of these individuals with municipal institutions can contribute to the development of innovation at the city and regional levels.

Developing an agent-based model Guida et al. (2024) explore the role of imitation in the exploration–exploitation dilemma. The results reveal that imitators decrease their performance in the presence of intensified competition, whereas explorers are hindered in their attempts at radical innovation due to the presence of other explorers and clusters of imitators. Thus, Guida et al. (2024) provide novel insights into the dynamics of organizational learning and strategic decision-making.

Morone et al. (2023) analyze how knowledge diffusion processes in socioeconomic systems are affected by different behavioural/sociological rules, studying the implications of diverse social network structures on efficiency, equity, and sustainability or resilience in knowledge diffusion. The knowledge diffusion process is framed as a complex process occurring through social interactions among heterogeneous agents in a society. Using an agent-based model and social network analyses, the research shows that different behavioural/sociological rules induced by diverse social network structures have varying effects on the knowledge diffusion process, with social structures characterized by both strong ties (intense contacts within communities) and weak ties (knowledge spillover across communities) outperforming others during crises in terms of better performances. The paper contributes, from a theoretical and methodological perspective to a better understanding of how the coexistence of weak and strong ties in socioeconomic systems supports the finding of the right trade-off between efficiency and equity towards learning and better economic performances.

Using a fuzzy-set Qualitative Comparative Analysis (fsQCA), Passavanti et al. (2024) investigate the influence of information asymmetries and moral hazards in the financing system of New Technology-Based Firms (NTBFs). Results help to improve our understanding of the dynamics between NTBFs and investors, and in particular on the interplay of various factors that influence the financing outcomes.

Cicerelli and Ravetto explore the intricate relationship between different dimensions of complexity, the management of sustainability issues, and the resilience and competitiveness of companies and production systems in the electrical and

electronic equipment industry. The study adopts an in-depth longitudinal case study approach applied to an Italian B2B company; results show that three core dimensions of complexity affect sustainability solutions at the company level: internal, supply chain, and external. The research also highlights the challenges and opportunities offered by managing complexities in the production systems in the electronics industry, revealing the higher possibilities of sustainable innovation transfer when adequate metrics and information flows are established in the complex environment under investigation.

Combining a systematic literature review and a quantitative empirical investigation Butkus et al. (2024) propose and test a framework of organisational resilience in the public sector. The empirical investigation analyses the Lithuanian public sector organisations explains the relationships among the model dimensions and identifies Planning, Adaptation, and Enhanced Learning as critical phases to explain organisational resilience. Results offer a model for theory development to understand the dimensions of the resilience of complex adaptive public sector organisations and how they interrelate with each other.

### 3 Concluding remarks and future directions

Collectively, the papers included in the Special Issue point out how adopting the complexity approach, including adequate conceptual and methodological perspectives, can help in advancing the understanding of organizations, management and innovation systems, particularly under uncertainty and shocks. The papers also show the need for integrated methods, where the traditional methodologies are combined with complex systems typical approaches. For example, Sabol (2024) and Butkus et al. (2024) integrate mixed classical methodologies like surveys and regressions with principles of complex adaptive systems; Cicerelli and Ravetto (2023) and Passavanti et al. (2024) use longitudinal case studies and the configurative approach adopted with the perspective of complexity; Guida et al. (2024) and Morone et al. (2023) develop agent-based models which are very useful for the what-if analyses, including also social network analysis elements.

In addition, the recent advent and spread of the availability of new technologies for massive data collection offers new opportunities to scholars. They permit to measure and evaluate complex system dynamics through data-driven methodologies. By providing automatic and more objective measurements of individual, team, and firm behaviours, these tools can efficiently collect a large amount of real-time data,—increasing the data richness, quality, and reliability. This aspect allows for opening of new scenarios for the advancement of models and tools (like those based on simulations and virtual experimentation) that could help support effectively not only theory building but also policy-making.

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## Declarations

**Conflict of interest** The Author(s) declare(s) the following conflict of interests-either non-financial or financial. Silvano Cincotti is an Associate Editor of the Journal of Economic Interaction and Coordination.

**Ethical approval** The Author(s) declare(s) that ethics approval is not applicable to the research, as the article does not report on or involve any humans, human data.

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