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Exploring Nestedness in Ecosystems: Towards a Taxonomy for Theory and Practice

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Preface

When I started university, I was certain of one thing: I did not want to follow in my parents' footsteps, a veterinarian and a university professor. On one side, I felt the weight of interrupting a family line of successful veterinarians; on the other, academia seemed like the very last place I would ever belong to. Yet life, in its mysterious way, had different plans.

In 2021, I went to Germany to study at TUM Munich and applied for a restricted-entry course, *"Advanced Seminar on Sustainable Entrepreneurship"*. I was not selected. Out of curiosity, and perhaps pride, I wrote to ask why. I was not particularly eager to take that course, but that *no* struck a chord within me. The professor replied, saying he appreciated my hunger for knowledge, and offered me a place, reminding me that if I had asked "why" it was clear that a course on research methodology was meant for me. The final exam required us to develop a research proposal. Among a group of brilliant international students, I wrote the best one. That experience changed me. I discovered that I loved research and teaching, and I finally understood the meaning behind the long nights my mother spent writing, while my sister and I sat beside her, carefully dictating those intricate legal citations.

When I returned to Rome, I carried that inner fracture with me. I completed my master's thesis, trying to silence a voice I didn't want to hear. Yet my professors immediately recognized that tiny little voice, gave it a name, and chose me. And they were right. Almost unconsciously, I said yes, and a new path began to unfold.

In September 2022, I applied for the PhD program. When I was not selected, that voice inside me felt almost relieved, perhaps because it feared that I might actually enjoy it. Meanwhile, job offers arrived from Munich: prestigious companies, tempting salaries, the promise of stability. I also longed to get my hands dirty, to experience the real world beyond academia. Then came the industrial PhD call with Eni. I applied, I won, and my wish to connect theory and practice became reality. That was the beginning of a long journey.

A PhD is a journey that encompasses different dimensions of one's spirit. In the art of writing and researching, we reconnect with many parts of ourselves; we *re-search*, in the most authentic sense of the word, to seek again, to never stop at a single dimension of the world.

This dissertation is the outcome of that journey. It is the result of many *no's*, but also of countless *yes's*. It is the fruit of those who believed that I could carry forward their way of inhabiting this world, first as a human being, and then as a professional. It is the fruit of the work of mentors and precious friends I met along the way. It is also the product of an ongoing dialogue with the practical world, sometimes easy, sometimes difficult, and of the conviction that research without real impact cannot truly exist. The voices of the professionals who walked this path with me have shaped not only my studies, but also my way of living and thinking about what it means to move forward.

It is, above all, the fruit of the passion of the people I have met along the way, those who carry that unmistakable spark in their eyes, the light of curiosity and creation. But perhaps even more, it is inspired by those who seem to have lost that spark. They remind me why I want to give back, to ignite in students the desire to dream, to believe, and to build something meaningful.

Some weeks ago, I discovered that when my mother defended her own doctoral dissertation, she was carrying me within her belly. I like to think that, even before I was physically in this world, I was already listening to her voice, her strength, and her determination. Perhaps that early echo of her words left an imprint that has lived inside me ever since.

Today, that dream is clear. My dream is clear. It lives deep within me, reminding me to remain forever a student. I also carry her dreams in my heart, and I will do my best to bring them to life, for myself and for the world.

Gutta cavat lapidem

Abstract

This dissertation explores how innovation and entrepreneurial ecosystems can be conceptualized and connected through the lens of nestedness and complex systems theory. By integrating theoretical reflection and empirical investigation, it develops a taxonomy that bridges fragmented perspectives and supports the design of adaptive, interconnected systems of innovation.

The first paper introduces the concept of *Interconnected Innovation Ecosystems* (IIEs) and presents a validated partner selection tool co-created with practitioners from FS Group through a design research approach. The tool operationalizes five key dimensions—partners' maturity, collaboration readiness, value co-creation, intellectual property management, and international network—enabling evidence-based partner assessment across national and institutional boundaries.

The second paper advances a scoping review of 48 studies to conceptualize the nestedness between *Entrepreneurial Ecosystems* (EEs) and *Innovation Ecosystems* (IEs). It identifies four archetypes—startup ecosystems, entrepreneurial university ecosystems, entrepreneurial innovation ecosystems, and regional innovation ecosystems—and interprets their interactions through systemic properties.

The third paper provides an empirical assessment of how participation in the International Association of Science Parks (IASP) network influences the evolution of regional entrepreneurial ecosystems. Based on a longitudinal analysis of European regions, the findings demonstrate that participation in global STP networks significantly reinforces the intermediary and knowledge functions of regional ecosystems, with particularly strong effects observed in low-income and peripheral areas where global connectivity acts as a catalyst for innovation diffusion.

The thesis contributes to the theoretical integration of ecosystem research and provides actionable insights for policymakers, firms, and orchestrators. As an industrial PhD, it also demonstrates the value of aligning theoretical and practical research to generate real societal and organizational impact.

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List of Abbreviations and Symbols

ADRES Adaptability and Resilience

ATT Average Treatment Effect among Treated

DiD Difference-in-Differences

DR Design Research

EE Entrepreneurial Ecosystem

EU European Union

FLCC Feedback Loops and Complex Causation

GDP Gross Domestic Product

HET Heterogeneity

IASP International Association of Science and Technology Parks and Areas of Innovation

ICC Intraclass Correlation Coefficient

IE Innovation Ecosystem

IIE Interconnected Innovation Ecosystem

IP Intellectual Property

NLCE Non-Linearity and Co-Evolution

OI Open Innovation

PRISMA-ScR Preferred Reporting Items for Systematic Reviews and Meta-Analyses – Scoping Review

R&D Research & Development

ROAD Rome Advanced District

RTD Research and Technological Development

SIPD Sensitivity to Initial Conditions and Path-Dependence

SORG Self-Organization

SP Strategic Partnerships

STP Science and Technology Park

TSCS Time-Series Cross-Sectional

TWFE Two-Way Fixed Effects

Introduction

The term *ecosystem* originates from the lexicon of biology and ecology, where it describes a dynamic assemblage of living organisms interacting with each other and with their physical environment, forming a functional unit. The concept was formally introduced by British ecologist Arthur George Tansley in his pioneering 1935 paper *"The Use and Abuse of Vegetational Concepts and Terms"*, in which he argued that *the more fundamental conception is... the whole system (in the sense of physics), including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome — the habitat factors in the widest sense"* (Tansley, 1935, p.299). Tansley's definition positioned ecosystems as open systems characterized by flows of energy and matter, feedback loops, and a constant evolution toward dynamic equilibria. This systemic perspective—originally intended to explain the coexistence and adaptation of species within natural habitats—proved surprisingly well suited for describing complex phenomena far beyond the natural sciences.

From the 1980s onwards, scholars in economics, strategic management, and organizational studies began to recognize the potential of this ecological metaphor to capture the intricate relationships among firms, institutions, and other economic actors. A pivotal moment in this intellectual migration came with James F. Moore's (1993) seminal introduction of the business ecosystem concept. Moore shifted the analytical focus from the individual firm as an isolated entity within a defined industry to a network of interconnected organizations that co-evolve, compete, and collaborate to create value. In this framing, industries were no longer seen as static, bounded structures but as dynamic communities of interdependent actors engaged in collective value creation.

The ecological analogy resonated particularly well with scholars and practitioners confronted with increasing technological turbulence, globalization, and the erosion of traditional organizational boundaries. Just as biological ecosystems comprise diverse species occupying complementary niches, business ecosystems encompass heterogeneous actors—suppliers, complementors, customers, competitors, and regulators—whose coordinated and uncoordinated actions jointly shape the competitive and cooperative dynamics of the system. This recognition marked a profound shift in strategic thinking: competitive advantage was no longer solely a function of a firm's internal resources and capabilities, but also of its position and role within a broader, evolving network of relationships.

For decades, the secrets of the corporate research laboratory have represented a strategic treasure for organizations, safeguarding the ideas, experiments, and technological breakthroughs that would shape their competitive advantage. Hidden behind closed doors, these laboratories were the places where innovation was cultivated in controlled environments, far from competitors' eyes. Over time, they evolved into specialized research and development (R&D) functions, becoming the beating heart of technological progress in many industries. Today, however, the traditional R&D

lab paradigm is being redefined, as organizations increasingly recognize the need to complement internal capabilities with external sources of knowledge and collaboration. This recognition has accelerated the adoption of more open, networked approaches to innovation, where competitive success depends not only on what a firm knows and can develop internally, but also on how effectively it can integrate and orchestrate resources from a diverse set of external partners.

The expansion of the ecosystem metaphor into the domain of innovation was a natural progression. By the early 2000s, Henry Chesbrough's (2003) formulation of open innovation provided fertile ground for the concept's application to innovation management. Open innovation emphasized the strategic use of both inflows and outflows of knowledge to accelerate internal innovation and expand markets for external use of innovation. Against this backdrop, Adner (2006) articulated the notion of the innovation ecosystem (IE) as a collaborative arrangement in which firms combine their individual offerings into coherent, customer-facing solutions. IEs were portrayed as arenas where the success of one actor often depends on the coordinated contributions of others, creating a web of complementarities and interdependencies (Kapoor, 2018).

This framing catalyzed a paradigmatic transition away from closed, vertically integrated models of research and development toward more distributed and collaborative innovation architectures. It also highlighted the fact that innovation increasingly occurs not within the confines of a single organization, but across interlinked networks that span industries, geographies, and institutional boundaries. In this sense, the diffusion of the ecosystem metaphor has paralleled, and arguably facilitated, a broader transformation in how value creation is understood and managed in contemporary economies.

Today, the term ecosystem has proliferated into a variety of subdomains—innovation ecosystems, entrepreneurial ecosystems, digital ecosystems, social ecosystems, and technological ecosystems, among others—each adapting the core ecological metaphor to specific theoretical and empirical contexts. This proliferation reflects the metaphor's flexibility but also raises challenges for conceptual clarity. As in biology, where ecosystems differ dramatically in scale, composition, and function, the organizational analogues of ecosystems vary widely in their structural features, governance mechanisms, and strategic purposes. The result is a diverse yet fragmented body of literature in which definitions, boundaries, and analytical lenses often diverge, complicating efforts to build cumulative knowledge.

It is within this expanding and increasingly heterogeneous landscape that the present thesis situates itself. By engaging with multiple ecosystem constructs—particularly IEs and entrepreneurial ecosystems (EEs)—and by integrating perspectives from complex systems theory, open innovation, and digital transformation, this work seeks to advance a more unified and operational understanding of ecosystems as interdependent, adaptive, and evolving systems of value creation.

In particular, the identities of ecosystems shape their functioning, reflecting their organizational culture, governance mechanisms, and orchestration dynamics, and ultimately influencing how actors coordinate, co-evolve, and generate collective outcomes. However, these identities also reveal diverse divisions and fragmentations between practice and theory, as the conceptualization of ecosystems often lags behind their empirical manifestations, resulting in multiple, sometimes conflicting interpretations of what ecosystems are and how they actually operate.

The concept of the IE has gained increasing prominence over the past two decades as a lens to understand how innovation emerges, diffuses, and is commercialized across interdependent networks of actors. In its most widely accepted interpretation, IEs are described as evolving sets of actors, activities, artifacts, institutions, and relationships—including both complementary and substitute linkages—that are critical for the innovative performance of an actor or a population of actors (Granstrand & Holgersson, 2020). Unlike traditional supply chains or industrial clusters, which are often geographically bounded and characterized by relatively linear flows of goods and information (Becattini, 2017) IEs are inherently multi-layered, fluid, and adaptive structures. They encompass both production- and use-side participants, ranging from incumbent firms and start-ups to universities, research institutions, investors, policymakers, and end-users (Autio et al., 2014; Lin, 2018; Suominen et al., 2019).

A distinctive feature of IEs is the interplay of complementarities and interdependencies. Complementarities arise when the value of one actor's contribution increases with the availability or quality of another actor's output, while interdependencies refer to the mutual reliance among participants for the creation and appropriation of value (Kapoor, 2018). These characteristics imply that the success of innovation in an IE often hinges not on the performance of a single organization, but on the coordinated alignment of multiple actors' strategies, resources, and capabilities (Adner, 2016; Hannah & Eisenhardt, 2018; Jacobides et al., 2018).

The ecosystem perspective also aligns closely with the principles of open innovation (H. W. Chesbrough, 2003), as it emphasizes the role of external knowledge sources and collaborative arrangements in driving innovation outcomes. Corporations increasingly recognize that sustaining competitiveness requires leveraging capabilities beyond their organizational boundaries, tapping into a diversity of external partners to co-create value (Bogers et al., 2016; Vanhaverbeke & Cloodt, 2006; West et al., 2014). This shift is particularly visible in industries characterized by rapid technological change, where the pace of innovation and the complexity of emerging challenges exceed the absorptive capacity of any single firm.

Research on IEs has examined their structural configurations, governance mechanisms, and evolutionary dynamics. Many studies have explored how focal firms orchestrate the activities of ecosystem participants, balancing cooperation and competition (Bacon et al., 2020; Jiang et al., 2020; Smorodinskaya et al., 2017). Others have investigated the conditions under which IEs enable the scaling of innovations, the diffusion of technological standards, and the resolution of systemic challenges (Primario et al., 2024; L. D. W. Thomas et al., 2020). Technological, economic, and cognitive perspectives have been used to shed light on how knowledge is shared, how complementarities are leveraged, and how ecosystem participants align their goals.

Despite the growing body of research on individual IEs, there remains a notable gap in understanding how ecosystems interact with one another. In practice, innovation frequently arises from cross-ecosystem interdependencies, where resources, knowledge, and capabilities flow between different but connected systems (Vasudeva et al., 2020). These interactions can take the form of alliances between ecosystems, partial overlaps in membership, shared technological platforms, or joint responses to societal challenges. However, analytical and operational tools to study and manage such interactions remain limited (Dias SantÁna et al., 2020). The increasing complexity of innovation landscapes calls for approaches that move beyond the analysis of isolated ecosystems, towards an understanding of how multiple ecosystems co-evolve, compete, and collaborate (Davis, 2016).

In the context of open innovation, managing partnerships between ecosystems requires not only coordination but also the deliberate creation of relationships (Usman & Vanhaverbeke, 2017). This involves identifying potential complementarities, aligning governance structures, and ensuring that the institutional, cultural, and technological contexts are conducive to collaboration. Yet, existing literature offers little guidance on the heuristics or tools needed to initiate and sustain such partnerships across national and institutional boundaries. Addressing this gap is particularly important for policymakers and innovation managers tasked with orchestrating collective action to address complex societal and technological challenges.

While IEs provide a powerful framework for understanding collaborative value creation in innovation-driven contexts, they are not the only ecosystem construct to have gained prominence in the past two decades. In parallel, the concept of EE has emerged from the fields of regional development, entrepreneurship, and economic geography, attracting increasing attention from policymakers, investors, and scholars (Ozkan et al., 2023; Tsujimoto et al., 2018). In particular, EEs are generally defined as multifaceted structures that generate entrepreneurial outputs through the interaction of financial, knowledge, institutional, social, and technological components (Audretsch et al., 2019; Nicotra et al., 2018; Spigel, 2017; Van de Ven, 1993). Unlike IEs, which are often orchestrated by a focal firm or platform with a specific innovation agenda, EEs are more commonly associated with geographically bounded environments where entrepreneurship flourishes as a result of a favorable mix of local resources, supportive institutions, and a vibrant entrepreneurial culture. Their dynamics are shaped by historical regional trajectories, path dependencies, and the cumulative effects of prior entrepreneurial activity (Acs et al., 2017; Cloutier & Messeghem, 2021; Molla & Biru, 2023). Although these distinctions are useful for analytical purposes, in practice the boundary between IEs and EEs is far from clear-cut. Many IEs rely on the entrepreneurial dynamism generated within EEs to supply new ventures, ideas, and capabilities. Conversely, many EEs are embedded in broader IEs that provide access to technologies, markets, and global networks. The two systems, while conceptually distinct, frequently overlap, intertwine, and co-evolve (Scaringella & Radziwon, 2018; L. D. Thomas et al., 2018; Xu & Maas, 2019).

This interdependence can be captured through the concept of *nestedness*. Borrowed from ecology, nestedness refers to a structural relationship in which the set of elements in a smaller or less complex system is a strict subset of those in a larger or more complex one, without substitution of elements (Baselga, 2012). Translated into the context of innovation and entrepreneurship, nestedness describes situations where an EE may exist as a subsystem within an IE, or an IE may function as part of a broader EE (Gomes et al., 2018; Guerrero & Martínez-Chávez, 2020). This relationship is not static: nestedness can evolve over time as ecosystems expand, contract, or reconfigure in response to technological change, market dynamics, and policy interventions(Spigel, 2022).

Viewing EEs and IEs through the lens of nestedness has important implications. It allows researchers and practitioners to move beyond debates over which construct is "broader" or "more relevant," and instead focus on the functional interdependencies that link them. For example, an EE in a specific city may be nested within a national IE, benefiting from national-level R&D programs, technology transfer infrastructures, and global partnerships. At the same time, that local EE contributes to the vibrancy and adaptability of the national IE by generating start-ups, fostering entrepreneurial talent, and experimenting with new business models.

From a complex systems perspective, both EEs and IEs can be seen as adaptive configurations where diverse actors interact, learn, and evolve over time. Ecosystems are not static networks but dynamic systems whose behavior emerges from key systemic properties such as adaptability, coordination, feedback loops, heterogeneity, non-linearity, and self-organization.

In EEs, self-organization unfolds bottom-up: entrepreneurial communities emerge organically as heterogeneous actors coordinate without a central authority, forming norms, roles, and ties spontaneously. In contrast, IEs are typically orchestrated top-down, with a lead organization aligning resources and actors around shared innovation goals.

Non-linearity and adaptability further differentiate the two. EEs evolve through discontinuous trajectories, co-evolving with local socio-economic contexts and relying on community resilience to absorb shocks and reconfigure ties. IEs, instead, adapt through iterative, feedback-driven innovation cycles guided by strategic roadmaps that ensure systemic continuity while accommodating change.

Feedback loops and path-dependence also play distinct roles. In EEs, feedback reinforces social and structural ties, shaping entrepreneurial outcomes and knowledge flows; in IEs, it is embedded in formal governance and coordination mechanisms that foster collective learning and resource exchange. Path-dependence in EEs reflects regional histories and early events, while in IEs it is more strongly influenced by the orchestrator's strategic vision.

Finally, heterogeneity stabilizes both systems, though with different origins. EEs draw robustness from the diversity of their members—entrepreneurs, investors, institutions—while IEs derive stability from the deliberate integration of complementary actors such as firms, universities, users, and public institutions aligned under a shared innovation agenda.

Today, despite the growing body of literature exploring EEs and IEs separately, relatively little attention has been devoted to their points of intersection, their functional interdependencies, and the systemic implications of their nestedness (Scaringella & Radziwon, 2018; L. D. Thomas et al., 2018; Xu & Maas, 2019). Much of the existing research focuses on single-ecosystem analyses, often isolating their boundaries and treating them as independent units of analysis. While this approach has been instrumental in establishing conceptual clarity, it overlooks the reality that innovation increasingly unfolds across overlapping and interacting ecosystems, where resources, actors, and governance structures are shared (Guerrero et al., 2020; Vasudeva et al., 2020).

Furthermore, the dominant analytical frameworks in the field tend to privilege structural descriptions over dynamic and functional perspectives. Studies frequently map the composition of ecosystems—identifying actors, roles, and connections—but less often do they investigate how systemic properties such as adaptability, self-organization, and feedback loops manifest across ecosystem boundaries (Cobben et al., 2022; Ritala & Gustafsson, 2018; Russell & Smorodinskaya, 2018). As a result, the mechanisms by which nested configurations influence innovation performance, resilience, and long-term sustainability remain underexplored.

This gap is particularly pronounced in contexts characterized by rapid technological change, globalization of innovation networks, and the proliferation of digital platforms (Modgil et al., 2022; Nambisan, 2017; Secundo et al., 2021). In such environments, cross-ecosystem collaborations are not only more frequent but also more strategically critical. Yet, the literature provides limited conceptual and operational guidance on how these collaborations emerge, how they are governed, and how they affect systemic properties at both the embedded and embedding levels (Gomes et al., 2018; Usman & Vanhaverbeke, 2017).

Another critical limitation lies in the lack of integrative methodologies for assessing nestedness. While the concept has been successfully applied in ecological and network sciences (Baselga, 2012;

Christensen & Rosenbloom, 1995), its adaptation to innovation and entrepreneurship studies has been largely theoretical, with few attempts to develop empirical tools or metrics capable of capturing multi-level interactions (Cobben et al., 2022; Rabelo Neto et al., 2024). This methodological shortfall hampers the ability to compare nested configurations systematically, identify best practices for governance, and measure their impact on innovation outcomes.

Addressing these gaps is not only an academic necessity but also a practical imperative. Policymakers, innovation managers, and ecosystem orchestrators face mounting pressure to design governance models that are adaptive, inclusive, and capable of leveraging synergies across systems (Adner, 2016; Autio et al., 2014). Without a clear understanding of how nestedness shapes systemic properties, strategic interventions risk being misaligned with the complex realities of multi-level ecosystem interactions.

Building on these motivations, the thesis is organized as follows.

The first chapter explores the creation and management of partnerships between IEs across national and international boundaries, addressing a critical gap in both the theoretical and operational literature. While prior studies have examined the internal structure and governance of ecosystems (Adner, 2006; Autio et al., 2014; Granstrand & Holgersson, 2020)), limited attention has been paid to how distinct IEs interact with one another, exchange resources, and form enduring strategic alliances across institutional and territorial boundaries (Vasudeva et al., 2020). This work responds to that gap by introducing the concept of Interconnected Innovation Ecosystems (IIEs), defined as dynamic configurations of multiple, distinct but interdependent IEs linked through flows of knowledge, resources, capabilities, and relational trust (European Commission, 2024). The research develops a partner selection tool grounded in a dual-phase methodology. In the first phase, a systematic review of academic literature on IEs (Adner & Kapoor, 2009; H. Chesbrough et al., 2014)is combined with a practice review of grey literature and field-based sources (Ajayi, 2025; Bocken et al., 2014), resulting in ten preliminary principles for assessing potential partners. These principles capture a balance between academic rigor and practitioner relevance. In the second phase, a design research approach (Romme & Reymen, 2018) is applied in collaboration with FS Group, a major player in Italy's mobility and infrastructure sector, through co-design workshops with five domain experts in innovation management, IP governance, and strategic partnerships. This process leads to the refinement of the principles into five final, practitioner-friendly dimensions: Partners' Maturity, Collaboration Readiness, Value Co-Creation, IP Management, and International Network. The tool is then applied to evaluate 75 IEs in ten countries, with statistical analysis confirming high inter-rater reliability and internal consistency for most dimensions, while revealing interpretive challenges in IP-related assessments across diverse cultural contexts (Grimaldi et al., 2021; Leten et al., 2013). The chapter advances theory by reframing IP as a relational asset central to ecosystem collaboration and by providing one of the first empirically validated, scalable tools for partner selection across IEs. Practically, it equips policymakers, innovation managers, and orchestrators with a structured, evidence-based framework for ecosystem matchmaking, enabling more effective portfolio composition, benchmarking, and cross-ecosystem strategic alignment.

The second chapter examines the intersection of EEs and IEs through the analytical lens of complex systems theory, seeking to clarify how the two constructs interact, overlap, and become nested within each other. While EEs are often framed as self-organizing, bottom-up systems driven by regional entrepreneurial activity (Audretsch et al., 2019; Isenberg, 2011) and IEs are depicted as orchestrated, top-down networks coordinated toward shared innovation goals (Adner, 2016; Cobben & Roijakkers, 2019), the reality is far more intertwined. Building on a scoping review of 48 peer-reviewed studies published between 2005 and 2025, this chapter identifies four distinct nested configurations: startup ecosystems, entrepreneurial university ecosystems, entrepreneurial innovation ecosystems, and regional innovation ecosystems. These configurations are mapped along two analytical dimensions: the dominant orientation—whether entrepreneurial or innovation-driven—and the prevailing form of complexity—emerging bottom-up from local interactions or cascading top-down from orchestrated coordination (Han et al., 2021; Wurth et al., 2022). The analysis traces how key complex system properties manifest differently across configurations: self-organization, non-linearity and co-evolution, adaptability and resilience, feedback loops, sensitivity to initial conditions, and heterogeneity. By conceptualizing nestedness not as a static structural embedding but as a dynamic, functional relationship shaped by flows of resources, governance logics, and systemic properties, the chapter advances the theoretical integration of EE and IE research. The resulting typology provides actionable guidance for policymakers and ecosystem orchestrators in designing governance models aligned with the intrinsic logic of each nested configuration, fostering adaptive strategies for regional and sectoral ecosystem development.

The third chapter extends the analytical trajectory of the thesis by moving from the relational and theoretical investigation of ecosystem configurations (developed in the first and second chapters) to an empirical assessment of their regional and systemic dynamics. Specifically, it explores how Science and Technology Parks (STPs) contribute to the development of regional EEs, focusing on the role of global networks as enabling infrastructures for cross-regional collaboration and knowledge diffusion. While the first chapter addressed the creation and management of interconnections across distinct innovation ecosystems (IIEs), and the second conceptualized the nestedness between EEs and IEs through the lens of complex systems theory, this chapter operationalizes these ideas by examining how network connectivity—in this case, among STPs—affects the adaptive capacity and structural evolution of regional ecosystems.

To this end, the study analyzes how participation in the International Association of Science Parks and Areas of Innovation (IASP), the largest global STP network, influences key EE dimensions over time. Drawing on a longitudinal dataset covering multiple European regions, the analysis employs a non-parametric generalization of the difference-in-differences estimator for time-series cross-sectional data (Imai et al., 2023), assessing the causal impact of joining IASP on two critical EE dimensions: intermediary services and knowledge (Leendertse et al., 2021; Stam, 2015). Results demonstrate that network participation significantly strengthens the intermediary function of regional ecosystems—enhancing talent attraction, knowledge spillovers, and cross-border collaboration—while the knowledge dimension reveals more heterogeneous effects, shaped by contextual and institutional differences across regions.

By linking the macro-regional evolution of EEs to the networked orchestration mechanisms discussed in earlier chapters, this study reinforces the view of ecosystems as interdependent, adaptive, and evolving systems. Theoretically, it bridges the STP and EE literatures, reframing STPs as intermediary orchestrators that operate at the intersection of policy, territory, and innovation. Practically, it provides actionable insights for policymakers and STP managers, underscoring the importance of fostering both the establishment of parks and their integration into global networks to enhance regional resilience, innovation capacity, and long-term competitiveness.

Chapter 1

A Tool for Partner Selection for Innovation Ecosystems in National and International Settings

Abstract

This paper presents a novel tool for assessing potential partnerships between Innovation Ecosystems (IEs) in both national and international contexts, addressing the growing need for frameworks that support the creation of Interconnected Innovation Ecosystems (IIEs). Developed through a combination of literature and practice review and a design research approach, the tool was co-created with practitioners from FS Group and tested by two researchers from different companies within the ROAD IE, evaluating 75 IEs across 10 countries. The study identifies and operationalizes five key principles—partners' maturity, collaboration readiness, value co-creation, intellectual property management, and international network—providing both theoretical insights into IE subtypes and a practical pre-assessment instrument for decision-makers. By introducing the concept of IIEs and fostering alignment between academic and practitioner perspectives, the research advances industry–university collaboration and offers a theoretically grounded yet operational method to guide partner selection, strengthen cross-boundary cooperation, and enable sustainable innovation in diverse contexts.

Keywords: innovation ecosystem, interconnected innovation ecosystem, partner selection, design research, IP management

1.1 Introduction

The idea of an ecosystem has grown beyond its biological origins, becoming a powerful metaphor to describe complex networks of organizations in different fields, including business, innovation, and entrepreneurship. In management studies, the epicenter of the ecosystems' research proliferation originated with the concept of business ecosystem introduced by Moore (1993) led to a significant abundance of research in related fields. The main assumption of his work recognized the increasing need for companies to be seen as members of a business, rather than a part of a single industry. Building on this foundation, Adner (2006) introduced the concept of the innovation ecosystem (IE), describing it as a collaborative arrangement where firms combine their offerings into coherent, customer-facing solutions. Analyzed through the innovation lens, the ecosystem perspective catalyzed the process that overcame the traditional research and development paradigm in favor of the open innovation (OI) construct promoted by H. W. Chesbrough (2003). In this vein, the incumbent need for corporations to externally find new solutions to address complex problems in dynamic environments contributed to the rise and evolution of IEs, fostering an open innovation culture (Nestle et al., 2019). These transformations have compelled organizations from all over the world to involve a broad series of participants, demanding changes not confined to the supply networks (Adner & Kapoor, 2009).

Today, there is wide consensus that IEs have become integral to economic development, acting as a hub for technological advancement and innovation (Granstrand & Holgersson, 2020). This recognition has sparked debate over the key components and characteristics of IEs, starting from the notion that describes ecosystems as organisms generally characterized by the simultaneous presence of complementarities and interdependencies between actors (Kapoor, 2018). More specifically, IEs are understood as networks of interconnected organizations linked to a focal firm or platform, incorporating both production and use-side participants to create and appropriate new value through innovation (Arena et al., 2021; Autio et al., 2014; Lin, 2018). Consequently, a great effort from several scholars was exerted in adopting a comprehensive view of those networks both within and outside their corporate boundaries. Indeed, researchers have identified IEs as critical enablers for harnessing external partners to create value, aligning with open innovation strategies (Bogers et al., 2016; Vanhaverbeke & Cloodt, 2006; West et al., 2014). Research in this domain has primarily focused on IE configurations (Adner & Kapoor, 2009; Hannah & Eisenhardt, 2018; Jacobides et al., 2018; Piantoni et al., 2023), their suitability for pursuing OI strategies (H. Chesbrough et al., 2014), and the evolving dynamics of collaboration, competition, and coopetition among diverse ecosystem actors (Bacon et al., 2020; Jiang et al., 2020; Smorodinskaya et al., 2017). These interactions are often analyzed through technological, economic, and cognitive lenses, with particular attention to the roles of big companies and start-ups (Primario et al., 2024; L. D. Thomas et al., 2018). While a vast body of research has explored innovation dynamics beyond the firm's boundaries—particularly within individual IEs—surprisingly little attention has been paid to how ecosystems interact with each other (Vasudeva et al., 2020). Yet, in a world where innovation increasingly emerges from cross-ecosystem interdependencies, understanding these inter-ecosystem dynamics is no longer peripheral—it is essential. In this vein, as Davis (2016) notes, the growing complexity of innovation landscapes calls for analytical frameworks that move beyond isolated ecosystem analysis and instead examine how ecosystems co-evolve, compete, and collaborate. Despite this theoretical shift, we still lack conceptual and operational tools to investigate how such interactions are initiated and managed across national and institutional boundaries, and more specifically between IEs (Dias SantÁna et al., 2020). Indeed, existing approaches such as ecosystem orchestration and platform complementor assessment provide important insights into how focal actors coordinate and manage relationships within or around a single ecosystem. In this sense, these processes reflect network-centric innovation, centered on how partners coordinate and align their activities (Nambisan, 2017). However, while orchestration describes how IEs internally and externally govern partner collaboration, it does not address how entire ecosystems interact with each other across institutional and geographic boundaries (Autio & Thomas, 2021). This is further reinforced in the platform complementor literature, which typically focuses on bilateral relations between platform owners and complementors rather than on interactions at the ecosystem-to-ecosystem level (Falcke et al., 2023). This gap is particularly significant in the context of open innovation, where managing and supporting networks of external partners is central to value creation (Usman & Vanhaverbeke, 2017). As Gomes et al. (2018) emphasize, managing partnerships also means creating them—yet current literature offers little guidance on the heuristics or tools needed to support this process across multiple ecosystems and geographies.

For these reasons, our research question is as follows: *"What tools can support the creation and management of partnerships between innovation ecosystems at national and international levels?"*

To explore our research question, we adopted a two-phase methodology that combined a literature and practice review with a design research (DR) approach. In the first phase, we identified a set of ten preliminary principles by synthesizing academic literature on IEs and analyzing grey literature and practice-based sources. This dual review allowed us to bridge the gap between theoretical abstraction and practical application, ensuring that the resulting criteria reflected both academic rigor and field relevance. In the second phase, these principles were translated into a tool through a series of co-design workshops with five professionals from FS Group, a leading company in Italy's mobility and infrastructure sector. The principles were then refined by merging overlapping constructs and selecting only those intelligible to both researchers and practitioners into five core dimensions: Partners' Maturity, Collaboration Readiness, Value Co-Creation, IP Management, and International Network.

Once developed, the tool was applied by two independent researchers to assess 75 IEs across ten countries. This empirical phase allowed us to evaluate the tool's reliability using three complementary statistical techniques: Pearson correlation, Cronbach's alpha, and ICC (2,1), which confirmed strong inter-rater reliability and internal consistency for four of the five principles. Notably, the IP Management dimension revealed interpretive variability, highlighting the inherent complexity of assessing intangible assets across heterogeneous ecosystems and cultural contexts. These findings confirm the need for more context-sensitive assessment frameworks in ecosystem research. This study contributes to the literature on IEs in several ways. First, it addresses the call for tools capable of supporting cross-ecosystem collaboration, moving beyond isolated ecosystem analyses to account for emerging forms of interconnected innovation ecosystems. By operationalizing five principles, our work provides a heuristic for evaluating IEs and mapping strategic complementarities across national and international contexts. Second, we extend the literature on IP management in OI environments by reframing IP as a strategic and relational asset within IEs. Rather than treating it merely as a legal protection mechanism, we show how IP practices shape collaboration,

trust, and value co-creation, aligning with recent work on collaborative IP strategies and ecosystem orchestration (Grimaldi et al., 2021; Leten et al., 2013; Reis et al., 2022).
From a practical standpoint, the tool offers innovation managers and policymakers a structured pre-assessment framework to support partner selection, internal benchmarking, and strategic alignment. It enables the identification of IEs with high potential for international collaboration, informs the composition of innovation portfolios, and supports evidence-based decisions in contexts where partnerships are key to addressing complex societal and technological challenges. Moreover, by offering a comparative lens on different types and maturities of IEs, the tool fosters transparency, standardization, and more inclusive governance practices, particularly relevant for nascent or underdeveloped ecosystems seeking to integrate into broader innovation networks.

The remainder of the paper is as follows: Section 1.2 introduces the conceptual background and defines the main theoretical constructs. Section 1.3 presents the methodological approach, including the design research process and reliability assessment. Section 1.4 discusses the results of the tool testing, offering insights into each of the five principles. Section 1.5 discusses the general findings, theoretical and practical contributions, limitations, and future research directions. Section 1.6 provides the conclusions.

1.2 Conceptual background

1.2.1 Innovation ecosystem types

The widespread adoption of the ecosystem concept has led to conceptual ambiguity. Starting from the business ecosystem, three different archetypes emerged (Scaringella & Radziwon, 2018): IEs (Adner, 2006; Adner & Kapoor, 2009), knowledge ecosystems (Clarysse et al., 2014; van der Borgh et al., 2012), and entrepreneurial ecosystems (Isenberg, 2011). Like a Hydra, the continuous fragmentation of these research streams led to new combinations of ecosystem definitions and characteristics, which are sometimes blurred and difficult to analyze both from a theoretical and practical perspective due to a lack of clarity and general consensus (Cobben et al., 2022; Gupta et al., 2019). Starting from the IE construct, new declinations of these organisms emerged, such as digital IEs (Ma et al., 2024; Rao & Jimenez, 2011), which model interactions and relationships between organizations and stakeholders using digital technologies to create value (Suseno et al., 2018); platform-based ecosystems (Gawer, 2014); hub ecosystems (Nambisan & Baron, 2013); and open IEs (H. Chesbrough et al., 2014). Furthermore, entrepreneurial IEs are sometimes considered a subtype of IEs (Gomes et al., 2018), combining network elements that are typical components of the entrepreneurial ecosystem area (Ancona et al., 2023; Guerrero et al., 2024; Stam & Van de Ven, 2021). Other emerging subtypes include artificial intelligence IEs (Secundo et al., 2024), which reflect a technological focus, and social IEs (Audretsch et al., 2021), emphasizing societal value creation. Analyzed from a territorial perspective, regional IEs are considered an area of growing interest (Viitanen, 2016), where universities seem to act as catalysts of regional development (Reichert, 2019; L. D. W. Thomas & Ritala, 2022). To avoid conceptual ambiguities, we strongly rely on the definition proposed by (Granstrand & Holgersson, 2020, p. 1), who conceptualize IEs as the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors. This framework encompasses actors with or without a focal firm, integrating resources, institutions, and policymaking entities at local, regional, and national levels (European Parliament and Council of the European Union, 2021).

From a theoretical standpoint, this work draws on orchestration and network centric perspectives, which emphasize the coordination of distributed capabilities, the alignment of heterogeneous actors, and the governance mechanisms that enable value co-creation across organisational boundaries (Autio & Thomas, 2021; Nambisan & Sawhney, 2011). These views highlight that effective ecosystem functioning depends not only on the maturity and internal structure of participating actors, but also on their readiness to establish strategic partnerships, their ability to generate mutual value, the robustness of their knowledge governance, and their degree of embeddedness within wider innovation networks. Despite growing interest from both academics and practitioners, and despite its theoretical foundations, significant gaps remain in investigating the dynamics between identical and different types of IEs (Vasudeva et al., 2020). This gap becomes particularly salient when considering the additional layers of complexity involved in cross-boundary alignment. Within this process, asymmetric information makes the establishment and governance of such collaborations especially challenging, as complementors often differ in their technological maturity, institutional constraints, and access to strategic knowledge (Mantovani & Ruiz-Aliseda, 2016). These tensions are especially pronounced in IP management, as the need for shared innovation creation coexists with pressures to appropriate and protect value (Genin et al., 2021; Granstrand & Holgersson, 2014). Indeed, the ability to manage uncertainty becomes a decisive factor in explaining why some ecosystems succeed in fostering radical innovation and building enduring collaborative partnerships (Gomes et al., 2022). In the context of partnership selection, it is important to distinguish between antecedents of selection which refer to the factors influencing the choice and initiation of potential partners, and predictors of post-selection performance, which refer to the conditions that help anticipate or explain the effectiveness of the collaboration once it has been established. For example, technological or strategic complementarity may act as an antecedent guiding the initial partner choice (Mantovani & Ruiz-Aliseda, 2016) whereas the degree of trust development or knowledge integration capability may serve as a predictor of post-selection performance, indicating how well the partnership is likely to perform over time (Cobben & Roijakkers, 2019). The innovation management literature has proposed several tools for partnership selection, but these instruments are frequently validated only at the national level, limiting their relevance in multi-scalar or cross-border ecosystem settings (Guertler & Lindemann, 2016). Likewise, existing scholarly contributions offer the "Ecosystem Pie model", a tool that captures how actors within an IE interact in creating and capturing value, yet these approaches remain largely confined to intra-ecosystem dynamics and do not examine how such interactions unfold across ecosystems (Talmar et al., 2020).

1.2.2 Interconnected innovation ecosystems and strategic partnerships

IEs can be studied at different spatial levels (e.g., local, regional, national, international). Local IEs have been explored by Haukipuro et al. (2023), offering guidelines for creating hubs that provide added value for multiple stakeholders, while regional IEs research has gained more attention. One the one hand, similarly to IEs, they have been analyzed under the lens of value creation and value capture (Radziwon et al., 2017) but on the other hand it has not yet adequately addressed how and under what conditions actors begin cooperation (Shakiba & Belitski, 2024). Conversely, despite prior studies having focused on measuring both the efficiency and key characteristics of national IEs (Prokop, 2021) there is still a growing need to gain a better understanding of the environment (Ghazinoory et al., 2023). Still unexplored is the international IEs notion, where the only significant contribution analyzes the role of intermediaries in the construction of such organisms Chen et al. (2024). Similarly, maturity models have often been conceptualized at the national level, focusing on country-wide innovation capacity and systemic readiness, but offering limited insights into how maturity manifests and evolves across more granular ecosystem layers (Bittencourt et al., 2021). Challenges in this contexts are inherently complex and systemic and require collaborative solutions that involve diverse actors and territories, as they cannot be addressed in isolation. A recent article from the European Commission (2024) recalls an urgent need to adopt a systemic approach that is inclusive, collaborative and involves diverse actors, institutions, and places, maximizing the value of innovation for all and ensuring equitable diffusion of its benefits. In this vein, IE networks are often treated in the literature as groups of actors collaborating across related ecosystems, but typically within a single national or sectoral scope (Wang et al., 2023; R. Zhang et al., 2023). While the notion of meta-ecosystems emphasizes the relationships between two or more distinct, mainly non-competing ecosystems, it does not clarify the institutional or spatial level at which these interactions take place (Palmié et al., 2022). This is typically reinforced in the platform complementor literature, which focuses on bilateral relations between platform owners and complementors rather than on interactions at the ecosystem-to-ecosystem level (Falcke et al., 2023).

At the ecosystem level, the nature of collaborations and strategic partnerships (SPs) has been frequently analyzed as public-private (Asplund et al., 2021; Mazzucato & Robinson, 2018; Schiuma & Carlucci, 2018) but also private-private (e.g., between companies and start-ups) as per Corvello, Cimino, and Felicetti (2023). In this vein, the interconnection between IEs in international context remains still unexplored as the existent body of literature linking IE literature with SPs remains limited, often anchored to perspectives on the dynamic interactions within the IE, including cooperation (Song, 2016), collaboration (Su et al., 2018), and coopetition (Bacon et al., 2020). However, there is still room to deepen understanding of the key drivers enabling these interactions to prosper beyond the boundaries of IEs. To this aim, there is an increasing need to incorporate an international perspective in the IE domain to explore regional contextual differences and develop tailored strategies (Rabelo Neto et al., 2024) since cross-sector partnerships within IEs have been studied by Dzhengiz and Patala (2023) but do not address cross-country collaboration. Also, the individualistic perspective that characterized the literature on IEs could benefit from an international openness since participating in numerous partnerships positively impacts knowledge sharing (Caiazza & Stanton, 2016) and, consequently, innovation. Indeed, there is a lack of research examining the key properties and characteristics of international IEs (Pikkarainen et al., 2025). In this context, building on Granstrand and Holgersson (2020) concept, we consider Interconnected Innovation Ecosystems (IIEs) as dynamic and complex configurations of distinct yet interrelated IEs, involving local, regional, national, and international actors, activities, artifacts, institutions, and relationships. These connections, which can be both complementary and competitive, interact to shape and influence each other's innovation performance. IIEs are linked through flows of knowledge, resources, and capabilities, creating evolving interdependencies that shape the boundaries, interactions, and outcomes of innovation across multiple contexts.

1.3 Methodology

Our research methodology is organized in two distinct phases. The first phase focuses on a literature and practice review to derive a set of IE principles. In this context, the general aim of the practice review is to clarify, as much as the current state of knowledge permits, what empirically-derived findings in a given area imply for practice in that and related areas. The second phase employs a DR approach to make the principles useful for practice in the form of a tool. In this phase, we conducted several workshops with five people working within FS Group to further refine the tool. After the creation of the tool, two researchers working for two different companies within the ROAD project, used the tool to conduct a desk-research analysis to assess a panel of IEs.

1.3.1 Literature and Practice Review

The literature and practice review aims to derive a set of principles of IEs. Principles can be considered as solution-oriented guidelines with the specific aim of creating knowledge that can be useful for theoretical and practical application (Romme & Reymen, 2018).

A preliminary search using the keyword "innovationANDecosystem" in Scopus (April 2025) yielded 8,512 English-language publications (articles, reviews, and editorials). To refine the sample, we focused on documents explicitly referring to IEs or their subtypes, with at least 5 citations. This filtering process resulted in 397 documents, from which a final subset of 220 publications was selected based on textual references to principles, definitions, or empirical findings. The practice review complemented the literature review. Often, practice information is ahead of the academic literature and may contain valuable insights for research (Bocken et al., 2014) also because it complements the primary data by integrating them in an easier and more rapid way (Ajayi, 2025). The practice examples were retrieved from internet desk-research (e.g., IEs websites, blogs, and articles) and the grey literature (e.g., business records, practice and institutional reports). Once the data were collected, they were analyzed and discussed among the authors. This led to a series of 10 principles that were discussed among authors (Table 1.1). To ensure conceptual clarity and operational potential, each principle was reformulated into a preliminary item using the logic of "observable indicators". Academic definitions were compared with managerial expressions drawn from practice sources, allowing a first mapping between theoretical constructs and measurable principles. These initial formulations were then discussed in workshops to test interpretability and practical relevance.

Table 1.1: Initial principles by combination of literature and practice review. *Source:* Authors' own work.

Principle	Source
Execution Capacity	Practice Review
Partners' Maturity	Literature Review and Practice Review
Proof of Value	Practice Review
Proof of Concept	Literature Review and Practice Review
Collaboration Readiness	Literature Review
Value Co-creation	Literature Review
Co-development	Literature Review and Practice Review
Startup development	Literature Review
IP Management	Literature and Practice Review
International Network	Literature Review and Practice Review

1.3.2 Tool development and evaluation

In this work we rely on the definition of March (2006) who defines these tools as "technologies of rationality" because they offer models of causal structures, provide spaces for collecting data, and establish decision rules for selecting among alternatives.

In DR, after deriving principles for design from the theory, there is a two-steps procedure that must be followed: 1) translating those principles in concrete design and 2) assessing the design to test whether they work Cobb et al. (2003). Starting from the literature and practice review, we decided to translate those principles in concrete design through a series of workshops conducted with the help of Ferrovie dello Stato Italiane (FS Group). FS group is at the heart of Italy's mobility system and plays a key role in its development with a view to integrating infrastructure and different modes of transport. The main objectives of FS Group include providing certainty regarding the execution of infrastructure works, promoting multimodal collective transport over private transport, increasing rail freight transport, and improving energy autonomy. With over 92,000 employees, FS Group is a leader in passenger and freight rail transport. The railway infrastructure covers more than 17,000 km, over 1,000 km of which are dedicated to High-Speed/High-Capacity services. The FS Group also operates a road network of about 32,000 km. We chose to conduct those workshops within FS groups for three main reasons: 1) a group of 5 people (Table 1.2) employed at FS group was already working on creating a rational selection criterion tool for identifying suitable IEs partners; 2) this group had a strong background in technology domains, with a focus in innovation, IP management and strategic partnerships; 3) and had already begun developing the tool to test it with a pool of prospective partners, meaning their insights could help us refine the initial principles. Indeed, iterated assessments with practitioners was employed because DR protocols require intensive and long-term collaboration involving researchers and practitioners Reeves (2006).

Table 1.2: Roles, expertise, and educational background of participants. *Source:* Authors' own work.

Role in FS group	Expertise	Educational background
Head of innovation	IP and Innovation management	Software Engineering, Computer Science, Business Administration and Management, Open Innovation
IP Management Team Lead	IP and Innovation management	Economics, Business Administration and Management
Innovation & Partnership Team Lead	IP and Innovation management	Environmental & Seismic Engineering, Business Administration and Management
Innovation Specialist	Innovation & Partnerships Agreements	Management Engineering, Data Science
IP management specialist	IP management	Economics

After the workshops with FS Group, we excluded those principles that were similar in terms of assessment (e.g., co-development and value co-creation), and unified those that were complementary (Proof of value and proof of market). In particular, during the discussions, it also became clear that practitioners often use different terms for concepts that in the academic literature are treated as separate. For this reason, we decided to keep only the principles that were meaningful and understandable in both the practical and academic domains, making sure the final version of the tool could work well in real contexts while staying connected to the literature. This led to 5 principles

(Table 1.3). Moreover, through its refinement, the proposed tool was implemented through a five-point Likert scale for revealing general differences (Table A.1, situated in the Appendix A). In this vein, for each principle, it was assigned a value from 1-5. After its development the tool was shared with ENI and other corporate partners within the ROAD innovation district that is a nascent IE in the Italian context. To assess the quality of the principles we decided to improve the tool by testing it with two researchers working on the ROAD project. The two researchers, from different companies, made the assessment operating autonomously and then compared the results. Before data collection, both raters received a short training protocol outlining the interpretation of each principle and scoring anchors, followed by a calibration exercise on ten pilot cases to harmonize understanding. During the assessment phase, researchers worked independently and were instructed to avoid consultation or sharing preliminary scores to minimize shared-method expectations. In this context, DR is particularly suitable for two main reasons: 1) it offers practical lessons that can be directly applied and engages researchers in the direct improvement of those practice (Edelson, 2002); 2) it is constituted within communities of practice that have certain characteristics of innovativeness, responsiveness to evidence, connectivity to basic science, and dedication to continual improvement (Bereiter, 2002).

Table 1.3: Derived principles and proposed tool. *Source:* Authors' own work.

Principle	Description
Partners' Maturity	Scouting for IEs populated by well-established companies with competencies aligned with the strategic areas of interest
Collaboration Readiness	Proximity of innovation development capacity to the market
Value Co-creation	In order to leverage mutual expertise and participate in innovation development initiatives, the establishment of partnership relationships is aimed at generating value in strategically significant markets.
IP Management	Building a portfolio of patents to promote an IP monetization strategy and negotiating with third parties to protect exclusive rights (market, geographic, temporal).
International Network	Every activity is carried out with the global market as a benchmark and is always designed with the possibility of experimenting and leveraging concrete innovation capabilities even beyond national borders.

1.3.3 Tool Testing and Reliability Assessment

In line with the second step of DR methodology, we assessed whether the tool produced consistent and meaningful results when used in practice. A total of 75 IEs have been selected in ten different countries to test the tool on a heterogeneous pool (Table 1.4. Data were collected via desk research combining institutional databases (e.g., European Cluster Observatory), ecosystem websites, corporate reports, and EU-funded project documentation. When available, secondary materials such as press releases and ecosystem strategy documents were used for triangulation. In cases where patent-related information was not available, we reconstructed missing data through the Wayback Machine, which proved particularly useful for retrieving historical technology-related information (Marchesani & Ceci, 2026). Cases were identified through purposeful sampling designed to ensure variation across geographical, institutional, and sectoral contexts, while maintaining comparability for desk-based assessment. Inclusion criteria required that each ecosystem (1) was explicitly recognized in public or institutional sources as an innovation ecosystem or equivalent collaborative initiative; (2) operated within one or more sustainability-related domains—specifically decarbonization, circular economy, and sustainable mobility; and (3) provided sufficient publicly available information (e.g., websites, annual reports, EU project databases, or press releases) to enable consistent scoring of the five assessment principles. The sample reflected a sectoral mix of IEs engaged in diverse sustainability transitions, including cleantech and energy transition hubs, circular manufacturing clusters, urban innovation labs, and mobility and transport networks. To mitigate geographical bias, a soft quota was applied to represent both Northern and Southern European contexts and countries with different levels of maturity

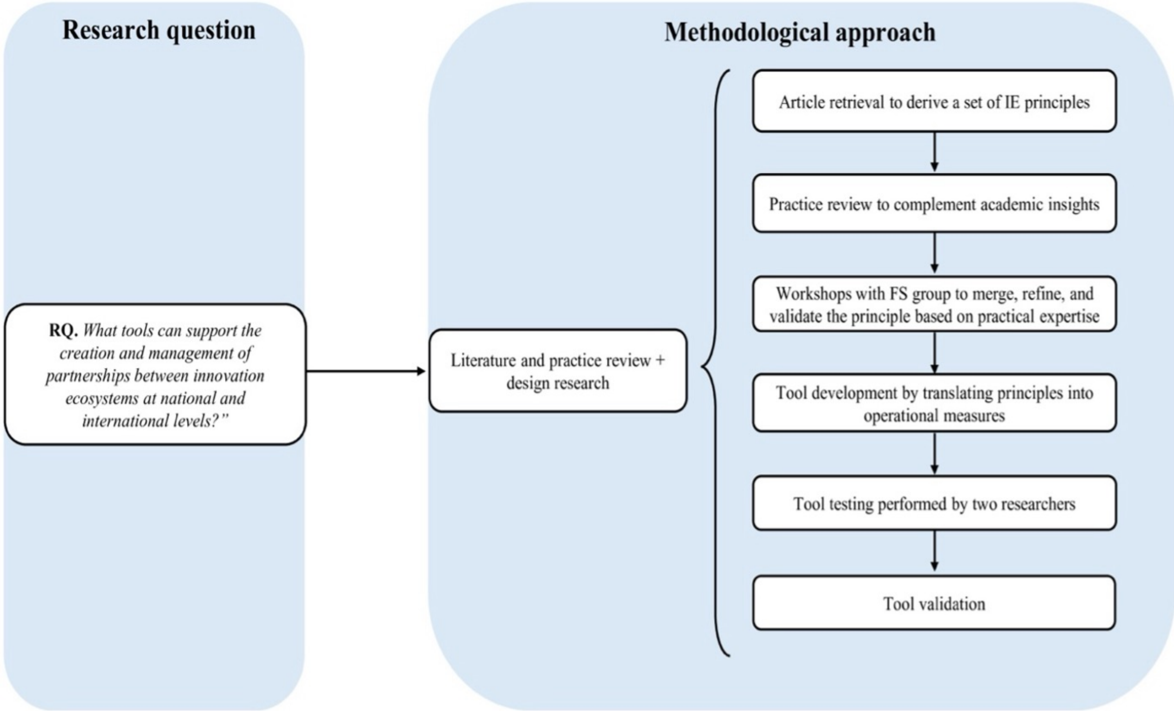
To evaluate the tool's reliability, we employed a triangulated approach using three complementary statistical techniques: Pearson correlation, Cronbach's alpha, and the Intra-Class Correlation Coefficient (ICC 2,1). Pearson correlation was used to measure the strength and direction of the linear association between the scores assigned by different raters (Cohen, 2013). Cronbach's alpha assessed the internal consistency of the items within each principle, ensuring that the items reliably captured the underlying construct (Nunnally, 1978). ICC (2,1), based on a two-way random effects model with absolute agreement, was applied to determine the level of inter-rater agreement, which is especially appropriate when all subjects are rated by the same randomly selected raters (Koo & Li, 2016). In particular, this combination of methods has become increasingly common in innovation management research, where the reliability of tools and assessment scales is often tested through multiple statistical lenses to ensure conceptual clarity and operational robustness (Alegre et al., 2006; Girardi et al., 2005; Widmann & Mulder, 2018).

Table 1.4: Distribution of IEs across countries. *Source:* Authors' own work.

Country	**Number of IEs**
France (FR)	8
Germany (DE)	16
Greece (GR)	5
Italy (IT)	7
Norway (NO)	1
Romania (RO)	3
Spain (ES)	12
Sweden (SE)	1
The Netherlands (NL)	7
United Kingdom (UK)	15
Total	**75**

Figure 1.1 provides an overview of the methodological flow, illustrating the sequential steps from principle derivation to tool development, testing, and validation. In the next section, we will present the principles, and in the conclusion, we will summarize the testing process, highlighting the contributions at both the theoretical and practical levels, as well as the limitations and future research avenues.

Figure 1.1: Overview of the research design and methodological steps; Source: Authors' own elaboration



1.4 Results

In this section, we present the results of the two independent evaluations and assess the reliability of the tool, drawing on the criteria outlined in Table A.1 in the Appendix A. The aim is to illustrate how the tool performs in terms of measurement consistency across evaluators. The general discussion section further interprets these findings, highlighting their theoretical and practical implications. The tool's reliability assessment reveals high inter-rater consistency and internal coherence across four of the five principles, with Partners' Maturity, Collaboration Readiness, Value Co-Creation, and International Network all exceeding thresholds commonly considered as indicators of good-to-excellent agreement (Table 1.5).

Table 1.5: Inter-rater reliability by principle (double-blind assessment). *Source:* Authors' own work.

Principle	**Pearson Correlation**	**Cronbach's Alpha**	**ICC (2,1)**
Partners' Maturity	0.88	0.94	0.88
Collaboration Readiness	0.85	0.92	0.85
Value Co-Creation	0.87	0.93	0.87
IP Management	0.66	0.79	0.79
International Network	0.85	0.92	0.85

To further substantiate its construct validity, we computed inter-item correlations across the five principles (see Table 1.6), and performed a basic sensitivity analysis (see Table 1.7) to test the robustness of results under alternative weighting and threshold scenarios. The detailed coding protocol, examples of scoring anchors, and data sources for the 75 ecosystems are reported in Appendix.

Table 1.6: Inter-item correlation matrix; Source: Authors' own work

Principle	PM	CR	VC	IP	IN
PM	1.00	0.62	0.54	0.41	0.59
CR	0.62	1.00	0.66	0.44	0.63
VC	0.54	0.66	1.00	0.49	0.55
IP	0.41	0.44	0.49	1.00	0.43
IN	0.59	0.63	0.55	0.43	1.00

Correlations ranged from 0.41 to 0.66, indicating moderate associations consistent with convergent validity while avoiding redundancy (all $r < 0.80$). This pattern suggests that the five principles capture related yet distinct constructs, supporting discriminant validity.

Table 1.7: Basic sensitivity analysis; Source: Authors' own work

Principle	Description	Conceptual role	Result
Equal weights	Each principle weighted 0.20	Spearman's ρ	0.93
Reliability-weighted	Weights proportional to Cronbach's α	Spearman's ρ	0.94
±20% stress-test	One principle at +20%, others rescaled (five runs)	Spearman's ρ (range)	0.91–0.96
Lower threshold ($\tau - 0.25$)	Go/No-Go threshold reduced	% same classification	88%
Higher threshold ($\tau + 0.25$)	Go/No-Go threshold increased	% same classification	86%

The sensitivity analysis tests whether conclusions remain consistent under alternative assumptions regarding principle weighting and decision thresholds. Across all weighting scenarios, Spearman correlations between the baseline and adjusted models ranged from 0.91 to 0.96, confirming that relative rankings are highly stable. When varying the "go/no-go" threshold by ±0.25, classifications remained consistent for 86–88% of the ecosystems - meaning that nearly nine out of ten cases would receive the same recommendation even under different cut-off assumptions. This level of stability is generally considered satisfactory for early-stage validation tools, indicating that the scoring logic is not overly sensitive to marginal parameter changes and thus reliable for practical decision-making. Given the exploratory nature of this validation, the sensitivity analysis was intentionally simple, focusing on the stability of results under plausible variations rather than on full model re-specification. Together with the inter-item correlations these findings provide preliminary evidence of convergent/discriminant validity and robustness, strengthening the scientific credibility of the tool beyond inter-rater reliability alone.

1.4.1 Principle-level interpretation

This section illustrates how each of the five principles performed in terms of reliability, interpretability, and empirical differentiation across cases. The discussion provides a qualitative interpretation of each construct and its manifestation within the 75 ecosystems analyzed. For full rating anchors and illustrative examples, see Appendix. The tool's reliability assessment reveals high inter-rater consistency and internal coherence across four of the five principles, with Partners' Maturity, Collaboration Readiness, Value Co-Creation, and International Network all exceeding thresholds commonly considered as indicators of good-to-excellent agreement. In general, a Pearson correlation coefficient (r) above 0.70 suggests strong linear association between raters. A Cronbach's alpha (α) greater than 0.90 is indicative of excellent internal consistency, while an ICC 2,1 above 0.75 reflects good inter-rater reliability and values above 0.90 reflect excellent agreement. The use of these complementary statistics ensures a robust evaluation of the tool's performance. *Partners' Maturity* assesses the structural and strategic sophistication of organizations within the IE. With a Pearson correlation of 0.88, Cronbach's alpha of 0.94, and ICC of 0.88, this principle showed outstanding reliability. According to Cohen (2013), a Pearson coefficient above 0.70 indicates a strong linear relationship between two raters, meaning the scorings were highly aligned in their direction and relative ranking. The Cronbach's alpha value of 0.94 exceeds the 0.90 threshold for excellent internal consistency, as defined by Nunnally (1978), suggesting that both raters relied on coherent and consistent criteria when applying the scale. Similarly, the ICC (2,1) value of 0.88 falls within the range of 0.75 to 0.90, indicating good agreement (Koo & Li, 2016). These statistical values confirm that the Partners' Maturity construct is both stable and interpretable across evaluators. Raters consistently distinguished between less mature or informal actors (score 1–2) such as early stage start-up accelerators that are usually confined to regional or domesting networks limiting their global influence (Frimanslund & Nath, 2022) and highly structured, strategically aligned organizations (score 5). Entities positioned in the mid-range (score 3) reflected occasional alignment with innovation domains and moderate resource availability as well as the presence of university-industry collaborations. This seems to be consistent with Mercan and Goktas (2011) who emphasizes how the strength of university-industry collaboration is a key dimension of IEs.

Collaboration Readiness captures a partner's capability to co-develop innovation and deliver market-relevant outcomes. Statistically, the principle is highly reliable (r = 0.85, α = 0.92, ICC = 0.85). A Pearson correlation of 0.85 indicates strong alignment between raters, suggesting they consistently evaluated partners in terms of their collaborative capacity. The Cronbach's alpha value of 0.92 surpasses the threshold of 0.90, indicating excellent internal consistency meaning that the two evaluators applied the assessment criteria in a coherent and repeatable manner. The ICC (2,1) score of 0.85 confirms good agreement between raters, supporting the conclusion that Collaboration Readiness is a well-defined and observable construct. IEs scoring at the lower end had no formal collaboration mechanisms; mid-range scores (3) reflected some defined procedures and growing engagement. This could be the case when considering the transfer of early stage technologies (Calza et al., 2020). The highest assessment (4-5) is given to organizations with a strong history of coordinating cross-industry projects (Dzhengiz & Patala, 2023) particularly those that have experience with managing funding and partnerships at a large scale. This principle is essential for assessing the credibility and readiness of potential partners to drive meaningful, co-developed innovation that can result in successful market outcomes and it is based on historical data that are usually available on IEs websites (or on organization websites, belonging to the focal IE). Indeed, in the literature of IEs, the typical criteria for selecting partners are an ongoing, well-established relationship; competence to fulfill respective needs; unique technologies and solutions; cultural fit and similar values, and R&D's proven capabilities and track record (Traitler et al., 2011).

Value Co-Creation measures mutual engagement and strategic value generation in joint innovation. High reliability scores (r = 0.87, α = 0.93, ICC = 0.87) support the robustness of this principle. A Pearson coefficient of 0.87 demonstrates a strong linear relationship between the two raters' as-

sessments. The Cronbach's alpha of 0.93 again exceeds the 0.90 threshold for excellent internal consistency, reinforcing the reliability of the scoring scale. An ICC of 0.87 indicates good agreement between raters, highlighting the consistency in identifying structured collaboration and shared value creation. At the lowest level (1-2), this involves merely participating in discussions, such as through an active role in strategic committees that define investment allocation criteria toward specific areas of interest, without guarantees of further involvement or prioritization. Slightly more advanced approaches (2-3) include joint definition of Proofs of Concept (POC) programs. POC programs are designed to increase the readiness level of early-stage research-based inventions and, therefore, their attractiveness to external factors such as firms (or group of firms) and investors (Battaglia et al., 2021). Indeed, POC programs can contribute to developing dynamic capabilities in public research organizations (Tolin & Piccaluga, 2024) while POC Centers can have potentially very relevant impact in the technology commercialization process in regional ecosystem (Maia & Claro, 2012). At a mid-level (3-4), prospective partners demonstrate openness to more robust models, such as offering the right of first refusal for the commercial exploitation of emerging IP or collaborating on Proofs of Manufacturing (POM). At the highest levels (4-5), value co-creation is supported by predefined governance frameworks, contractual models, and a willingness to engage in fully customized intermediation upon request. This principle can be extended to digital IEs as physical proximity alone is not sufficient to grant shared value creation (Piantoni et al., 2023).
IP Management within IEs involves the strategic protection, and exploitation of intellectual assets while IP models can be used for the orchestration of IEs (Leten et al., 2013). In this vein, IP management strategies ensure that innovative ideas and inventions are safeguarded and properly utilized to advance technological progress and economic growth. To this aim, in OI contexts, it is crucial to assess IP strategies given that firms with collaborative IP strategies usually outperform those with defensive strategies (Grimaldi et al., 2021). In our case it is the dimension with the lowest reliability in this analysis, with r = 0.66, $\alpha = 0.79$, and ICC = 0.79. While a Pearson correlation of 0.66 still reflects a moderate relationship, it falls below the preferred threshold for strong alignment (Cohen, 2013). The Cronbach's alpha value of 0.79 is at the lower end of acceptability for internal consistency (Nunnally, 1978), indicating that raters may have interpreted the criteria differently. The ICC score of 0.79, although still within the 'good' reliability range (Koo & Li, 2016), confirms this moderate level of agreement. At lower scores, raters identified a lack of IP strategy or ad-hoc practices; at mid-levels, rights negotiation mechanisms such as right of first refusal were evident; and at high levels (score 5), the presence of monetization strategies, legal enforcement, and global IP portfolios was noted. Disagreements between scores 3 and 4 reflected uncertainty about what constitutes operational versus advanced IP frameworks. Given the multidimensional nature of IP and the sensitivity of related data, this principle may benefit from sub-dimensions and clearer operational guidance.
International Network evaluates the extent to which a partner is globally embedded in IEs. With r = 0.85, $\alpha = 0.92$, and ICC = 0.85, this principle demonstrates strong alignment between raters. A Pearson coefficient of 0.85 indicates a high degree of correlation in scoring. The Cronbach's alpha of 0.92 confirms excellent internal consistency (Nunnally, 1978), and the ICC of 0.85 supports a good level of inter-rater reliability (Koo & Li, 2016). Score 1 indicates entirely local operations; 2–3 mark transitional levels involving short-term international projects or moderate network engagement; 4–5 reflect long-term participation in cross-border platforms, leadership in international

consortia, and innovation export capabilities. This indicator intersects with Partners' Maturity but adds the dimension of geographic scope and international legitimacy. Minor discrepancies in scoring reflect subjectivity in evaluating depth versus breadth of global involvement but overall validate the indicator's clarity and applicability. In particular, this principle emphasizes the extent to which a partner is globally embedded within interconnected IEs, while also highlighting the spatial scale of its involvement—be it local, regional, national, or international—thus acknowledging the multi-layered nature of innovation dynamics (Chen et al., 2024; Haukipuro et al., 2023; Prokop, 2021; Shakiba & Belitski, 2024).

1.4.2 Illustrative examples

To illustrate how the tool informs collaboration decisions in practice, we present two anonymized cases. Their identities cannot be disclosed due to confidentiality constraints and the risk of inadvertently revealing strategic information. The emphasis is therefore not on the actors themselves, but on how the tool enabled the interpretation of their profiles and the activation of coherent and purposeful collaboration pathways. In the first case, the archived assessment of a Northern European IE revealed a score pattern of 2-4-5-2-4 across the five principles (Partners' Maturity; Collaboration Readiness; Value Co-Creation; IP Management; International Network). This combination immediately communicated a clear message to the team: the ecosystem was structurally immature and only minimally formalized in its IP practices (both scores of 2), yet it possessed substantial operational dynamism, documented co-innovation capability, and strong connectivity across international networks (with scores of 4, 5, and 4). In other words, it was not uniformly strong nor uniformly weak; rather, it embodied a highly specific configuration. The low maturity score indicated limited structure and unclear strategic positioning, but the high co-creation score signaled deep mutual engagement potential. The discrepancy between these dimensions was not a contradiction but a pattern - the tool's architecture allowed the team to see it immediately. This pattern became meaningful when strategic priorities shifted. The ROAD ecosystem required a partner capable of supporting rapid experimentation, iterative prototyping, and fluid knowledge exchange in an emerging domain. In this context, the high Collaboration Readiness (4) and Value Co-Creation (5) became decisive, outweighing concerns linked to maturity and IP governance. The international network score (4) further reinforced the sense of alignment: an IE deeply connected abroad could accelerate learning and import insights from parallel projects. By reading the profile through this lens, the team identified the perfect characteristics for the moment: agility, openness, and relational density supported by sufficient international exposure. The collaboration was activated through short-cycle engagements, weekly technical exchanges, and fast-track integration of prototypes. Within a short timeframe, the partnership generated tangible outputs: shared experimentation spaces, an early demonstrator, rapid technical validation, and a mutual learning loop that strengthened both parties' innovation capacity. The tool did not merely identify a promising IE; it enabled recognition of why this partner was suitable and where the suitability resided. In the second case, the archived assessment showed a markedly different pattern: 5-3-4-5-2. Here, the IE was extremely mature and strongly governed (both maturity and IP management at level 5), with good co-creation capability (4), but only moderate readiness for structured collaboration (3) and very limited international scope (2). This configuration communicated something very different from the first case. The high maturity and strong IP handling indicated robust internal organization and clear, well-structured processes. The moderate collaboration readiness indicated partial openness and some procedural friction. The low international network score signaled that the ecosystem primarily operated within national boundaries, with limited engagement beyond them. Whereas the first ecosystem was dynamic but less mature, this one was structured but inward-looking. Initially, the senior team had perceived this ecosystem as highly promising due to a strong interpersonal impression formed during an international conference. Only upon revisiting the stored score profile did the team realize the structural misalignment with the collaboration initially envisioned. The conference context had amplified the ecosystem's maturity and governance messaging, but obscured its lack of international exposure and moderate readiness for co-innovation. The tool revealed this asymmetry immediately: the numbers communicated it even before the discussion began. Rather than abandoning the opportunity altogether, the team used this understanding to reposition the ecosystem. Its strengths - maturity and rigorous IP systems - were ideal for long-term capability building, standardization, methodology development, and cross-project stabilization. Its weaknesses - limited network amplitude and moderate readiness - became irrelevant in this new framing. By shifting the collaboration stream, the organization was able to activate a partnership that capitalized on what the ecosystem could genuinely offer. Over the following months, the collaboration produced a shared documentation framework, structured workflows, improved alignment of governance practices, and a replicable standard for future cross-ecosystem engagements. Similarly, the tool helped match the ecosystem to the activity domain in which its characteristics became assets rather than constraints. These two cases collectively highlight the central interpretive function of the tool. The scores do not form a linear ranking, nor do they prescribe a single "ideal" configuration. Instead, they convey patterns: structural "immaturity" paired with agility; procedural robustness paired with inward focus; high co-creation potential paired with flexible governance. The meaning of each pattern depends on timing, purpose, and context. In the first case, the 2-4-5-2-4 pattern became perfect for rapid experimentation. In the second, the 5-3-4-5-2 pattern became ideal for long-term structural refinement. In IEs collaborations, and more specifically in IIEs, suitability is not a fixed attribute but a dynamic relation between needs and capabilities. The tool supports this by revealing how different principles gain or lose relevance depending on the strategic horizon. It transforms isolated scores into interpretive signals. It enables organizations to read ecosystems through evolving priorities, ensuring that collaboration activation is intentional, informed, and strategically coherent. Rather than imposing a universal hierarchy, it makes visible the shifting relevance of each principle, supporting decisions that evolve as innovation unfolds.

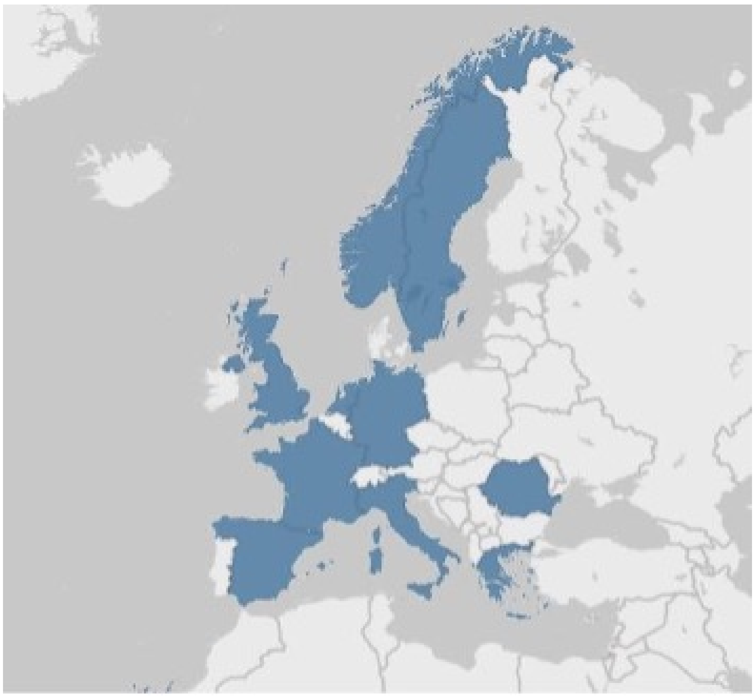
1.5 Discussion

1.5.1 General discussion

Starting from both needs to develop cross-national studies (Zen et al., 2023) and to formalize a heuristic approach to assess potential partnerships between IEs (Gomes et al., 2018) we developed a tool that could be beneficial for both theoretical advancement and practitioners. Research suggest that managers use tools to support situation analysis and evaluation of strategic choices (Orndoff, 2002) and this work represents an attempt to catalyze and trigger both national and international partnerships at the ecosystem level. Our research journey was mainly characterized by a continuous combination and iteration of theoretical and practical perspective: the conceptual background who emphasized a fragmentation of IEs subtypes (Gupta et al., 2019) was balanced by an increasing need for institutional bodies to call for more IIEs globally (European Commission, 2024); a practice review complemented the literature review; a group of five practitioners (engineers and managers) translated those principles in concrete design and two researchers assessed the designed principles to test whether they worked (Cobb et al., 2003).

On the one hand, the mutual contamination and exchange between our research group and the practitioners emphasized how the different IEs declinations (e.g., digital IEs, entrepreneurial IEs) are more blurred in the academic literature than in reality. Indeed, we believe that these ecosystems, which share similar characteristics, can benefit from the development of our tool that can be a useful framework for a pre-assessment for their interactions. Indeed, there is an increasing need to address interaction between the different types of ecosystem (Valkokari, 2015), attempting to avoid the “disconnections” between the different heads of the Hydra (the different types of IEs). In this context, the DR approach helped us overcome these obstacles as the group of practitioners was part of a community of practice that have characteristics of innovativeness, responsiveness to evidence, connectivity to basic science, and dedication to continual improvement (Bereiter, 2002). On the other hand, when the two researchers compared the results, we were surprised to see that the IP management principle was the only one that revealed two different assessments. Given the extensive expertise and background of the FS group task force (Table 1.2) on IP aspects, we were confident that the strength of the assessment criteria could lead the two researchers to similar evaluations of the IEs. However, despite the initial surprise, we found that those discrepancies fit with the literature on IEs. Indeed, the valorization of emerging patents is an intricate process that entails the transformation of these intellectual assets into tangible, marketable, and revenue-generating entities. This seems to be consistent with Granstrand and Holgersson (2020) who stated that firms who adopt various types of open innovation strategies need to match their IP strategies. Moreover, the IP ecosystem structure is particular to each country Figure 1.2, generating different investment stimuli during the innovation life cycle (Reis et al., 2022) meaning the perspectives of the two researchers may have been influenced by cultural barriers in recognizing these differences. Additionally, through desk-research analysis, the two researchers had access to only a limited amount of data, and in this assessment, the dynamic of trust within IEs could act as a critical enabler in understanding each IP management strategy (Cobben & Roijakkers, 2019; Steinbruch et al., 2021). In this case, the literature complemented the practical assessment, leaving room for interesting future directions and emphasizing how university-industry collaboration is one of the most important dimension of an IE (Mercan & Goktas, 2011).

Figure 1.2: Geographical distribution of examined IEs in Europe. *Source:* Authors' own work.



1.5.2 Theoretical contributions

This work addresses our research question by offering several key contributions.
First, we advance the literature on IEs by formalizing a heuristic approach for selecting IE partners. We identify five guiding principles namely Partners' Maturity, Collaboration Readiness, Value Co-Creation, IP Management, International Network that have been operationalized to enable preliminary assessment of IEs on a global scale. While previous studies have primarily focused on the dynamics within IEs (Bacon et al., 2020; Jiang et al., 2020; Smorodinskaya et al., 2017) or on the interaction between IEs and other entities such as universities (Mercan & Goktas, 2011), surprisingly little attention has been paid to the development of tools that can support national and international partnerships at the ecosystem level. Our contribution fills this gap by demonstrating how the tool can be used to trigger such partnershipsat the ecosystem level.

Our work responds to these gaps by offering a multi-contextual assessment applied across both national and international settings and by integrating principles - such as IP management and international network - not addressed in existing frameworks. As a result, it complements existing tools by enabling a richer understanding of how ecosystems align and interact across boundaries (Guertler & Lindemann, 2016; Talmar et al., 2020). Similarly, maturity models have often been conceptualized at the national level, focusing on country-wide innovation capacity and systemic readiness, but offering limited insights into how maturity manifests and evolves across more granular ecosystem layers (Bittencourt et al., 2021). By contrast, our tool examines maturity not only at the national scale but also across diverse local, regional, and international ecosystems, thereby advancing our understanding of how structural development and strategic alignment vary across different territorial configurations.

Second, by considering multiple IEs operating in varied settings and in line with growing institutional interest, we introduce the concept of Interconnected Innovation Ecosystems. This notion offers a more holistic perspective on the complex networks of actors that span multiple ecosystems and supports recent calls for better typologies of ecosystems (Cobben et al., 2022; Gupta et al., 2019). Our tool opens the way for analyzing interactions between different types and subtypes of ecosystems potentially revealing previously unexamined distinctions and complementarities (Dias SantÁna et al., 2020; Valkokari, 2015). Moreover, by incorporating the concept of IIEs, this study seeks to enhance understanding of how different IEs operate and what key factors drive their collaboration, particularly across national and international contexts (Pikkarainen et al., 2025).

In particular, the definition of IIEs overcomes the limitations of ecosystem networks defined primarily at the national scale and extends previous concepts such as meta-ecosystems by offering a clearer articulation of the spatial scales at which cross-ecosystem interactions emerge and evolve (Palmié et al., 2022; Wang et al., 2023; R. Zhang et al., 2023).
Third, our study addresses the growing demand for novel methodologies to understand how IEs function in diverse and rapidly evolving environments. By combining insights from literature and practice within a design research framework, we introduce an original, practice-oriented approach that responds to recent calls for methodological innovation in the field (Youtie et al., 2021).
Fourth, we contribute to the literature on IP management within IEs by reframing it as a strategic and relational component of ecosystem. Traditionally viewed through a legalistic or transactional lens, IP management within IEs requires a broader interpretation that encompasses collaboration, knowledge flows, and value co-creation. As suggested by Leten et al. (2013), IP can function as a coordination mechanism across actors, while recent research emphasizes the superiority of collaborative over defensive IP strategies in open innovation settings (Grimaldi et al., 2021). In line with this evolution, our contribution further advances the view of IP as a relational and strategic asset emerging from ecosystem-level interactions rather than isolated firm-level mechanisms (Genin et al., 2021; Granstrand & Holgersson, 2014).

Lastly, our work refines our understanding of the framework introduced by (Nambisan & Sawhney, 2011) by applying their conceptualization of openness to the domain of innovation ecosystems, where openness encompasses both structural and decisional dimensions. While their formulation highlights how networks are configured and how decision rights are allocated, our work advances this perspective by unpacking the structural dimension into more operational and evaluable components. In our model, structural openness is articulated through two distinct principles - Partners' Maturity and International Network - allowing for a more granular assessment of the ecosystem's readiness, capability alignment, and cross-border partnerships. This decomposition offers a clearer analytical pathway to examine how structural conditions shape orchestration effectiveness across IIEs.

Our findings point to a high degree of interpretive variability in assessing this principle, which we consider not as a weakness but as a theoretical signal. It reflects the complexity and contextual nature of IP practices within IEs, where strategic approaches range from informal agreements to structured monetization and licensing models. This suggests the need to move beyond standardized frameworks and develop more articulated conceptualizations that account for the heterogeneous configurations of IP in interconnected and evolving ecosystems.

1.5.3 Practical implications

The practical aim of this work lies in the creation and assessment of the tool that can be used by a wide range of practitioners both within (e.g., orchestrators, innovation managers) and outside the boundaries of IEs (e.g., potential members, policymakers).

First, the tool can be effectively used to conduct a structured pre-assessment of potential partners, offering a clear indication of the maturity and scope of different IEs. A high overall score tends to signal engagement with a more internationally oriented and mature ecosystem, while a lower score may point to partnerships within more local or less structured ecosystems. This quick and comparative overview is valuable not only for ecosystem-level decision-making but also for individual actors seeking strategic alignment. In particular, it allows local ecosystems to assess the compatibility of potential "twin" ecosystems abroad, supporting internationalization strategies. Moreover, the tool can be employed as a mechanism for partner scouting and member recruitment, which becomes essential in contexts where ecosystems actively compete to attract strategic collaborators (Jacobides et al., 2018).

Second, the tool offers innovation managers a practical framework for internal reflection and benchmarking. It enables a self-assessment of the ecosystem's composition and capabilities, fostering a better understanding of member profiles and supporting strategic decisions about resource allocation, governance, and development priorities. This responds to recent calls for more granular analyses of actor-level dynamics within IEs (Robertson et al., 2023).

Third, the tool can also support policymakers and institutional bodies in promoting ecosystem connectivity and cross-sector collaboration. It aligns with broader agendas aimed at enabling inclusive, green, and digital transitions by providing a foundation for setting shared priorities and identifying synergies among diverse territorial and organizational actors (European Commission, 2024). In this vein, the tool helps public authorities recognize when low-maturity or structurally fragile ecosystems - such as social IEs, cooperative networks, and community-driven initiatives - may hold strong collaborative readiness or high co-creation potential despite limited resources or weak formal governance structures. These profiles often remain overlooked in traditional assessments focused on technological intensity or market performance. The tool can therefore support policymakers in redirecting targeted investment, capacity-building programs, or facilitation services toward ecosystems where collaboration readiness is high but structural conditions remain underdeveloped, enabling more inclusive and place-sensitive innovation strategies. A further practical application lies in the digital integration of the tool within innovation management systems. The structured and scalable nature of the scoring system enables the creation of a shared and interoperable database, where assessments can be stored, compared, and updated across time, departments, or geographies. This opens the way to assess potential collaborations across countries and to support real-time dashboards that help coordinate strategic partnerships. In contexts such as the ROAD IE, this supports centralized monitoring of ecosystem maturity, guides internal resource allocation, and informs HR strategies related to partner engagement and capability development. From a human resource management perspective, the tool supports a more structured approach to ecosystem governance, enabling targeted allocation of talent and internal champions based on assessed collaboration potential. For instance, an ecosystem scoring highly on value co-creation and partners' maturity may justify the deployment of cross-functional teams or dedicated partnership managers. Conversely, a lower score may indicate the need for capacity building or a gradual engagement strategy.

In terms of policy, the tool's application revealed relevant differences in national approaches, especially regarding IP practices. Traditionally, Italy has shown a stronger orientation toward formalized IP protection mechanisms, whereas countries like the Netherlands often initiate partnerships in more informal and fluid ways. This reflects broader cultural and legal differences in innovation governance. Importantly, low scores on IP management should not be interpreted as a weakness per se: for start-ups testing early-stage technologies, informal agreements and flexible collaboration models can instead be a sign of openness to experimentation.

In the domain of education and skills development, the tool can inform training programs for innovation managers, ecosystem facilitators, and orchestrators by highlighting which principles require stronger competencies in different territorial contexts. Ecosystems with high value co-creation but weak collaboration readiness may benefit from capacity-building in project management, ecosystem orchestration, or OI practices; others with strong IP management but low partner maturity may require programs focused on inclusive governance or capability alignment.

1.5.4 Research limitations and future research avenues

This work is not without limitations, which also suggest directions for further development. First, while the literature review may not have captured all relevant contributions, it was intentionally guided by the aim of connecting theoretical insights with practical application. Second, although the tool demonstrated overall reliability, the assessment of the IP management principle showed some interpretive variability. This reflects the inherent complexity of evaluating IP strategies across different ecosystems despite having organized workshops involving professionals with IP expertise. A further consideration relates to the background of the two researchers who conducted the assessment. Although they worked in different organizations, both are based in Italy and involved in the same project. Their shared context may have influenced how they interpreted certain elements of the tool, despite applying it to a range of national and international IEs. Lastly, the sampling focused on potential partners in similar technological areas. While this was appropriate for an exploratory study, limited information was available about the internal structure and governance of the selected IEs, which were kept anonymous to avoid unintended consequences.

In light of these limitations, further research and collaboration with key stakeholders and IE representatives from different contexts may be needed to refine and test the tool. By addressing these challenges, the tool can offer a more robust and holistic assessment of IEs, fostering successful, sustainable, and mutually beneficial collaborations at both national and international levels. Second, the principles could be integrated through workshops or hackathons involving a broader pool of practitioners, not limited to innovation domains, to generate different feedback and expand the framework. In this regard, the tool could explicitly incorporate other subtypes of IEs (e.g., digital IEs, entrepreneurial IEs). A promising direction for future research is the integration of human resource management perspectives into the study of IEs. Exploring how collaboration, role distribution, and talent management are handled across ecosystem actors could shed light on the human dynamics that underpin ecosystem performance and sustainability.

1.6 Conclusions

This paper presents a tool for assessing potential partners between IEs. The tool is developed through a combination of literature and practice review, and design research. We operationalized five principles to evaluate IEs and support the development of partnerships both at a national and international level. The methodology combined a review of existing literature on IEs with a practice review with five practitioners who translated these principles into concrete design. Design research was then used to test the applicability of the tool, with two researchers assessing its effectiveness on a total of 75 IEs in 10 different countries. Our findings reveal variation in how IEs perform across the five assessed principles, namely Partners' Maturity, Collaboration Readiness, Value Co-Creation, IP Management, International Network. The tool helped distinguish between local and international ecosystems, offering insights into both their maturity and openness to collaboration. It proved especially useful for innovation managers seeking to evaluate potential partners and map strategic opportunities. Future research could refine the tool by incorporating more diverse practitioner feedback and addressing the complexities of IP management across IEs.

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As an open, accessible, and inclusive space, ROAD functions as a talent forge, an advanced knowl-

edge and research center, a community aggregator, and a playground where engineers, designers, and natural and social scientists collaboratively develop solutions for a sustainable future.
ROAD's scientific research not only focuses on cutting-edge technologies but also explores, evaluates, and studies potential new innovation ecosystems worldwide. This represents an opportunity for evolution through the exchange of know-how among talents and positions itself as a key player in the international innovation ecosystem through value-generating partnerships.

Chapter 2

Entrepreneurial and innovation ecosystems: a scoping review on the complexity of nested configurations

Abstract

Entrepreneurial ecosystems (EEs) and innovation ecosystems (IEs) have long been conceptualized as distinct constructs, yet their interplay remains theoretically fragmented. This study addresses this gap through a scoping review of 48 peer-reviewed publications, investigating how the literature conceptualizes their intersection. Guided by complex systems theory, our analysis reveals four nested configurations that emerge from the selected papers: startup ecosystems, entrepreneurial university ecosystems, entrepreneurial innovation ecosystems, and regional innovation ecosystems. These configurations are classified along two dimensions: the dominant orientation of the ecosystem, which leans toward either an entrepreneurial or innovation logic, and the prevailing form of complexity, shaped by bottom-up or top-down dynamics. Our findings reveal that each configuration varies in the extent to which entrepreneurial processes are embedded within broader innovation structures or, conversely, how innovation dynamics are driven by entrepreneurial foundations. We also identify systems where complex dynamics originate either at the micro-level or at the macro-level, subsequently influencing the other dimension. In this way, the study contributes to ecosystem literature and to the theoretical development of complex systems theory by showing that EEs and IEs can coexist within nested configurations rather than as separate domains. The analysis advances conceptual understanding by explaining how these configurations are shaped by different forms of complexity: bottom-up dynamics are grounded in effectuation logics, and top-down patterns reflect causation and coordinated strategies. Practically, the study offers guidance for policymakers and ecosystem orchestrators by indicating how governance strategies can be aligned with the specific systemic dynamics of each configuration.

Keywords: entrepreneurial ecosystem; innovation ecosystem; complex systems theory; nestedness; scoping review

2.1 Introduction

Entrepreneurial ecosystems (EEs) and innovation ecosystems (IEs) have attracted the increasing attention of policymakers, federal agencies, venture capitalists, business enterprises, and members of academia (Ozkan et al., 2023; Tsujimoto et al., 2018). On the one hand, EEs are typically defined as multifaceted structures (Spigel, 2017; Van de Ven, 1993) with entrepreneurial outputs generated from the combination of financial, knowledge, institutional, social, and technological components (Audretsch et al., 2019; Nicotra et al., 2018). On the other hand, IEs are represented as the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors (Granstrand & Holgersson, 2020). While these two concepts have often been treated separately, a number of contributions have focused on delineating their boundaries and divergences (Cobben et al., 2022; De Bernardi & Azucar, 2019; Valkokari, 2015).

Strongly rooted in the regional development literature (Acs et al., 2017), EE dynamics are shaped by historical regional trajectories and exhibit high sensitivity to initial conditions (Cloutier & Messeghem, 2021; Molla & Biru, 2023). By contrast, IEs are frequently associated with orchestrated, innovation-driven value networks, typically coordinated by a focal firm that aligns the activities of diverse actors towards shared innovation goals (Adner, 2016; Cobben & Roijakkers, 2019). However, despite these differences, the distinction between the two ecosystems is not always clear-cut. As noted by Scaringella and Radziwon (2018), little is known about how different ecosystem types mutually influence and intersect with each other. Indeed, while EEs and IEs may follow different logics, they are not mutually exclusive, even though the nature of their interconnection is rarely addressed in the literature (L. D. Thomas et al., 2018; Xu & Maas, 2019). The interdependence of such ecosystems is particularly evident when certain configurations of EEs emerge as subtypes of IEs, or vice versa. For example, Gomes et al. (2018) suggest that some types of EEs are effectively subtypes of IEs, while other contributions frame specific types of IEs as being situated within broader EE domains (Guerrero et al., 2020).

Given their grounding in ecological and biological domains, both EEs and IEs can be viewed as complex adaptive systems of heterogeneous agents that learn, adapt, and co-evolve over time through feedback loops and dynamic interactions (Roundy et al., 2018; Russell & Smorodinskaya, 2018). However, as noted by several scholars, there is still a pressing need to investigate the dynamics of ecosystems through the analytical lens of complex systems theory, in order to capture their evolution, emergent properties, and behaviors (Cobben et al., 2022; Phillips & Ritala, 2019; Rabelo Neto et al., 2024; Ritala & Gustafsson, 2018; Wurth et al., 2022). This perspective provides a fertile ground to explore their interrelation and nestedness. In particular, the concept of nestedness is well suited to capture the complexity that arises from interrelations, overlaps, and mutual dependencies among different systems. In ecology, in fact, nestedness describes a situation in which the species composition of a poorer site is a strict subset of that of a richer site (i.e. the richer site includes unique species not found in the poorer site), but no species is replaced by others (Baselga, 2012). This logic has been extended beyond ecological systems to other domains, such as technological change. For instance, Christensen and Rosenbloom (1995) describe how the hierarchical structure of value networks can be decomposed into interdependent subsystems that simultaneously operate as part of a broader system of use. In their view, the concept of nestedness emerges when complex systems are examined beyond a rigid interpretation. In this sense, their characteristics are nested within one another and interrelated, forming dynamic configurations that constitute the broader system.

This line of reasoning can be extended to ecosystem research, particularly within the fields of innovation and entrepreneurship. In this context, the present study aims to map how academic literature conceptualizes the relationship between IEs and EEs, and to identify the nested configurations that emerge at their intersection. At the same time, it seeks to interpret these configurations through the lens of complex systems theory, assessing the extent to which key properties of complex systems are present and discussed in the literature. To guide this scoping review, we formulated the following research questions: *"How does the academic literature conceptualize the relationship between innovation ecosystems and entrepreneurial ecosystems?"* and *"What nested configurations emerge from their intersection? and What type of systemic complexity characterizes the nested configurations of innovation and entrepreneurial ecosystems as described in the existing literature?"*

In this way, this study contributes to ecosystem theory by clarifying how EEs and IEs can coexist within nested configurations, rather than as distinct or competing types. First, we advance theoretical understanding by introducing the notion of nested configurations as a bridge between EEs and IEs showing how these systems interact and evolve as interdependent rather than separate domains. Using complex systems theory, we show how systemic properties vary across configurations, depending on whether bottom-up or top-down complex dynamics emerge. On one side, our study shows that bottom-up complexity arises from micro-level interactions driven by effectuation logics – more adaptive in identifying and capturing emerging opportunities. On the other side, top-down complexity is shaped by macro-level structures and interventions, reflecting causation, goal-driven logics centered on coordinated strategies. Second, we reconceptualize nestedness as a dynamic, functional relationship between ecosystems, offering a more integrated framework for understanding their evolution and interaction. In particular, within entrepreneurial-nested configurations innovation activities are driven by growth-oriented strategies and orchestrated by entrepreneurial actors. By contrast, in innovation-nested configurations, entrepreneurship is embedded within broader innovation structures and integrated into formal infrastructures and regulatory frameworks. Practically, our findings support policymakers in tailoring governance strategies to the specific logic of each configuration, promoting adaptive, context-sensitive approaches to ecosystem development. Finally, we outline future research directions to explore the interplay between EEs and IEs.

The remainder of the paper is structured as follows. Section 2 outlines the theoretical background, introducing complex systems theory and highlighting its application to both EEs and IEs. Section 3 details the methodology, which follows the PRISMA Extension for Scoping Reviews (PRISMA-ScR). Section 4 presents the findings, including a descriptive analysis of the selected studies and the identification of four nested configurations, offering a conceptual synthesis of each configuration and their implications for complexity and nestedness. Section 5 outlines directions for future research, while Section 6 presents the main theoretical insights, practical implications and concluding remarks.

2.2 Theoretical Background

Complex systems theory, originally rooted in the natural and physical sciences, has increasingly gained momentum in the fields of innovation (Frenken, 2006), management (R. B. Mason, 2007), and entrepreneurship (McKelvey, 2004). It focuses on the dynamic analysis of complex systems, emphasizing the bidirectional and non-separable relationship between the identity of the parts and the identity of the whole. These systems are shaped by reciprocal interactions among their constituent elements, which collectively give rise to emergent behaviors (Estrada, 2023; Thurner et al., 2018). Complex systems can be examined through their structural properties to map systemic dynamics and behavioral patterns, and are often modeled as networks of interacting entities (Barabási, 2016; Newman, 2018). The interactions within such systems are typically non-uniform, non-linear, and heterogeneous, yet specific to the nature of the elements involved (Thurner et al., 2018).

In the last decade, EEs have increasingly been examined through the lens of complex systems theory (see, e.g., Isenberg, 2011; Leendertse et al., 2021; Roundy et al., 2018). This approach largely builds on Isenberg (2016)'s pioneering contribution, which first introduced the concept of self-organization into the conceptualization of EEs. Applying complex systems theory to the study of EEs can contribute to delineating ecosystem boundaries and their interactions with the external environment, identifying emergent and adaptive behaviors, and analyzing the evolving interlinkages among ecosystem components over time (Fredin & Lidén, 2020). In this vein, Roundy et al. (2018) provided the first definition of EEs grounded in complex systems theory, describing them as self-organized and adaptive communities of complex agents that operate at multiple levels and interact in a non-linear way over time. Thus, self-organization, adaptation, and non-linearity, along with sensitivity to initial conditions (Han et al., 2021), emerge as defining complex system properties of EEs.

EE evolutionary behavior, indeed, follows inherently chaotic and non-linear trajectories (Brown et al., 2022; Haarhaus et al., 2020), unfolding through sequential phases of "creative destruction" and crises, followed by restructuring periods shaped by self-organizing mechanisms (Auerswald & Dani, 2017; Cloutier & Messeghem, 2021; Horváth & Rabetino, 2019). This evolutionary process is strongly path-dependent, driven by self-reinforcing mechanisms (Cloutier & Messeghem, 2021) and highly sensitive to initial conditions. Contextual factors, in particular, are central to understanding and mapping the emergence of EEs, with regional pre-conditions, pre-entry capabilities, and historical trajectories influencing their development (Molla & Biru, 2023). The emergence of successful entrepreneurial actors indeed, co-evolves within multidimensional geographical boundaries (Han et al., 2021). In addition to being self-organized and path-dependent, EE dynamics are adaptive, exhibiting a certain degree of resilience in the face of shocks and disturbances. This allows EEs to absorb tensions, reconfigure internal structures, and pursue new entrepreneurial opportunities (Cantner et al., 2021; Roundy, 2017). Such mechanisms are enabled by the interplay between stability and diversity (Ives & Carpenter, 2007), with the presence of heterogeneous actors affecting equilibrium conditions (Ancona et al., 2023).

A final foundational property of complex systems, increasingly recognized in EE research, is their causal complexity and associated feedback mechanisms. As noted by Wurth et al. (2023), such complexity arises from the interdependence between ecosystem components, involving both upward and downward causation among elements and entrepreneurial outputs and outcomes. These dynamics generate feedback loops, manifest structurally through reciprocal interactions among ecosystem actors and components (Ancona et al., 2023). However, this level of causal complexity tends to decrease as EEs mature because of a typical reduction in the number of input factors affecting outputs over time and a gradual decline in causal asymmetry (Vedula & Fitza, 2019).

Similarly, IEs have been framed as complex adaptive systems, a perspective that helps explain their dynamic, non-linear, and evolving nature (Boyer, 2020; Phillips & Ritala, 2019; Russell & Smorodinskaya, 2018). This theoretical lens shifts the focus away from linear models of innovation, emphasizing instead the complex and interconnected nature of the relationships that underpin ecosystem dynamics (Autio & Thomas, 2014; Jackson, 2011; Kirkels & Duysters, 2010). One of the core properties of IEs is non-linearity. Innovation processes within IEs do not unfold in predictable, step-by-step sequences but rather follow iterative and nonlinear patterns shaped by continuous feedback (Autio & Thomas, 2014). Indeed, feedback loops emerge from the reciprocal interactions among ecosystem actors and components, reinforcing patterns of collaboration, learning, and resource exchange that sustain and evolve the innovation process over time (Arthur et al., 2022; Jackson, 2011). Moreover, self-organization, heterogeneity of actors and co-evolution have been increasingly used to describe IEs (Jucevičius & Grumadaitė, 2014). In particular, IEs are typically orchestrated by a lead organization, sometimes referred to as an "ecosystem leader" (Adner, 2016). From an organizational perspective, firms orchestrate IEs through open innovation initiatives over time (Remneland Wikhamn & Styhre, 2022). Through interactions, agents react to each other's behavior, which adjusts the behavior of the entire ecosystem, ensuring high adaptability to change and dynamic sustainability through continuous internal recombination of shared assets (Russell & Smorodinskaya, 2018). Path dependency in IEs refers to how past decisions, interactions, and structures constrain the range of future strategic options (Taibi-Voigts et al., 2025). Actors within IEs are highly sensitive to coordination dynamics and must be strategically aligned with the value proposition defined by the orchestrator, who typically holds a position of power (Lingens & Huber, 2021; Taibi-Voigts et al., 2025)). Heterogeneity assumes critical characteristics. IEs are composed of a diverse set of actors—firms, universities, public institutions, intermediaries, users—each with their own goals, capabilities, and perspectives (Granstrand & Holgersson, 2020; Reiter et al., 2024). Finally, IEs are characterized by co-evolution. Ecosystem actors and components evolve together over time, responding to and influencing each other's trajectories (Breslin et al., 2021; Ritala & Almpanopoulou, 2017).

Thus, both EEs and IEs have recently been investigated through the lens of complex systems theory. However, what emerges from the existing literature is that the complexity inherent in such systems tends to revolve around one predominant dynamic within the bidirectional and inseparable relationships between the parts (micro-level) and the whole (macro-level) (Estrada, 2023; Funtowicz & Ravetz, 1994; Thurner et al., 2018). To address this, we introduce the concepts of bottom-up and top-down complexity. Bottom-up complexity characterizes systems in which dynamic interactions at the micro-level give rise to emergent properties at the macro-level. In contrast, top-down complexity refers to systems where complex dynamics originate at the macro-level and exert influence over micro-level behavior. In this context, EEs are typically associated with bottom-up complexity, driven by self-organizing processes and path-dependent mechanisms, strongly induced by regional pre-conditions. Conversely, IEs tend to reflect top-down complexity, where non-linear and co-evolutionary dynamics - mostly in terms of collaborative ties and resource exchanges - are often shaped by the coordination of a complex agent, such as an orchestrator. To better interpret these dynamics, it is useful to recall the distinction between causation and effectuation introduced by Sarasvathy (2001). Causation refers to a goal-driven logic in which actors begin with a specific objective and select the most efficient means to achieve it. It relies on prediction, planning, and deliberate design, features that characterize more managed and coordinated innovation processes. By contrast, effectuation is a means-driven logic in which actors start from their existing resources ("who I am, what I know, and whom I know") and progressively co-create goals through interaction and experimentation. Effectuation thus emphasizes non-predictive control, adaptability, and the capacity to leverage contingencies and emergent opportunities. These two logics well reflect the different modes of systemic complexity introduced above. Effectuation represents a bottom-up and emergent approach in which ecosystems evolve through adaptive interactions, experimentation, and self-organization. This logic is particularly associated with entrepreneurship, where the creation of new ventures and opportunities often emerges from local initiatives, contextual conditions, and evolving stakeholder commitments (Sarasvathy, 2008). In contrast, causation aligns with a top-down perspective, where ecosystem evolution is often guided by coordinated strategies, planning, and deliberate design. This logic is more consistent with innovation processes, which tend to be managed through institutional frameworks, orchestrating actors, and structured policy interventions (Berends et al., 2013).

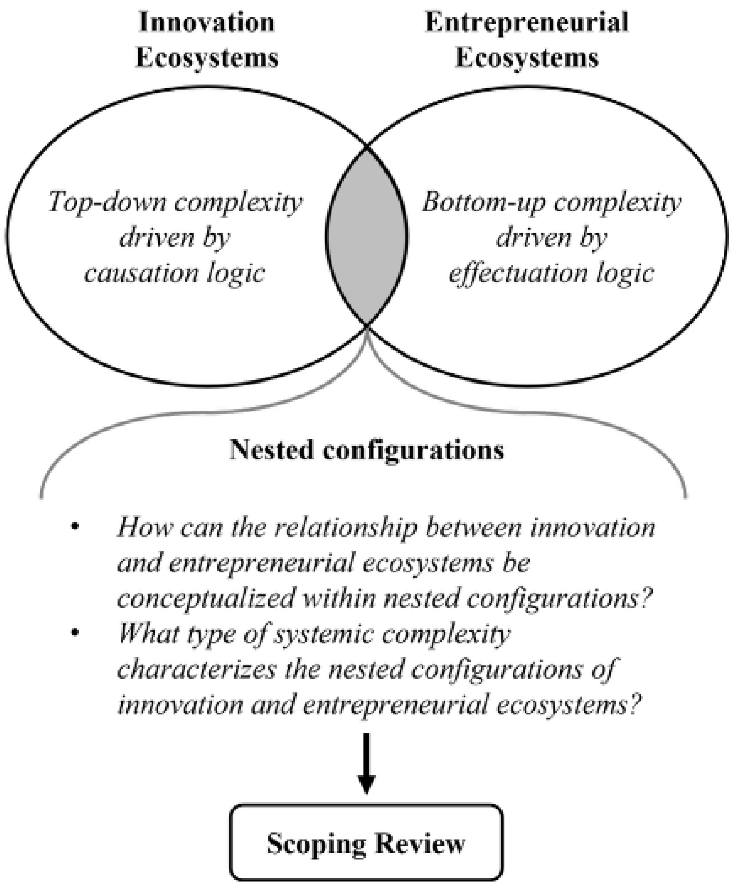
A summary of how the different complex system properties manifest within EE and IE research is presented in Table 2.1.

Table 2.1: Complex systems properties in EE and IE research

Property	Entrepreneurial Ecosystems	Innovation Ecosystems
Self-organization	Self-organized communities of complex agents emerging from the bottom-up dynamics (Isenberg, 2016; Roundy et al., 2018).	Self-organization often unfolds through top-down orchestration by a lead organization that coordinates actors and resources over time (Adner, 2017; Remneland Wikhamn & Styhre, 2023).
Non-linearity and co-evolutionary behaviors	Evolutionary trajectories are chaotic and discontinuous (Brown et al., 2023), with entrepreneurial activities and actors co-evolving with regional patterns (Han et al., 2021).	Innovation processes unfold through iterative, nonlinear patterns shaped by continuous feedback, and mutual co-evolution of actors and components (Autio & Thomas, 2014; Breslin et al., 2021; Ritala & Almpanopoulou, 2017).
Adaptability and resilience	Ability to absorb shocks, reconfigure internally, and pursue new opportunities (Cantner et al., 2021; Roundy et al., 2017).	Dynamic sustainability is achieved through internal recombination of shared assets (Russell & Smorodinskaya, 2018).
Feedback loops and complex causation	Structural feedback among actors and components, also affecting entrepreneurial outcomes and reinforcing system dynamics (Ancona et al., 2023; Wurth et al., 2023).	Feedback reinforces collaboration, learning, and resource exchange among actors (Arthur et al., 2023; Jackson, 2011).
Sensitivity to initial conditions and path-dependence	Sensitivity to regional conditions and historical trajectories influencing ecosystem emergence (Han et al., 2021) through self-reinforcing mechanisms (Cloutier & Messeghem, 2022).	Path dependency describes how early decisions, interactions, and structures constrain future strategic options, with actors particularly sensitive to the orchestrator's value proposition (Lingens & Hiber, 2023; Taibi-Voigts et al., 2025).
Heterogeneity	The system maintains a certain degree of stability and equilibrium due to the presence of diverse and heterogeneous actors (Ancona et al., 2023; Ives & Carpenter, 2007).	Presence of diverse actors (firms, universities, users, institutions) with different roles and objectives (Granstrand & Holgersson, 2020; Reiter et al., 2024).

While both EEs and IEs have been examined using complex systems theory, this scoping review seeks to shed light on the complex system nature of those nested configurations that emerge at their intersection. Specifically, we aim to understand whether nested environments characterized by both entrepreneurial and innovation drivers predominantly exhibit bottom-up or top-down forms of complexity. Figure 2.1 provides an overview of the logic guiding our research design.

Figure 2.1: Overview of the logic guiding our research design.



2.3 Methodology

This study adopts a scoping review approach following the PRISMA-ScR protocol (Tricco et al., 2018). The aim is to map how academic research frames the relationship between EEs and IEs, with a particular focus on studies that discuss, compare, or integrate both constructs.

This approach is well suited to clarify key concepts and definitions by identifying their core characteristics and related knowledge gaps (Munn et al., 2018). In particular, we employ this method as scoping reviews are used to present a broad overview of the evidence pertaining to a topic (Tricco et al., 2018) allowing us to capture the diversity of theoretical and conceptual approaches in the literature.

2.3.1 Protocol and registration

The review protocol was developed prior to data collection and aligned with PRISMA-ScR guidelines. Although the review was not formally registered, the search strategy, inclusion criteria, and analytical framework were documented in advance. The protocol was jointly discussed and refined by three researchers with expertise in innovation and entrepreneurship studies, as well as in complex systems theory, to ensure methodological consistency and theoretical coherence. An initial screening conducted in February 2025 confirmed the absence of previous scoping reviews addressing this specific conceptual inquiry. Before launching the full search, a pilot test of the Boolean query was carried out to verify the adequacy of database coverage and the relevance of retrieved records.

Minor adjustments were made to refine the search syntax and reduce noise in the results. All steps of the review process - including search, screening, and synthesis - were recorded in a shared research log to guarantee transparency and traceability. The overall methodological design followed four main stages: (1) database search and bibliometric preprocessing, (2) screening and selection, (3) data extraction and charting, and (4) thematic analysis and conceptual synthesis.

2.3.2 Eligibility criteria

We included peer-reviewed articles published in English between 2005 and early 2025 that explicitly mention "entrepreneurial ecosystem(s)" or "innovation ecosystem(s)" in the title, abstract, or keywords. To be eligible, articles had to engage conceptually with the literature on IEs and EEs. Additional inclusion criteria required that articles be peer-reviewed, written in English, and have full-text availability for data coding. We excluded unpublished or non peer-reviewed works, articles not in English, studies published before 2005, those without accessible full texts, and papers lacking theoretical engagement with either EE or IE.

Inclusion and exclusion criteria are presented in Table 2.2.

Table 2.2: Inclusion and Exclusion Criteria

SN	Inclusion Criteria	Exclusion Criteria	Motivation
1	Articles engaging with literature on IEs and EEs	Articles lacking theoretical engagement with IE or EEs	To avoid general definitions of ecosystems
2	Articles that have been published in the English language	Articles that are not in English	To ensure accessibility and consistency in the analysis
3	Articles that have been published in a peer-reviewed journal	Unpublished and non-peer-reviewed articles	To ensure the reliability and academic rigor of the sources
4	Articles that were published between the years 2005 to early 2025	Articles that have been published before the year 2005	To align with the foundational conceptualization of IEs (Adner, 2006)
5	Full texts of publications chosen for data coding are available	Full texts of publications chosen for data coding are not available	To guarantee completeness and allow for in-depth analysis

2.3.3 Information sources

Scopus was selected as the primary database due to its broad coverage of innovation and entrepreneurship literature. We chose Scopus as it provides broader coverage than Web of Science, particularly in the social sciences, management, and interdisciplinary research (Falagas et al., 2007). Although Google Scholar may offer access to additional grey literature, its inclusion of preprints and non-peer-reviewed material raises concerns about source quality and reliability (Falagas et al., 2007). The dataset was exported from Scopus into a Microsoft Excel file, including complete citation information, author affiliations, publication years, keywords, and source titles. These data were primarily used to manage the corpus, remove duplicates, and verify the disciplinary and temporal distribution of the retrieved articles. Although basic descriptive information such as publication trends and source distribution was reviewed to contextualize the dataset, bibliometric indicators were not included in the analytical stage. This decision reflects the main purpose of the study, which was not to perform a bibliometric mapping of the field but rather to develop a conceptual synthesis linking EEs and IEs through the lens of nested configurations and complex systems theory. The cleaned dataset thus served as the foundation for the subsequent screening and thematic analysis. To ensure completeness, we also conducted backward and forward citation tracking on the identified articles. The last search was completed in May 2025.

2.3.4 Search strategy

To focus exclusively on studies addressing both EEs and IEs, we used the following query in `TITLE-ABS-KEY`:

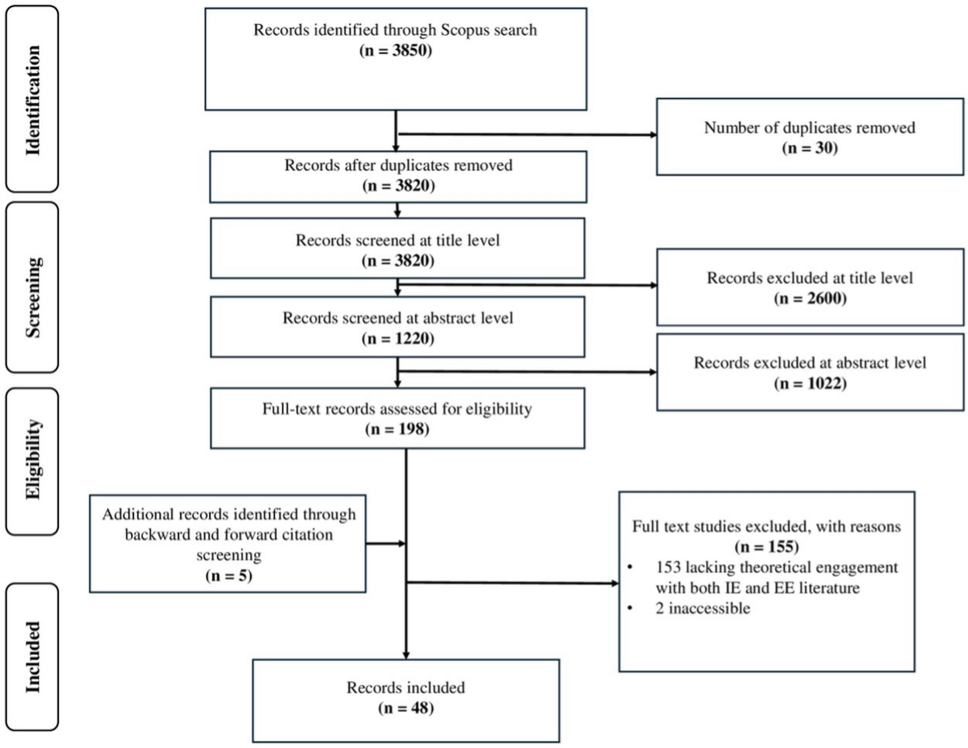
> "innovation ecosystem*" OR "entrepreneurial ecosystem*" OR "entrepreneurship ecosystem*"

The search was limited to publications in English between 2005 and early 2025. A pilot test of the Boolean string was conducted to verify the adequacy of database coverage and the precision of retrieved results. Minor adjustments were made to refine the syntax and remove semantically unrelated records (e.g., studies referring to natural or biological ecosystems). No disciplinary filters were applied, as the objective was to capture the broadest conceptual articulation of how the two constructs are framed across different domains. This strategy ensured the retrieval of articles that engage with both constructs, allowing derivations, overlaps, and conceptual interlinkages to emerge organically from the literature.

2.3.5 Selection of sources of evidence

Following duplicate removal, three reviewers independently screened titles and abstracts based on the inclusion criteria. The screening process was organized in two stages: an initial assessment of relevance (title and abstract) followed by a full-text review of the remaining studies. Each reviewer applied the eligibility criteria outlined in Section 3.2 to ensure consistency and reduce potential bias. All screening decisions were recorded in a shared Excel file, where inclusion and exclusion rationales were documented to ensure transparency and traceability throughout the process. Full texts were then reviewed for relevance and conceptual depth. We resolved disagreements on study selection and data extraction by consensus and discussion with other reviewers when needed. A PRISMA flow diagram will illustrate this selection process (Figure 2.2).

Figure 2.2: PRISMA Flow Diagram. *Source:* Authors' own work.



2.3.6 Data charting process

Data from each selected paper were recorded in a structured Excel sheet. Each record included fields for terminology, presence of definitions, conceptual alignment, and emergent insights. Three researchers charted the data independently and reconciled differences via regular meetings to maintain consistency.

2.3.7 Data items

For each article, we captured: bibliographic details (author, year, journal); keywords; whether the article aligned the construct with EE, IE, both, or left the relationship undefined; the nature of the conceptual relationship; any theoretical rationale supporting their interpretation; and all the properties derived from complex systems theory that ecosystems exhibited. Additional columns in the Excel sheet were created to record the way each study described the relationship between EEs and IEs and to capture references to ecosystem properties derived from complex systems theory.

2.3.8 Critical appraisal of individual sources of evidence

The quality of the evidence from the studies was assessed to verify the adequacy of the study design in relation to the research objectives, the elimination of potential biases, and the thorough documentation of the research process. Given the conceptual focus of this review, this evaluation was extended beyond methodological aspects to include theoretical soundness, conceptual rigor, and internal coherence. The aim was not to exclude studies, but to ensure that the selected sources provided sufficient conceptual clarity and theoretical depth to meaningfully inform the synthesis of how EEs and IEs are framed and interrelated. Each contribution was therefore examined with respect to four main aspects:

1. The presence of a clear and explicit definition of the ecosystem construct;
2. The theoretical rationale used to explain or frame the relationship between EEs and IEs;
3. The internal coherence between theoretical assumptions, conceptual arguments, and analytical reasoning;
4. The transparency and completeness with which the research process and reasoning were documented.

This assessment was conducted reflexively throughout the charting and thematic analysis phases, rather than through a formal scoring procedure. Particular attention was devoted to how studies engaged with complex systems theory, assessing whether properties (e.g., adaptability, feedback loops) were employed in a theoretically consistent and meaningful way. The critical assessment thus acted as a qualitative lens for conceptual robustness, guiding the interpretation of results and supporting the development of a coherent and theoretically anchored understanding of how EEs and IEs are conceptualized in the literature.

2.3.9 Synthesis of results

We analyzed results through an inductive thematic process that involved coding article terminology, classifying EE–IE relationships, and identifying emergent ecosystem constructs. Where we identified systematic reviews, we counted the number of studies included in the review that potentially met our inclusion criteria and noted how many studies had been missed by our search. Findings were aggregated into thematic groups, and a conceptual matrix visually represented how these constructs relate to EE and IE frameworks. Finally, we summarized the key patterns and developed a typology of how the literature positions and interrelates EEs and IEs as proposed by Mwangakala et al. (2024).

A summary of the key steps of the employed methodology is provided below, accompanied by a graphic representation of the PRISMA research design (Figure 2.2):

1. Coding data from included articles
2. Categorizing the coding into major themes
3. Building themes
4. Displaying the data
5. Identifying key patterns in the data and identifying sub-categories
6. Summarising the findings

2.4 Results

2.4.1 Descriptive analysis

The final pool of 48 studies[1] comprises 47 journal articles and 1 book chapter, reflecting a predominantly peer-reviewed academic production.

These publications span from 2014 to 2025, despite the initial search query including articles as early as 2005. This time lag is justified by the fact that the EE construct gained conceptual maturity only in the mid-2010s, following the publication of several foundational studies. Among these, the work of Stam (2015) represents a milestone in the field, offering one of the first systematic efforts to conceptualize EEs and define their core components.

As a result, the number of publications begins to intensify from 2014 onward, with a clear acceleration after 2019 and a peak in 2023 (eight publications) and 2024 (seven publications), reflecting the growing academic interest in ecosystem-related research. The studies are distributed across 19 distinct academic journals, highlighting the conceptual fluidity and fragmentation that characterize the field. This fragmentation likely reflects the multidimensional nature of ecosystem research, which spans innovation studies, entrepreneurship, regional development, and technology management.

While no single outlet dominates the field, some journals appear more frequently than others. *The Journal of Innovation & Knowledge* hosts four articles, followed by *R&D Management* and the *Journal of Open Innovation: Technology, Market, and Complexity*, each with three articles. Other journals with at least two publications include the *Technology Innovation Management Review*, the *Journal of Business Research*, and *Growth and Change*

2.4.2 Thematic classification of nested configurations from the selected literature

To interpret how the literature articulates the relationship between EEs and IEs, the 48 eligible studies were thematically classified. This process led to the identification of four distinct configurations that integrate elements from both EEs and IEs: i) startup ecosystems, ii) entrepreneurial university ecosystems, iii) entrepreneurial innovation ecosystems, and iv) regional innovation ecosystems. The list of contributions identified within each configuration is presented in Table 2.3.

[1] The full list of selected articles is provided in the Appendix B, Table B.1.

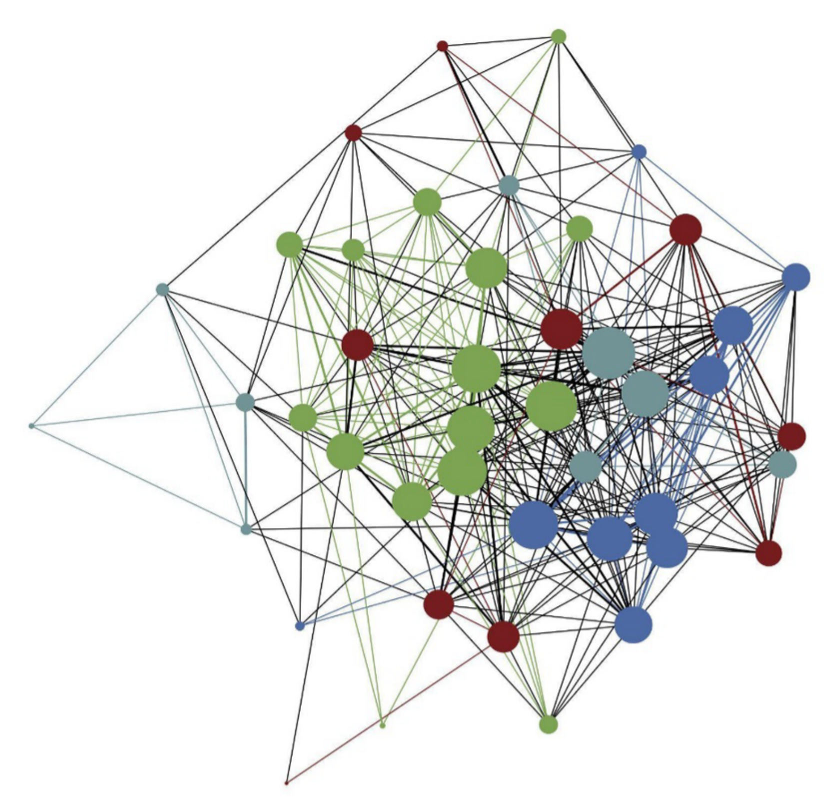
Table 2.3: Thematic classification of nested configurations. *Source:* Authors' own work.

Thematic groups	Articles
Startup Ecosystems	(Ancona et al., 2023; Baloutsos et al., 2020; Berger & Kuckertz, 2016; Corvello, Cimino, & Felicetti, 2023; Corvello, Felicetti, et al., 2023; Eslamloo et al., 2025; Haines, 2016; Krishnan & Krishna, 2024; Marcon & Ribeiro, 2021; Motoyama & Knowlton, 2017; Ojaghi et al., 2019; Primario et al., 2024; Saccol Filho et al., 2023; Singh et al., 2019; Ziakis et al., 2022)
Entrepreneurial University Ecosystems	(Abreu & Grinevich, 2024; Alam et al., 2024; Guerrero et al., 2020; Johnson et al., 2019; Kwong et al., 2022; Lahikainen et al., 2018; Prokop, 2021; Schäeffer et al., 2021; Tejero et al., 2019; L. D. Thomas et al., 2018)
Entrepreneurial Innovation Ecosystems	(Audretsch et al., 2023; Autio et al., 2014; Ferreira et al., 2023; Guerrero & Martínez-Chávez, 2020; Leceta & Könnölä, 2019; Ozkan et al., 2023; Shashlo et al., 2018; Vargas & Arias, 2022; Vettik-Leemet & Mets, 2024)
Regional Innovation Ecosystems	(Bramwell et al., 2019; Carayannis et al., 2017; Cooke, 2016; Farinha et al., 2018; Freire-Gibb & Gregson, 2019; Fu & Qian, 2023; Kraus et al., 2021; López-Rubio et al., 2020; Markkula & Kune, 2015; Nieth et al., 2018; Pidorycheva et al., 2020; Radziwon et al., 2017; E. Thomas et al., 2020)

The classification was carried out inductively, organizing studies according to their central themes and focus. For each cluster, we identified whether the literature primarily engaged with EE concepts, IE concepts, or treated both domains equally. This helped assess the degree of conceptual balance or dominance in each configuration. To interpret how nested configurations between EEs and IEs are articulated in the literature, we introduce a classification grounded in two analytical dimensions. The first concerns what we define as the logic of nestedness, that is, whether the ecosystem is primarily engaging with the EE or IE literature. In particular, in entrepreneurial-nested configurations, innovation is embedded within entrepreneurial dynamics. By contrast, in innovation-nested configurations, entrepreneurship is incorporated within broader innovation structures. The second dimension captures the type of systemic complexity. In particular, we aim to determine whether complex dynamics observed across different configurations predominantly emerge from micro-level interactions (bottom-up complexity) or are driven by macro-level structures and interventions (top-down complexity). To do so, all studies are analyzed through the lens of complex systems theory, assessing how the properties outlined in Table 2.1 - namely, adaptability and resilience (ADRES), feedback loops and complex causation (FLCC), heterogeneity (HET), nonlinearity and co-evolution (NLCE), sensitivity to initial conditions and path-dependence (SIPD), and self-organization (SORG) - are addressed within each configuration.

Before delving into the discussion of the four nested configurations, we present an analysis of selected papers based on keyword co-occurrence. In particular, Figure 2.3 displays a network where each node represents a paper from our final selection , and links between nodes indicate the co-occurrence of one or more keywords shared between the corresponding papers.

Figure 2.3: Network of selected papers based on keyword co-occurrence. Node colors represent different ecosystem configurations: blue nodes correspond to the *Entrepreneurial University Ecosystem* group; red nodes to the *Regional Innovation Ecosystem* group; green nodes to the *Startup Ecosystem* group; and sky blue/light grey nodes to the *Entrepreneurial Innovation Ecosystem* group. *Source:* Authors' own work.



Accordingly, node size reflects the degree of each node - that is, the number of connections it has within the network - and thus indicates the extent of potential thematic overlap with other contributions. Similarly, edge weight is proportional to the number of keywords shared between any two papers.

To enhance interpretability, nodes are colored according to the different configurations to which they belong[2], while edges are colored to reflect intra-cluster (green, blue, sky-blue/light grey, or red) or inter-cluster (black) connections. In this way, we are able to visualize the thematic overlaps both within and across configurations. As Figure 2.3 clearly illustrates, the majority of links are black (63.4%), indicating a substantial level of thematic nestedness between the different conceptual clusters and a notable degree of fuzziness at their intersections. This observation reinforces the rationale for conducting this scoping review. In particular, the clusters related to startup ecosystems and entrepreneurial university ecosystems exhibit high levels of internal connectivity, with subnetwork densities[3] of 64.8% and 73.3%, respectively - clearly visible through the prevalence of green and blue intra-cluster links. In contrast, the clusters corresponding to entrepreneurial innovation ecosystems and regional innovation ecosystems are more weakly connected internally, with subnetwork densities of 41.7% and 26.7%, respectively. This suggests that the concepts of startup

[2]Geen nodes represent papers within the startup ecosystem thematic group; blue nodes correspond to the entrepreneurial university ecosystem group; sky blue/light grey nodes indicate the entrepreneurial innovation ecosystem group; and red nodes represent papers within the regional innovation ecosystem thematic group.

[3]Network density is computed as the ratio between the actual number of links and the maximum possible number of ties among nodes in the network.

ecosystems and entrepreneurial university ecosystems are comparatively more mature and better defined in the literature, whereas the notions of entrepreneurial innovation ecosystems and regional innovation ecosystems are still emerging and less conceptually consolidated. Further discussion of these patterns and their possible implications is provided in the following sections.

Startup Ecosystems: entrepreneurial-nestedness and bottom-up complexity

The selected literature on startup ecosystems portrays them as emergent, dynamic, and interaction-driven configurations, where innovation unfolds through adaptive behavior and mutual learning. A key insight across studies is that these ecosystems function without centralized control, relying instead on informal mechanisms and feedback loops. Several contributions highlight the centrality of network structures and fluid relational patterns in shaping the ecosystem dynamics. Ancona et al. (2023) and Motoyama and Knowlton (2017) emphasize the embeddedness of startups in locally evolving networks. In these studies, actors continuously adapt their ties and strategies in response to contextual shifts, allowing the ecosystem to evolve in non-linear ways. Singh et al. (2019), through social media analytics, reinforce this idea by showing how digital interactions trace dynamic shifts in attention, influence, and collaboration, mapping real-time transformations in entrepreneurial behavior. Another set of studies focuses on the interface between startups and institutional or corporate actors, particularly where intermediation plays a crucial role. Corvello, Cimino, and Felicetti (2023) explore how acceleration capabilities support startups' development by fostering iterative learning and strategic flexibility. Corvello, Felicetti, et al. (2023) extend this perspective to corporate-startup collaboration units, where knowledge brokering and informal bridging mechanisms replace structured governance. Baloutsos et al. (2020) similarly explore contradictions between startups and incumbents, illustrating how tensions stimulate transformation rather than breakdown - fueling ecosystem evolution through iterative feedback loops. In contrast, studies like Berger and Kuckertz (2016) and Haines (2016) examine the social and geographic embeddedness of startup activity. The first study shows how gendered pathways to entrepreneurship emerge in varying cultural contexts, influenced by informal support systems. The second research describes the formation of a startup ecosystem in a peripheral region of Australia, where sparse institutional support fosters improvisation, self-reliance, and locally grounded innovation pathways. A number of contributions emphasize adaptation and self-organization over time. Marcon and Ribeiro (2021) examine how startups reconfigure their external resource use as they evolve, while Marcon et al. (2024) explore how market contingencies reshape ecosystem behavior. Both highlight the non-linear nature of start-up development, where each strategic move recalibrates the surrounding ecosystem. Other works focus on frameworks and measurement tools that conceptualize the ecosystem as inherently open and evolving. Ojaghi et al. (2019) propose a synthesized model that captures diverse actor constellations and their emergent alignments, while Ziakis et al. (2022) offer an empirical conceptualization emphasizing configurational diversity. Saccol Filho et al. (2023) take a more instrumental approach, introducing metrics that reflect the indirect effects of interaction intensity, diversity, and support mechanisms on ecosystem competitiveness. Primario et al. (2024) provide a unique view into peer-based open innovation, where collaboration and competition coexist in dynamic balance. Their findings reveal how startups mutually adjust without pre-defined roles, fostering spontaneous alignment over time. Notably, Krishnan and Krishna (2024) offer a more holistic synthesis, noting how startups function as catalysts of innovation within broader ecosystems. In this vein, the innovation dynamics are embedded within the context of the startup ecosystem, though they do not act as the engine of entrepreneurial behaviors. Finally, Eslamloo et al. (2025) demonstrate how the effectiveness of startup accelerators varies across institutional environments. Their comparative analysis illustrates how ecosystem maturity and contextual factors shape adaptive patterns. Across all studies, a set of core complex system properties emerges, as summarized in Table 2.4. Adaptability is reflected in how startups and intermediaries respond to shifting conditions. Feedback loops - whether in digital discourse, accelerator models, or learning cycles - can potentially enable collective virtuous cycles. Heterogeneity across actor types and strategies promotes resilience and innovation. Non-linearity is a shared trait, evident in the unpredictable trajectories of all the actors interacting in the ecosystem, despite a certain degree of path-dependence and sensitivity to cultural, social, and geographical conditions emerge. Most prominently, self-organization is consistently present: ecosystems evolve through localized interactions, reciprocal adjustments, and shared experimentation, rather than formalized policy interventions. This aligns with the characterization of startup ecosystems as entrepreneurial-nested systems exhibiting bottom-up complexity, where innovation is not imposed by design but continuously shaped by interaction, context, and emergence.

Table 2.4: Characterization of the startup ecosystem configuration

Authors	Year	Title	EE	IE	Complex Systems Properties
Ancona et al.	2023	Network-based principles of entrepreneurial ecosystems: A case study of a start-up network	x		ADRES, FLCC, HET, NLCE, SORG
Baloutsos et al.	2022	Identifying contradictions in an incumbent–startup ecosystem – an activity theory approach	x	x	ADRES, FLCC, HET, NLCE, SORG
Berger and Kuckertz	2016	Female entrepreneurship in startup ecosystems worldwide	x		ADRES, FLCC, NLCE, SIPD, SORG
Corvello et al.	2023a	Building start-up acceleration capability: A dynamic capability framework for collaboration with start-ups	x		ADRES, FLCC, NLCE, SORG
Corvello et al.	2023b	Start-up collaboration units as knowledge brokers in Corporate Innovation Ecosystems: A study in the automotive industry	x	x	ADRES, FLCC, NLCE, SORG
Eslamloo et al.	2025	Successful commercialisation in startup accelerator programmes: How different startup ecosystems matter	x	x	ADRES, FLCC, HET, NLCE, SORG
Haines	2016	Developing a Startup and Innovation Ecosystem in Regional Australia	x	x	ADRES, FLCC, HET, NLCE, SIPD, SORG
Krishnan and Krishna	2024	Introduction: Start-ups and innovation ecosystems	x	x	ADRES, FLCC, HET, NLCE, SORG
Marcon and Duarte Ribeiro	2021	How do startups manage external resources in innovation ecosystems? A resource perspective of startups' lifecycle	x	x	ADRES, FLCC, HET, NLCE, SORG
Marcon et al.	2024	How the interplay between innovation ecosystems and market contingency factors impacts startup innovation	x	x	ADRES, FLCC, HET, NLCE, SORG
Motoyama and Knowlton	2017	Examining the connections within the startup ecosystem: A case study of St. Louis	x		ADRES, FLCC, NLCE, SORG
Ojaghi et al.	2019	A synthesized framework for the formation of startups' innovation ecosystem: A systematic literature review	x	x	ADRES, FLCC, HET, NLCE, SORG
Primario et al.	2024	Peer innovation as an open innovation strategy for balancing competition and collaboration among technology start-ups in an innovation ecosystem	x	x	ADRES, FLCC, HET, SORG
Saccol Filho et al.	2024	A measurement tool for the competitiveness of startups' innovation ecosystem	x	x	ADRES, FLCC, HET, NLCE, SORG
Singh et al.	2020	Analyzing the startup ecosystem of India: A Twitter analytics perspective	x		ADRES, FLCC, NLCE, SORG
Ziakis et al.	2022	Start-Up Ecosystem (StUpEco): A conceptual framework and empirical research	x		ADRES, FLCC, NLCE, SORG

Notes: EE = entrepreneurial ecosystem; IE = innovation ecosystem. ADRES = adaptability and resilience; FLCC = feedback loops and complex causation; HET = heterogeneity; NLCE = non-linearity and co-evolution; SIPD = sensitivity to initial conditions and path-dependence; SORG = self-organization.

Entrepreneurial University Ecosystems: entrepreneurial-nestedness and top-down complexity

The literature on entrepreneurial university ecosystems portrays them as structured environments where entrepreneurial activity is institutionalized through deliberate policy choices, strategic infrastructures, and actor engagement. Yet, these ecosystems remain dynamic, adaptive, and actor-driven.

Notably, several contributions emphasize how strategy and structure emerge through ongoing negotiation within the university setting. Abreu and Grinevich (2024) illustrate how entrepreneurial strategies are continuously shaped by competing institutional goals, such as balancing research excellence with revenue generation, revealing internal tensions and adaptive recalibration. Similarly, Alam et al. (2024) identify multiple success drivers in entrepreneurial university ecosystems, including leadership, culture, and inter-organizational collaboration, whose effects are contingent on local configurations and continuous actor interactions. Other studies focus on the interplay between formal educational programs and evolving career patterns. Guerrero et al. (2020), for instance, demonstrate how entrepreneurship education and business incubators contribute to long-term graduate outcomes, with impact shaped by contextual responsiveness and evolving student trajectories. In parallel, Johnson et al. (2019) examine how physical and organizational infrastructure influences entrepreneurial dynamism, revealing a mutual shaping between material resources and entrepreneurial behavior. Kwong et al. (2022) bring attention to variation in the implementation of social entrepreneurship courses across institutions. Their findings point to institutional path-dependency, where seemingly similar initiatives diverge due to differences in university culture, support systems, and external pressures. In contrast, Lahikainen et al. (2018) uncover how well-intentioned policy interventions may be hindered by organizational rigidity, slow uptake, and inconsistent actor engagement—highlighting friction within otherwise formalized systems. When it comes to spin-off generation and commercialization, Prokop (2021) offers a detailed account of how support mechanisms evolve across time, adapting to new demands and feedback from the entrepreneurial process. Similarly, Schäeffer et al. (2021) frame university-industry relationships as mutualistic, showing how the evolution of these linkages is shaped by bidirectional learning, role flexibility, and co-adaptation. Tejero et al. (2019) highlight how entrepreneurial roles within universities are enacted differently across departments and disciplines. Their assessment reveals internal differentiation and the importance of informal routines in shaping formal mechanisms. L. D. Thomas et al. (2018), meanwhile, present a case where EEs and IEs converge, documenting how shared goals, produce a dynamic yet institutionally grounded ecosystem.

Across these studies, entrepreneurial university ecosystems emerge as configurations where formalized policies and infrastructures provide a stable testing ground for entrepreneurial behavior, but outcomes are not predetermined. Rather, they are shaped by the interaction of actors (i.e., research institutions and start-up; universities and corporations) and contextual contingencies. The ecosystems exhibit characteristics such as responsiveness to feedback, internal differentiation, and emergent trajectories driven by evolving actor constellations. In this vein, the complexity and non-linearity arise at the macro-level, with path-dependent mechanisms strictly related to institutional frameworks. Thus, while the formalization is high, anchored in university structures and policy instruments, the entrepreneurial dynamics remain locally enacted and non-linear. This dual nature confirms the positioning of entrepreneurial university ecosystems as entrepreneurial-nested systems driven by top-down complex dynamics. Such characterization is summarized in Table 2.5.

Table 2.5: Characterization of the entrepreneurial university ecosystem configuration

Authors	Year	Title	EE	IE	Complex Systems Properties
Abreu and Grinevich	2024	The entrepreneurial university: strategies, processes, and competing goals	x		ADRES, FLCC, NLCE
Alam et al.	2023	Success Components of University Entrepreneurial Ecosystem: A Multimethod Exploration	x		ADRES, FLCC, NLCE
Guerrero et al.	2020	Entrepreneurial university ecosystems and graduates' career patterns: do entrepreneurship education programmes and university business incubators matter?	x		ADRES, FLCC, NLCE
Johnson et al.	2019	Entrepreneurial dynamism and the built environment in the evolution of university entrepreneurial ecosystems	x		ADRES, FLCC, NLCE
Kwong et al.	2022	How entrepreneurial are social entrepreneurship education providers? The role of universities' entrepreneurial ecosystems in the provision of elective social entrepreneurship courses to business students	x		ADRES, FLCC, NLCE, SIPD
Lahikainen et al.	2019	Challenges to the development of an entrepreneurial university ecosystem: The case of a Finnish university campus	x		ADRES, FLCC, NLCE
Prokop	2021	University entrepreneurial ecosystems and spinoff companies: Configurations, developments and outcomes	x		ADRES, FLCC, HET, NLCE
Rücker Schaeffer et al.	2021	Mutualism in ecosystems of innovation and entrepreneurship: A bidirectional perspective on universities' linkages	x	x	ADRES, FLCC, HET, NLCE
Tejero et al.	2019	Analysis of the Dynamism in University-Driven Innovation Ecosystems Through the Assessment of Entrepreneurship Role	x	x	ADRES, FLCC, HET, NLCE
Thomas et al.	2018	Linking entrepreneurial and innovation ecosystems: The case of AppCampus	x	x	ADRES, FLCC, HET, NLCE

Notes: EE = entrepreneurial ecosystem; IE = innovation ecosystem. ADRES = adaptability and resilience; FLCC = feedback loops and complex causation; HET = heterogeneity; NLCE = non-linearity and co-evolution; SIPD = sensitivity to initial conditions and path-dependence; SORG = self-organization.

Entrepreneurial Innovation Ecosystems: innovation-nestedness and bottom-up complexity

The literature on entrepreneurial innovation ecosystems reveals dynamic and context-sensitive structures where innovation is deeply embedded within entrepreneurial processes, and where coordination unfolds with limited formal regulation. These systems are shaped by local contingencies, emergent dynamics, and multi-actor interactions that reinforce adaptability and learning.

Initially, Autio et al. (2014) set the conceptual foundations by arguing that innovation should be viewed through entrepreneurial lenses, emphasizing how outcomes arise from context-dependent, interactive, and path-dependent processes. The "entrepreneurial innovation" perspective underlines the ecosystem's non-linear evolution and its capacity to self-adapt and organize through local feedback. Building on this, Ferreira et al. (2023) demonstrate how entrepreneurial innovation ecosystems address technological and social challenges by leveraging the complementarities of diverse actors. Their findings highlight the ecosystem's responsiveness to complexity through collective sense-making and flexible coordination, underscoring its adaptive and self-organized configuration. Likewise, Leceta and Könnölä (2019), reflecting on the European Institute of Innovation and Technology, show how strategic experimentation and the heterogeneous group of actors within the ecosystem should benefit from greater autonomy and more informal, flexible policy frameworks in order to operate more effectively. Their case illustrates that self-organization and heterogeneity are not only tolerated but are integral to entrepreneurial innovation ecosystem vitality. Concurrently, Guerrero and Martínez-Chávez (2020) examine how regional and business strategies co-evolve in the Basque Country ecosystem. Their work brings attention to feedback loops between institutional actors and firms, revealing how systemic realignment emerges over time in response to contextual shifts. Moreover, Ozkan et al. (2023) explore how next-generation technologies are absorbed into entrepreneurial innovation ecosystems, showing how new actors and entrepreneurial ideas are incorporated through continuous recombination. Their insights reflect the system's non-linearity and capacity to generate novel outputs from unpredictable configurations. Comparably, Vargas and Arias (2022) illustrate the Guadalajara tech ecosystem's capacity to register feedback mainly from the failures and the lessons learned by the entrepreneurs. In this sense, innovation emerges bottom-up, driven by entrepreneurial employees whose contributions reshape the local landscape as a clear case of adaptation and self-organization. On a broader scale, Shashlo et al. (2018) analyze macro-regional entrepreneurial innovation ecosystems and emphasize the importance of mutualism and co-evolution. Rather than relying on imposed structures, integration occurs via shared incentives and networked interdependence, again reinforcing the role of feedback loops. Additionally, Audretsch et al. (2023) argue that even in weak institutional environments, entrepreneurial innovation ecosystems can thrive when they align sustainability-oriented values with flexible governance. Their findings echo the importance of learning mechanisms and contextual adaptability in driving long-term innovation performance. Finally, Vettik-Leemet and Mets (2024) synthesize the overlap between entrepreneurial and innovation processes into a convergent process-dynamic model within entrepreneurial innovation ecosystems. Their work conceptualizes the ecosystem as an iterative, emergent cycle - shaped by actor interactions, contingent opportunities, and continuous renewal. In particular, the venture creation process within innovative entrepreneurship is both entrepreneurial and an innovation process.

Across these studies, entrepreneurial innovation ecosystems emerge as configurations where innovation is deeply embedded within entrepreneurial dynamics, yet not steered by rigid institutional frameworks. These ecosystems evolve through bottom-up complex dynamics, where actor heterogeneity, context sensitivity, and feedback loops generate emergent and often unpredictable innovation patterns. Despite the absence of centralized control or strong formal governance, these systems exhibit coherence through adaptive learning, mutual adjustment, and recurring recombination of resources and roles. The low formalization allows for experimentation and responsiveness, while the innovation-nested structure ensures that entrepreneurial action is continuously oriented toward technological and societal transformation. This duality leads to the classification of entrepreneurial innovation ecosystems as innovation-nested configurations characterized by bottom-up complexity. This characterization is summarized in Table 2.6.

Table 2.6: Characterization of the entrepreneurial innovation ecosystem configuration

Authors	Year	Title	EE	IE	Complex Systems Properties
Audretsch et al.	2023	Sustainable orientation management and institutional quality: Looking into European entrepreneurial innovation ecosystems	x	x	ADRES, FLCC, HET, NLCE, SORG
Autio et al.	2014	Entrepreneurial innovation: The importance of context	x	x	ADRES, FLCC, NLCE, SORG
Ferreira et al.	2023	The role of entrepreneurial ecosystems in technological and social challenges	x	x	ADRES, FLCC, HET, NLCE, SORG
Guerrero and Martínez-Chávez	2020	Aligning regional and business strategies: Looking inside the Basque Country entrepreneurial innovation ecosystem	x	x	ADRES, FLCC, HET, NLCE, SORG
Leceta and Könnölä	2021	Fostering entrepreneurial innovation ecosystems: Lessons learned from the European Institute of Innovation and Technology	x	x	ADRES, FLCC, HET, NLCE, SIPD, SORG
Ozkan et al.	2023	The Next Generation of Innovation	x	x	ADRES, FLCC, HET, NLCE, SORG
Rivera Vargas and de León Arias	2022	The entrepreneurial ecosystem of Guadalajara, Jalisco, Mexico: Its technology-based and fast-growing startups and entrepreneurial-employees	x	x	ADRES, FLCC, HET, NLCE, SORG
Shashlo et al.	2018	Determinants of integration interaction among the subjects of the entrepreneurial innovation ecosystem of macro region	x	x	ADRES, FLCC, HET, NLCE, SIPD, SORG
Vettik-Leemet and Mets	2024	Entrepreneurship and Innovation—Process Overlap or the Same? Systematic Overview and Converging Process-Dynamic Model	x	x	ADRES, FLCC, HET, NLCE, SORG

Notes: EE = entrepreneurial ecosystem; IE = innovation ecosystem. ADRES = adaptability and resilience; FLCC = feedback loops and complex causation; HET = heterogeneity; NLCE = non-linearity and co-evolution; SIPD = sensitivity to initial conditions and path-dependence; SORG = self-organization.

Regional Innovation Ecosystems: innovation-nestedness and top-down complexity

Regional innovation ecosystems emerge in the literature as highly structured yet dynamic configurations in which innovation is deeply embedded within institutional and territorial frameworks. A common theme is the role of formalized infrastructures - such as public agencies, universities, and policy instruments - in enabling innovation while accommodating evolving actor interactions and localized adaptations.

For instance, Bramwell et al. (2019) examine public intermediaries in Canada and highlight how these agents enable learning and adaptive responses through policy experimentation and regional coordination. Similarly, Freire-Gibb and Gregson (2019), focusing on Latin America, emphasize the interplay between institutional design and entrepreneurial agency, suggesting that ecosystems are shaped by iterative engagement among diverse actors across multiple governance levels. The central role of institutions is assumed to shape the ecosystem due to historical path-dependencies of both regions and countries. Carayannis et al. (2017) propose a theoretical framing of regional innovation ecosystems using the Quadruple/Quintuple Helix model, pointing to the fluid co-existence of academia, industry, government, and civil society. This reflects a non-linear pattern of interaction, where new innovation trajectories emerge through recombination of knowledge from heterogeneous actors. In the same vein, Cooke (2016) underscores the importance of variety in regional systems—arguing that institutional diversity fosters adaptability and both path dependency and path-creating trajectories. Building on this, Farinha et al. (2018) explore the concept of entrepreneurial embeddedness, showing how regional ecosystems co-evolve with the entrepreneurial activities they host. Nieth et al. (2018) reinforce this by focusing on effectual discovery processes, where entrepreneurs navigate uncertain environments through trial-and-error learning, grounded in regional innovation ecosystems. Fu and Qian (2023) provide an empirical comparison between startups and incumbents, revealing that startups tend to leverage informal networks and agile responses, while incumbents benefit more from formal policy structures. This coexistence of formal and informal mechanisms illustrates the ecosystem's internal differentiation. E. Thomas et al. (2020) take a complementary angle, showing how universities act as orchestrators of ecosystem development in emerging economies, channeling resources and partnerships toward evolving regional needs. In this vein, the orchestration process is primarily top down, and emerges when universities formally take on leadership positions within the regional innovation ecosystems. López-Rubio et al. (2020) trace the evolution of the regional innovation system research and demonstrate how knowledge management practices have become central to ecosystem effectiveness. Meanwhile, Kraus et al. (2021) identify knowledge as a key driver in linking entrepreneurship with regional development outcomes, pointing to a recursive process of knowledge accumulation and application. Radziwon et al. (2017) highlight the value co-creation among SMEs in manufacturing contexts, showing how collaborative solutions arise not from top-down mandates but from shared practices and iterative adjustments. Similarly, Markkula and Kune (2015) discuss how smart specialization strategies can enhance regional innovation, stressing the orchestrating role of universities in aligning place-based assets with innovation pathways. However, the success of these regions is strongly related to the previous innovation capacity that they exhibited. Lastly, Pidorycheva et al. (2020) offer a conceptual model for regional innovation ecosystems, reinforcing the need for a tailored regional policy coherence, actor alignment, and adaptive capabilities to sustain innovation competitiveness over time.

Across these studies, regional innovation ecosystems are depicted as ecosystems governed by institutional frameworks, policy logic, and formalized roles, yet animated by emergent dynamics, actor interdependence, and regional specificities. Innovation is deeply nested in these territorial configurations, and although the systems are highly formalized, the outcomes remain contingent on context-sensitive learning, feedback loops, and collective adaptation. Moreover, sensitivity to initial conditions frequently emerges, as historical trajectories and early policy or investment decisions exert a lasting influence on ecosystem paths and actor behavior, reflecting the regional development roots of such systems. This leads to the characterization of regional innovation ecosystems (summarized in Table 2.7) as innovation-nested systems shaped by top-down complexity, where innovation - though influenced by emerging regional dynamics - is primarily driven by institutional arrangements.

Table 2.7: Characterization of the regional innovation ecosystem configuration

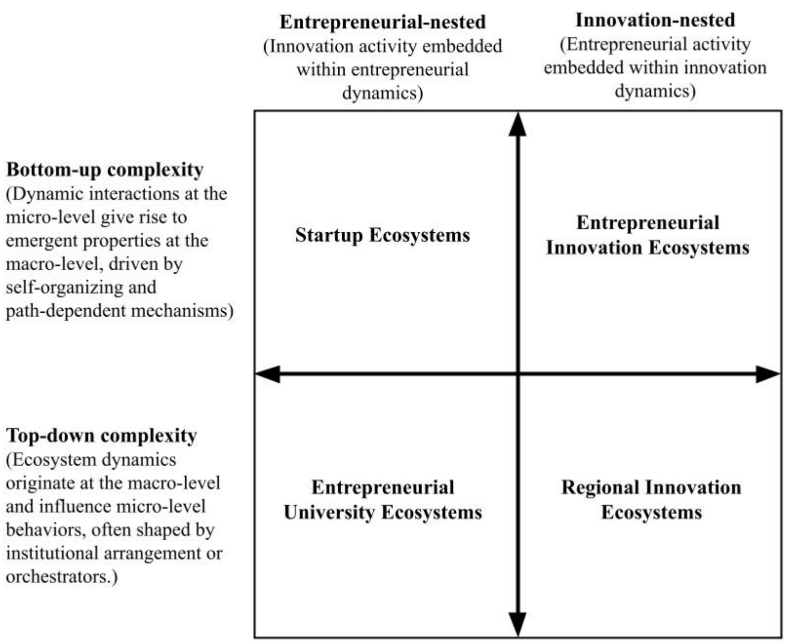
Authors	Year	Title	EE	IE	Complex Systems Properties
Bramwell et al.	2019	Growing entrepreneurial ecosystems: Public intermediaries, policy learning, and regional innovation	x	x	ADRES, FLCC, HET, NLCE, SIPD
Carayannis et al.	2018	The ecosystem as helix: an exploratory theory-building study of regional co-opetitive entrepreneurial ecosystems as Quadruple/Quintuple Helix Innovation Models	x	x	ADRES, FLCC, HET, NLCE, SIPD
Cooke	2016	The virtues of variety in regional innovation systems and entrepreneurial ecosystems	x	x	ADRES, FLCC, HET, NLCE, SIPD
Farinha et al.	2018	Regional innovation systems and entrepreneurial embeddedness	x	x	ADRES, FLCC, HET, NLCE, SIPD
Freire-Gibb and Gregson	2019	Innovation systems and entrepreneurial ecosystems: Implications for policy and practice in Latin America	x	x	ADRES, FLCC, HET, NLCE, SIPD
Fu and Qian	2023	Building innovative capacity in regional entrepreneurship and innovation (eco)systems: Startups versus incumbent firms	x	x	ADRES, FLCC, HET, NLCE, SIPD
Kraus et al.	2021	The role of innovation and knowledge for entrepreneurship and regional development	x	x	ADRES, FLCC, HET, NLCE, SIPD
López-Rubio et al.	2020	Regional innovation system research trends: toward knowledge management and entrepreneurial ecosystems	x	x	ADRES, FLCC, HET, NLCE, SIPD
Markkula and Kune	2015	Making Smart Regions Smarter: Smart Specialization and the Role of Universities in Regional Innovation Ecosystems		x	ADRES, FLCC, HET, NLCE, SIPD
Nieth et al.	2018	Embedding entrepreneurial regional innovation ecosystems: reflecting on the role of effectual entrepreneurial discovery processes	x	x	ADRES, FLCC, HET, NLCE, SIPD
Pidorycheva et al.	2020	A Conceptual Framework for Developing of Regional Innovation Ecosystems		x	ADRES, FLCC, HET, NLCE, SIPD
Radziwon et al.	2017	Creating and capturing value in a regional innovation ecosystem: A study of how manufacturing SMEs develop collaborative solutions		x	ADRES, FLCC, HET, NLCE, SIPD
Thomas et al.	2021	Universities as orchestrators of the development of regional innovation ecosystems in emerging economies		x	ADRES, FLCC, HET, NLCE, SIPD, SORG

Notes: EE = entrepreneurial ecosystem; IE = innovation ecosystem. ADRES = adaptability and resilience; FLCC = feedback loops and complex causation; HET = heterogeneity; NLCE = non-linearity and co-evolution; SIPD = sensitivity to initial conditions and path-dependence; SORG = self-organization.

2.4.3 Classification of nested configurations

Based on the discussion above regarding the four configurations identified at the intersection of EEs and IEs, we introduce a classification of these nested configurations along two key dimensions: the logic of nestedness and the level of complexity. In particular, we classify startup ecosystems, entrepreneurial university ecosystems, entrepreneurial innovation ecosystems, and regional innovation ecosystems based on whether they are predominantly entrepreneurial- or innovation-nested, and whether they exhibit bottom-up or top-down systemic complexity. The outcome of this classification is illustrated in Figure 2.4.

Figure 2.4: Classification of nested configurations.



As it is possible to notice, startup ecosystems and entrepreneurial university ecosystems are characterized as entrepreneurial-nested configurations, in which innovation activity is primarily driven by entrepreneurial logics. In both cases, innovation strategies are typically growth-oriented and orchestrated by entrepreneurial actors. In the former, startups catalyze innovation activities around entrepreneurial principles; in the latter, universities play a central role by aligning research and educational programs with an entrepreneurial culture. Conversely, entrepreneurial innovation ecosystems and regional innovation ecosystems emerge as innovation-nested configurations, where entrepreneurship is embedded within broader and more formal innovation infrastructures, typically shaped by policies and regulatory frameworks. In the former configuration, entrepreneurial outcomes are closely related to context-dependent innovation systems, while in the latter, entrepreneurial activity is continuously affected by the interplay between institutional arrangements and market opportunities. The complexity dimension enriches the understanding of these configurations, clarifying whether their systemic dynamics primarily emerge from micro-level interactions (bottom-up complexity), driven by effectuation logics - more adaptive in identifying and capturing emergent opportunities - or are instead shaped by macro-level structures and interventions (top-down complexity), reflecting a causation, goal-driven logics centered on coordinated strategies. In startup ecosystems and entrepreneurial innovation ecosystems, dynamic interactions and non-linear relationships among heterogeneous actors give rise to self-organizing mechanisms at the ecosystem level. These mechanisms reflect a predominant effectuation logic that is opportunity-driven and guided by iterative learning. By contrast, entrepreneurial university ecosystems and regional innovation ecosystems exhibit complexity that emerges from institutional arrangements and policy frameworks. Their dynamics are often shaped by path-dependent mechanisms rooted in historical trajectories and align with a causation- and goal-oriented logic. Thus, startup ecosystems and regional innovation ecosystems show internal coherence across both dimensions, aligning respectively with EE and IE paradigms. More nuanced insights emerge from the classification of entrepreneurial university ecosystems and entrepreneurial innovation ecosystems. Despite their formal structures - anchored in universities and supported by policy instruments - entrepreneurial university ecosystems demonstrate locally enacted, non-linear entrepreneurial dynamics. On the other hand, although entrepreneurial innovation ecosystems prioritize innovation objectives, their complex dynamics arise primarily from local interactions, feedback loops, and adaptive learning processes rather than centralized coordination. The dual nature of these two configurations makes them the most highly nested systems among the four emerging from the literature at the intersection of EE and IE research.

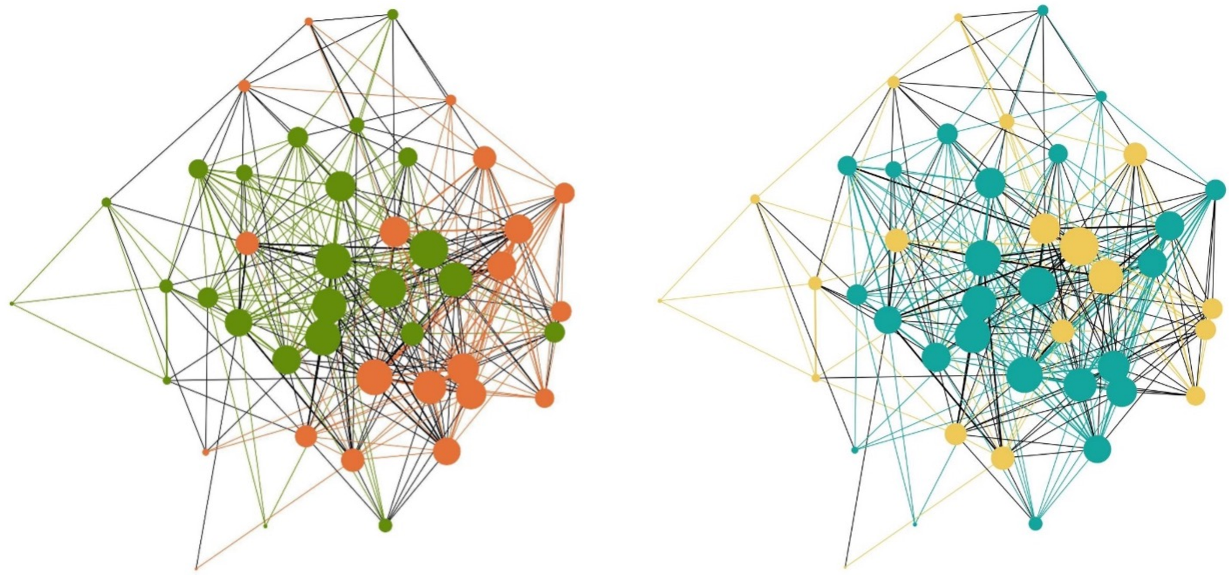
To explore this further, we re-analyzed the network of selected papers based on keyword co-occurrence Figure 2.3, coloring nodes according to the two-dimensional classification introduced above. In Figure 2.5, the left panel differentiates papers based on complexity type (bottom-up vs. top-down), while the right panel reflects the logic of nestedness (entrepreneurial- vs. innovation-nested). Our findings show that inter-cluster connections (edges in black) are more prevalent when considering complexity level (42.9%) than when analyzing nestedness logic (40.3%), suggesting that boundaries are less clearly defined when it comes to the systemic complexity of nested configurations. Regarding subnetwork densities, we observe similar levels for papers addressing bottom-up and top-down complexity (41.7% and 44.7%, respectively). However, a more pronounced difference emerges between the entrepreneurial-nested and innovation-nested groups. The latter appears less internally connected (33.9%) compared to the former (50.9%), suggesting that innovation dynamics are frequently explored in relation to entrepreneurial outcomes, while entrepreneurial processes are more often studied independently of innovation frameworks in the ecosystem literature.

2.5 Toward a Future Research Agenda

Building on the typology of nested configurations and the type of systemic complexity identified, several promising avenues emerge for future research on the interplay between EEs and IEs. These avenues aim to move beyond static taxonomies and toward a deeper understanding of ecosystem dynamics, interrelations, and implications for governance and performance measurement.

First, our analysis of the keyword co-occurrence networks suggests that the concepts of startup ecosystems and entrepreneurial university ecosystems are comparatively more mature and conceptually well-defined in the literature. In contrast, the notions of entrepreneurial innovation ecosystems and regional innovation ecosystems appear to be still emerging and less theoretically consolidated. This highlights a need for future research to further explore and refine these latter configurations - particularly with regard to their systemic complexity - and to move beyond the current focus on

Figure 2.5: Network of selected papers based on keyword co-occurrence. Node colors represent the level of complexity on the left (green nodes correspond to bottom-up complexity; orange nodes to top-down complexity) and the logic of nestedness on the right (aqua green nodes correspond to the entrepreneurial-nested group; yellow nodes to the innovation-nested group). *Source: Authors' own work.*



ecosystem boundaries. Instead, scholars should aim to develop a more integrated discourse that addresses the interconnections, overlaps, and nested relationships across different ecosystem types. A first research direction in this regard concerns the evolutionary processes of nested ecosystems. To what extent do nested configurations follow distinct life-cycles or transition from one archetype to another? Under what conditions do entrepreneurial-nested ecosystems evolve into innovation-nested ones, or vice versa? And how do tipping points, crises, or technological shifts influence these transformations? Future studies could adopt a longitudinal and comparative lens, using life-cycle models or complex adaptive system perspectives to trace the emergence, consolidation, and potential decline of ecosystem configurations. Particular attention could be given to how these evolutionary paths are shaped by initial conditions, feedback loops, or the actions of orchestrators and intermediaries. A second area for exploration relates to the robustness, adaptability, and resilience of nested ecosystems. While all configurations exhibit some form of adaptive behavior, there is limited empirical insight into how these ecosystems respond to external shocks such as economic downturns, technological disruptions, or geopolitical crises. How do ecosystems reconfigure in response to such events? What internal mechanisms - such as heterogeneity, feedback loops, or self-organization - enable recovery and renewal? Comparative case studies across regions or sectors could clarify which types of nested ecosystems are more resilient and which are more vulnerable to external shocks. A further research direction concerns the types of empirical designs needed to unpack these complex interrelations. Qualitative studies could provide rich insights into how nested configurations between EEs and IEs manifest within specific institutional or industrial settings. For instance, case-based research could examine how university entrepreneurial ecosystems evolve toward more innovation-oriented configurations through intensified industry collaboration, or how IEs develop entrepreneurial components through the emergence of spin-offs and technology transfer activities. How these nested configurations emerge and stabilize over time, and under what conditions do they become more or less interconnected? Comparative analyses across sectors such as biotechnology, energy, and creative industries could further clarify how nested configurations vary according to knowledge intensity, regulatory environments, and market dynamics, shedding light on how ecosystems transition from one archetype to another. In this regard, Social Network Analysis represents a powerful methodological approach for quantitatively examining mutual interactions and shifting ecosystem boundaries. Finally, what mechanisms drive these transitions, and how do institutional structures or technological paradigms influence their evolution? Complementarily, configurational approaches such as fuzzy set Qualitative Comparative Analysis could identify the combinations of institutional, technological, and relational conditions that enable the formation or persistence of nested configurations. Which constellations of factors are necessary or sufficient for such configurations to occur, and how do they differ across regions or industries? Another stream of inquiry could focus on the governance of nested ecosystems and the evolution of their coordination structures. How do governance mechanisms adapt over time in ecosystems that span both entrepreneurial and innovation logics? How is orchestration exercised in nested or overlapping systems, and what role do universities or public authorities play in enabling or constraining ecosystem dynamics? Additionally, how does organizational culture evolve in such systems, especially when entrepreneurial informality interacts with institutional formalization? These questions call for deeper engagement with the micro-foundations of ecosystem governance, including actor motivations, institutional embeddedness, and informal coordination routines. Further compelling directions involve the interactions and transitions between different ecosystem types. What are the mechanisms through which startup ecosystems contribute to regional innovation ecosystems? How do entrepreneurial university ecosystems interact with broader IEs? Are there hybrid or layered ecosystems that span multiple logics simultaneously? And how do actors navigate such cross-ecosystem dynamics? Mapping these interactions could clarify how resources, capabilities, and practices circulate across different configurations, leading to convergence, conflict, or co-evolution.

A critical issue that remains underexplored is how to measure the impact and performance of nested ecosystems. Existing indicators often fail to capture the emergent, non-linear, and systemic nature of ecosystem value creation. What alternative metrics could better reflect the dynamic interplay of entrepreneurship and innovation? How can we incorporate real-time analytics, digital trace data, or complexity-sensitive indicators into performance measurement? Can we move beyond static outputs to assess adaptability, learning capacity, and systemic alignment over time? These questions are particularly relevant for policymakers seeking to design evidence-based interventions tailored to specific ecosystem configurations.

Lastly, a largely overlooked but increasingly relevant dimension involves how organizational roles, leadership, coordination processes, and human resource management strategies evolve in nested ecosystems. Key questions include: how do roles such as orchestrators adapt across different ecosystem configurations? What leadership styles and human resource management practices best support learning, adaptability, and cross-organizational collaboration? How do coordination routines align with bottom-up or top-down complexity? And how do institutional logics shape the cultural coherence of nested systems over time?

2.6 Discussion

This study set out to explore the complex relationship between EEs and IEs, aiming to clarify how the literature conceptualizes their interaction and determine whether complex dynamics observed across different configurations predominantly emerge from micro-level interactions (*bottom-up complexity*) or are driven by macro-level structures and interventions (*top-down complexity*).

To this end, two main research questions guided our analysis:

1. *How does the academic literature conceptualize the relationship between innovation ecosystems and entrepreneurial ecosystems, and which nested configurations emerge from their intersection?*

2. *What type of systemic complexity characterizes the nested configurations of innovation and entrepreneurial ecosystems as described in the existing literature?*

To answer these questions, we conducted a scoping review in accordance with the PRISMA-ScR protocol. After screening 3,850 records, we selected 48 eligible studies published between 2005 and 2025 that conceptually engaged with both EE and IE frameworks. We extracted and thematically analyzed these studies to identify typologies of nested configurations and to assess how different complex system properties — *adaptability and resilience, feedback loops and complex causation, heterogeneity, non-linearity and co-evolution, sensitivity to initial conditions and path-dependence, and self-organization* — are addressed within each configuration.

Specifically, we identified four distinct configurations emerging from the nestedness between EEs and IEs, each reflecting a dominant underlying logic: *startup ecosystems*, *entrepreneurial university ecosystems*, *entrepreneurial innovation ecosystems*, and *regional innovation ecosystems*. The first two are classified as entrepreneurial-nested configurations, where innovation activity is embedded within entrepreneurial dynamics and culture. In contrast, the latter two represent innovation-nested configurations, in which entrepreneurial activity is shaped and coordinated within broader innovation frameworks.

This classification offers a structured lens through which to interpret how nested ecosystems integrate entrepreneurial and innovation functions in different ways. Moreover, the systemic complexity of startup ecosystems and entrepreneurial innovation ecosystems is predominantly driven by bottom-up, non-linear dynamics emerging from micro-level interactions and path-dependent processes — features typical of EEs. Conversely, entrepreneurial university ecosystems and regional innovation ecosystems exhibit top-down complexity, where systemic properties largely derive from institutional arrangements and policy frameworks, consistent with the dynamics observed in IEs. Thus, our analysis reveals that the *logic of nestedness* and the *level of systemic complexity* provide valuable lenses for distinguishing among different ecosystem configurations. While startup ecosystems and regional innovation ecosystems align coherently with the entrepreneurial and innovation paradigms, respectively, more nested and complex dynamics characterize entrepreneurial university ecosystems and entrepreneurial innovation ecosystems. Notably, despite their formal institutional frameworks, these latter configurations exhibit bottom-up complexity, driven by local interactions, feedback mechanisms, and adaptive learning. The keyword co-occurrence network further supports these distinctions: papers on entrepreneurial-nested systems are more internally cohesive than those on innovation-nested systems, suggesting a stronger conceptual convergence. Additionally, thematic overlaps are more prominent when comparing systems by their complexity type than by their nestedness logic, indicating fuzzier boundaries in how complexity is framed and operationalized in the literature. These findings highlight the need for greater conceptual clarity in mapping complex system dynamics within nested ecosystem configurations.

Theoretically, this study offers several contributions. First, this logic of nestedness clarifies how EEs and IEs may coexist and interact within a shared configuration, rather than being mutually exclusive. In doing so, we address a gap highlighted in prior research, which notes that although the two ecosystem types are analytically distinct, the nature of their interconnection remains largely unexplored (Scaringella & Radziwon, 2018; L. D. Thomas et al., 2018; Xu & Maas, 2019). Second, we respond to the call for greater use of complex systems theory to investigate the dynamic nature of ecosystems (Cobben et al., 2022; Phillips & Ritala, 2019). While both IEs and EEs are increasingly framed as complex adaptive systems, existing studies rarely explore how complex system properties manifest in nested or intersecting configurations. In this work, we provide a more integrative, systems-based framework for studying ecosystem evolution and interaction. Third, we advance the theoretical understanding of nestedness by reframing it as a dynamic and functional relationship rather than a static structural feature. While previous works have framed ecosystem nestedness in terms of organized groups within particular domains - such as industry-specific communities (e.g., Spigel, 2022) - our approach builds conceptually on Christensen and Rosenbloom (1995) notion of value networks as hierarchically structured systems, where each subsystem is composed of interdependent elements and simultaneously functions as part of a broader system. Accordingly, we argue that nested configurations should not merely be interpreted as sectoral subgroups, but rather as ecosystems that assume the properties of complex systems at a sub-systemic level. These include distinctive forms of self-organization, feedback mechanisms, non-linearity, and adaptability, which characterize each configuration not just in terms of structural embeddedness, but in terms of their dynamic system behavior. Finally, we refine the concept of self-organization by showing how it varies according to the type of systemic complexity. In ecosystems characterized by top-down complexity, such as regional innovation ecosystems or entrepreneurial university ecosystems, self-organization tends to emerge through formal coordination mechanisms, either orchestrated by a focal firm or a university, or embedded in structured policy frameworks. In contrast, ecosystems characterized by bottom-up complexity such as startup ecosystems and entrepreneurial innovation ecosystems exhibit self-organizing dynamics driven by informal interactions, emergent practices, and adaptive learning. This distinction contributes to a more refined understanding of how self-organization operates not as a universal property, but as a context-contingent mechanism.

In addition to theoretical contributions, this work offers a set of insights that can support policymakers and ecosystem orchestrators in designing more context-sensitive approaches to ecosystem development and governance. The typology of nested configurations developed in this work provides a useful interpretive lens to distinguish between ecosystems that are primarily driven by entrepreneurial dynamics and those where innovation structures dominate. This distinction can inform the design of policy interventions that are aligned with the internal logic of each configuration. Entrepreneurial-nested ecosystems, such as startup or university-based ecosystems, may benefit from policies that support bottom-up experimentation, informality, and agile coordination mechanisms. In contrast, innovation-nested ecosystems, such as regional innovation ecosystems, are better served by top-down strategies that emphasize institutional alignment, long-term investment, and coordinated governance. Furthermore, by framing ecosystems as complex adaptive systems, the study highlights the importance of fostering environments that are capable of adapting, learning, and evolving through feedback loops and interaction among heterogeneous actors. For governments and regional authorities, this implies the need to move beyond static policy instruments and develop dynamic, responsive frameworks that can adjust to shifting conditions and emergent opportunities. The conceptual distinction between bottom-up and top-down complexity also offers practical guidance on ecosystem governance models. Bottom-up configurations call for enabling mechanisms that support distributed agency, peer learning, and fluid network formation. Top-down ecosystems instead require strong orchestrating roles, clearly defined institutional responsibilities, and mechanisms to ensure vertical coordination among actors at different levels.

This study is not without limitations. First, despite our efforts to ensure a comprehensive search, some relevant papers may have been excluded due to issues of accessibility or database coverage. We attempted to mitigate this limitation by combining database searches with backward and forward citation tracking, yet we cannot fully rule out the omission of pertinent studies, particularly those published outside indexed journals or in grey literature. Second, while the scoping review follows the PRISMA-ScR protocol and includes a robust analytical framework, it remains inherently interpretive. The thematic classification of nested configurations and the mapping of complex system properties are based on inductive reasoning and may reflect subjectivity in judgment, despite triangulation among multiple reviewers. Third, our review focused exclusively on peer-reviewed articles published in English, which may have excluded valuable contributions written in other languages.

2.7 Conclusions

This study advances the understanding of how entrepreneurial and innovation ecosystems intersect and co-evolve within nested configurations characterized by varying forms of systemic complexity. Through a scoping review of 48 peer-reviewed studies guided by complex systems theory, we identified four main configurations—startup ecosystems, entrepreneurial university ecosystems, entrepreneurial innovation ecosystems, and regional innovation ecosystems—each reflecting a specific balance between entrepreneurial and innovation logics. Our analysis highlights that while startup ecosystems and entrepreneurial innovation ecosystems are primarily shaped by bottom-up, adaptive, and self-organizing dynamics, entrepreneurial university ecosystems and regional innovation ecosystems tend to display top-down complexity driven by institutional coordination and policy frameworks. These distinctions reveal that ecosystem evolution is not linear but contingent on the interaction between local contexts, actor heterogeneity, and feedback mechanisms. By framing nestedness as a dynamic and functional relationship rather than a static structural condition, the study contributes to bridging the conceptual gap between entrepreneurial and innovation ecosystem research. The proposed typology provides a lens to interpret how different forms of complexity shape ecosystem behavior and outcomes, helping scholars and policymakers to better understand the interdependencies that characterize hybrid and evolving systems.

Chapter 3

Fostering regional entrepreneurial ecosystem development: the role of science and technology park networks

Abstract

Science and Technology Parks (STPs) are recognized as key drivers of regional development, although their relationship with regional entrepreneurial ecosystems (EEs) remains underexplored, particularly in terms of longitudinal and comparative analyses. This study addresses these gaps by examining how participation in a global STP network impacts regional EE development. Using a longitudinal dataset on STPs' entry and exit dynamics in the International Association of Science and Technology Parks and Areas of Innovation (IASP) across multiple European regions, we analyze the effects of joining a global STP network on two key EE dimensions: intermediary services and knowledge. To do so, we apply a non-parametric generalization of the difference-in-differences estimator for time-series cross-sectional data. The results reveal that joining IASP strengthens the intermediary dimension of regional EEs where parks are located, facilitating talent attraction and enhancing cross-regional knowledge spillovers. These effects are both immediate and context-dependent, with more pronounced impacts observed in regions with lower GDP per capita and outside the European Union. Theoretically, the study advances the STP literature by adopting a dynamic, macro-regional perspective, extending micro-level findings and linking STPs' increased R&D efficiency to international collaboration. Additionally, it bridges STP and EE literatures, emphasizing the role of STPs as catalysts of regional EE development. Practically, our findings provide insights for policymakers and STP managers, highlighting the importance of supporting not only the creation of STPs but also their participation in global networks to foster innovation, especially in regions with fragmented or underdeveloped policy frameworks.

Keywords: science and technology park; entrepreneurial ecosystem; regional development; global network; intermediary services; knowledge.

3.1 Introduction

An increasingly growing number of countries have implemented Science and Technology Parks (STPs) to develop and revitalize regions, boost high-tech industry sectors, foster greater industry-academia interaction, support new technology-based firms, and encourage academic spin-offs (Henriques et al., 2018). In this view, the multifaceted benefits of STPs can be summarized within two categories: i) the benefits they provide to tenant firms and ii) the benefits they provide to local economies (Guadix et al., 2016). On the one hand, academic research has extensively shown that firms within STPs outperform off-park firms in terms of patenting activity, research and development (R&D) investment, job creation rates, and collaboration with universities (Siegel et al., 2003; Squicciarini, 2008; Ubeda et al., 2019; Yang et al., 2009). On the other hand, there is broad consensus that STPs serve as regional innovation policy tools, enhancing innovation capacity and promoting regional development (Albahari et al., 2023; Jacobsen et al., 2024; F. Zhang & Wu, 2012). In both contexts, STPs act as intermediary actors, stimulating and managing knowledge flows among key stakeholders (IASP, 2025).

Traditionally, the discourse surrounding STPs' functioning and organization has adopted a regional innovation system perspective to analyze simultaneously the complex interplay between tenant firms and their impact on regional development (Rip, 2002; Zhu & Tann, 2005). However, the representation, analysis, and role of STPs in shaping regional outcomes are progressively shifting toward the adoption of an entrepreneurial lens (Löfsten et al., 2020). In particular, more recent studies have recognized STPs as essential actors and components of entrepreneurial ecosystems (EEs) (Kanda et al., 2025; Mohammadi et al., 2025). The popularity of EEs has indeed dramatically increased in the past decade (Cao & Shi, 2021; Stam, 2015). Differently from other ecosystem types, EEs are inherently linked to regional development and economic growth (Acs et al., 2018; Hakala et al., 2020), contributing to local economic development by fostering productive entrepreneurship (Audretsch & Belitski, 2021). This shift in the landscape has led policymakers and governments to consider STP actors as crucial elements in enhancing regional competitiveness and contributing to the creation of EEs (Cumming et al., 2019; Theeranattapong et al., 2021).

Despite the abovementioned streams, the literature on STPs presents relevant gaps. Notably, most studies offer a static view of STPs, failing to capture the dynamic nature of these parks (Lecluyse et al., 2019). Indeed, the lack of longitudinal data has been identified as a significant barrier to advancing knowledge in the field of STPs (Albahari et al., 2023; Audretsch & Belitski, 2019). Moreover, comparative studies analyzing multiple STPs on a large scale remain scarce, limiting our understanding of their impact across different geographical contexts (Lopes et al., 2025; Sandoval Hamón et al., 2024). In particular, despite their growing relevance, the role of STPs in fostering regional EE growth remains underexplored (Germain et al., 2023) compared to other intermediary organizations, including incubators, accelerators, and universities (e.g., Fuster et al., 2019; Pustovrh et al., 2020; Roundy et al., 2017), while potentially contributing to setting a policy-oriented agenda (Hess, Wurth, et al., 2025). As a consequence, while previous research has examined how participation within STPs influences tenants' innovation performance, networking, and intermediation mechanisms at the micro-level (Albahari et al., 2023; Koçak & Can, 2014; Laspia et al., 2021), little attention has been paid to how and whether STPs' networking and intermediation mechanisms are exerted at the macro-level. In this context, collaboration among

STPs and key relevant stakeholders has been demonstrated to enhance talent acquisition and, consequently, STPs' success (Cadorin et al., 2021), whereas the effect of the STP networks – or associations – on regional development remains largely underinvestigated.

These gaps highlight the need for a more dynamic and comprehensive exploration of how STP networks can contribute to the development of regional EEs. To this aim, the following research questions are proposed: (i) "Do STP networks affect regional EE development?" and (ii) "What EE dimensions are impacted by participation in STP networks, and when does the effect become observable?".

To address our research questions, we propose a multi-stage approach focusing on the largest global STP network: the International Association of Science and Technology Parks and Areas of Innovation (IASP). Specifically, we obtained access to data on STPs' entry and exit dynamics, enabling us to assess whether participation in IASP affects the regional EE in which a park is embedded through a longitudinal analysis spanning multiple countries. As a first step, we conducted an expert interview with the Knowledge and Project Manager of IASP to gain insights into the association's membership mechanisms and selection criteria. During the interview, we presented EE dimensions as defined by Stam (2015) and operationalized by Leendertse et al. (2021), namely: formal institutions, culture, network, physical infrastructure, finance, leadership, talent, knowledge, intermediary services, and demand. This discussion helped us identify which regional EE dimensions could be affected by IASP membership, integrating insights from the literature review. This resulted in the selection of two key EE dimensions likely to be influenced by STPs' entry into global networks: intermediary services and knowledge. We then collected data to monitor key regional EE dimensions over time and assess their relationship with STPs' participation in IASP. For the analysis, we employed a non-parametric generalization of the difference-in-differences (DiD) estimator for time-series cross-sectional (TSCS) data. This method overcomes the limitations of previously introduced DiD estimators (e.g., Callaway and SantÁnna, 2021) and synthetic control methods (Abadie et al., 2010), as it (i) does not rely on parametric assumptions, (ii) does not require a long pre-treatment period for constructing control units, and (iii) is particularly suitable when the number of treated units is small (Imai et al., 2023).

Our results demonstrate that STP participation in global networks contributes to strengthening the intermediary services of regional EEs and fosters collaborative R&D activities beyond regional boundaries. These effects are typically immediate, taking place in the year of entry into IASP, and exhibit heterogeneous patterns depending on the regions' GDP per capita level and EU membership status. These findings suggest that global STP networks may serve as complementary mechanisms for talent attraction and cross-border collaboration, particularly in regions lacking cohesive policy frameworks, such as European countries outside the EU.

The remainder of the paper is organized as follows. An overview of the state of the art on STPs and EEs is provided in Section 3.2. Section 3.3 presents our multi-stage approach, starting with the description of the case study, followed by the introduction to our methodology and data selection. Finally, the results are reported and discussed in Section 3.4, while Section 3.5 highlights the main theoretical and practical contributions, as well as possible limitations and further developments of this work.

3.2 Literature review

In this section, we provide a comprehensive review of the literature on STPs and their impact on regional innovation systems. Then, we introduce the concept of EEs, grounded in regional development and strategic management literatures. In particular, we examine the role of intermediary actors and identify key contributions that bridge these two research streams, highlighting critical gaps concerning the role of STPs in regional EE development. Building on this discussion, we formulate two research questions to guide our analysis.

3.2.1 Science and technology parks as a policy for regional development

STPs have evolved over time, with various terms such as "research park," "technology park," "science and technology industrial park," "high technology development," "innovation center," and "technology incubator" often used interchangeably (Y. Zhang, 2005). This conceptual complexity has led to diverse interpretations, influenced by the constellation of the actors populating these ecosystems. A widely accepted definition from IASP has been employed by several scholars in the economic field to assess the role, organization, and purpose of the different stakeholders at all levels (Bellavista & Sanz, 2009; Cadorin et al., 2021; Etzkowitz & Zhou, 2018; Lecluyse et al., 2019). In this view, STPs are described as "organizations managed by specialized professionals with the primary aim of fostering innovation, enhancing the competitiveness of associated businesses and knowledge institutions, and ultimately increasing the wealth of the surrounding community" (IASP, 2025). Based on this definition, the primary reasons for the existence of STPs are the benefits they provide to tenant firms and local economies (Guadix et al., 2016). STPs have indeed increasingly become key instruments for business innovation and economic development, particularly due to their ability to coordinate agents involved in micro- and macro-level processes within network-based innovation systems (Bellavista & Sanz, 2009).

At the micro-level, studies have examined interorganizational relationships within STPs, focusing on how participation in these environments influences tenants' innovation performance, networking, and intermediation mechanisms (Albahari et al., 2023; Koçak & Can, 2014; Laspia et al., 2021). In particular, STPs foster knowledge spillovers and generate positive externalities for tenant firms (Díez-Vial & Montoro-Sánchez, 2016; Montoro-Sánchez et al., 2011). They typically act as innovation intermediaries for university-industry collaboration, balancing aspirations for knowledge-based development with the challenge of limited resources (Etzkowitz & Zhou, 2018; Phongthiya et al., 2022). Interesting insights are provided by studies comparing firms inside and outside STPs to analyze the effects induced by participating in the park. These studies reveal heterogeneity in outcomes, particularly with respect to firm age and size (Anton-Tejon, Barge-Gil, et al., 2024). Historically, scholars showed that firms within STPs tend to perform better than those outside, particularly in terms of patenting activity, as technology-based firms within STPs have been found to invest more efficiently (Siegel et al., 2003; Squicciarini, 2008; Yang et al., 2009). In particular, younger firms tend to benefit more from being located within STPs than older ones in terms of patent quality, and a similar result holds for larger firms compared to smaller ones (Anton-Tejon, Martinez, et al., 2024). Additionally, firms inside STPs typically establish stronger links with universities and exhibit higher job creation rates, possibly due to supportive policies and incentives (Löfsten et al., 2020). While it was largely shown how STPs strengthen collaborations with universities and research centers enhancing knowledge flows and transfer among actors (Bakouros et al., 2002; Ng et al., 2022), STPs promoted by universities do not seem to perform better (Anton-Tejon, Martinez, et al., 2024).

Moving to the meso-level, STPs have been analyzed as instruments of regional innovation policy, as they foster collaboration and strengthen regional networks (Jacobsen et al., 2024). Over the past decades, national and regional governments have increasingly invested in STPs as key tools to drive technological advancement and economic growth (Albahari et al., 2023), with broad agreement that they enhance innovation capacity, regional technological development, and competitiveness (Minguillo et al., 2015; Olcay & Bulu, 2018; Zeng et al., 2011; F. Zhang & Wu, 2012). In these contexts, STPs represent "top-down short cuts to create a Silicon Valley-like high-tech conurbation," i.e., attractive environments for both R&D units of firms and government agencies (Etzkowitz & Zhou, 2018).

Despite these insights, significant research gaps remain. On the empirical side, the literature has been developed mainly in the form of case studies of individual parks. Conversely, there are few comparative studies presenting large-scale analyses across many parks (Sandoval Hamón et al., 2024). Additionally, most of current research offers a static view of STP role, while a longitudinal design would provide novel insights into the dynamic nature of STPs, considering firms entering and leaving the park (Lecluyse et al., 2019). This lack of longitudinal analyses using large-scale datasets beyond national contexts limits the generalizability of findings. Furthermore, while existing research has largely focused on interorganizational relationships within STPs or their role as policy tools for fostering economic growth, little attention has been given to the potential impact of STP networks – that is, the collaboration between different STPs – on regional development. In fact, a growing trend of collaboration among STPs and other organizations, both nationally and internationally, has emerged, aimed at enhancing the accessibility of resources for tenant firms (Cadorin et al., 2021). In particular, global networks of STPs allow for greater impact and enhanced innovation capabilities but a clear understanding of how and why they generate added value for the ecosystem is still lacking (Hrebennyk et al., 2024). Indeed, there is an increasing need for causal studies linking a firm's membership in an ecosystem to performance, rather than limited to the STP environment (Shipilov & Gawer, 2020). In this vein, the concept of regional innovation system has gained popularity given its link with both regional competitiveness and innovation activities and processes (López-Rubio et al., 2020). In the last decades, the discourse on STPs has often adopted the regional innovation system perspective to analyze the complex interplay between universities and industries and its impact on regional development (Theeranattapong et al., 2021; Zhu & Tann, 2005). However, the debate has increasingly shifted toward an entrepreneurial lens to investigate the role of STPs in shaping regional outcomes (Löfsten et al., 2020), laying the groundwork for integrating STPs in the discourse on EEs.

3.2.2 Intermediary actors in entrepreneurial ecosystem research

The concept of EEs has gained significant attention over the past decade (Cao & Shi, 2021), evolving rapidly and generating greater enthusiasm than previous frameworks, such as entrepreneurial systems, particularly within policy discourse (Alvedalen & Boschma, 2017; Brown & Mawson, 2019). The EE approach emerged in response to the need for fostering supportive environments for regional development, enabling high-growth firms to thrive (C. Mason & Brown, 2014). Given this strong regional connection, cultural and social norms, along with internal market dynamics, contribute to interregional differences in the prevalence of high-growth firms (Corrente et al., 2019) and the emergence of knowledge-intensive business service areas (Horváth & Rabetino, 2019).

The genesis of the EE concept can be traced back to the late 1980s and early 1990s, rooted in the works of Van de Ven (1986, 1993) and Moore (1993), which paved the way for the adoption of the ecosystem metaphor in business and management studies. Differently from other ecosystem types – such as business, innovation, digital, and knowledge ecosystems – EEs are intrinsically linked to regional development and economic growth (Acs et al., 2018; Hakala et al., 2020). Specifically, EEs contribute to regional economic development by fostering productive entrepreneurship, particularly in regions with a strong presence of the creative class and creative industries (Audretsch & Belitski, 2021). The notion that economic transformation unfolds unevenly across EEs, driven by geographically specific mechanisms, is central to evolutionary economic geography (Boschma & Martin, 2007). This perspective has been applied to regional innovation systems and clusters (Hassink et al., 2014), further leading to the adoption of the regional lens in EE research.

The theoretical antecedents of EEs lie, in fact, in regional development and strategic management literatures, as they integrate value creation perspectives and emphasize the socioeconomic characteristics of innovation systems (Acs et al., 2017). The relationship between EEs and other regional development frameworks, such as regional and industrial clusters, is often highlighted due to their shared systemic focus (Alvedalen & Boschma, 2017). While EEs, regional clusters, and industrial districts all pertain to the same broad phenomenon, they differ in scope. Specifically, industrial districts refer to the concentration of small firms within an industry, regional clusters focus on firms within a specific sector located in a defined geographical area, and EEs emphasize the entrepreneurial dimension of economic development (Autio et al., 2018; Rocha & Audretsch, 2022). Further distinctions between EEs and earlier conceptual frameworks arise from the role of regional cultural identity and the combinatorial nature of ecosystem elements (Muñoz et al., 2022). Additionally, EEs evolve around the processes of entrepreneurial opportunity discovery and pursuit (Autio et al., 2018), as well as the accessibility of regional resources, often influenced by government interventions (Spigel & Harrison, 2018).

The complexity of EEs is reflected in their multidimensional nature, integrating financial, knowledge, institutional, and social components (Nicotra et al., 2018; Spigel, 2017; Van de Ven, 1993). These elements both shape and are shaped by the broader economic, technological, and societal contexts in which they are embedded (Audretsch et al., 2019). In this view, ecosystem actors interact through networks of knowledge, labor, and social capital (Malecki, 2018), which collectively shape the network-based structure of EEs (Ancona et al., 2023; Cavallo et al., 2021; Neumeyer et al., 2019). Most contemporary EE models build on the foundational frameworks of Isenberg (2011) and Stam (2015), which were among the first to map the key elements of these systems. According to Isenberg's framework, EEs lie on six fundamental pillars: finance, policy, culture, markets, human capital, and support mechanisms. These domains partially overlap with those introduced later by Stam (2015) and refined in Stam and Van de Ven (2021), who identify ten EE elements linked to productive entrepreneurship outcomes: formal institutions, culture, network, physical infrastructure, finance, leadership, talent, knowledge, intermediary services, and demand. These elements have been operationalized by Leendertse et al. (2021) into a set of measurable indicators at different geographical scales, now serving as the predominant framework in EE research for monitoring and assessing EE development in Europe. Notably, the interconnected nature of these elements results in strong ecosystems exhibiting high levels across all dimensions, while weak ecosystems tend to show uniformly low levels, with no evidence of "polarization" effect (Cavallo et al., 2023).

The relational nature of EEs, grounded in ecological systems theory (Acs et al., 2017), highlights the role of proximity in fostering collaboration. In particular, the interrelatedness between cognitive, organizational, social, institutional, and geographical proximities is essential to facilitate interactions among ecosystem actors and enable the formation of viable ecosystems (Yamamura & Lassalle, 2020). Frequent interactions are indeed at the core of EEs, ensuring that resources are more readily accessible to all actors (Feld, 2012).

The distribution of resources within EEs is mediated by intermediary organizations, such as incubators, accelerators, and universities, which play a crucial role in coordinating knowledge flows, facilitating access to venture capital, and fostering regional economic growth (Fuster et al., 2019; Pustovrh et al., 2020; Roundy, 2017). Specifically, incubators are pivotal to strengthen network ties among startups and between startups and investors, shaping the collaborative structure of EEs according to different levels of dependence (Hernández-Chea et al., 2021; van Rijnsoever, 2020). Accelerators, in turn, act as catalysts for the development of startup infrastructures within entrepreneurial clusters (Bliemel et al., 2019). This meso-level intermediary role enhances the commitment of actors to the EE by promoting cooperation and knowledge sharing practices (Goswami et al., 2018; Pustovrh et al., 2020). In addition to providing technical knowledge ("know-what") and practical expertise ("know-how"), accelerators facilitate access to crucial entrepreneurial networks ("know-who"), which are central in entrepreneurial learning experiences (Seet et al., 2018). In this way, accelerator programs strengthen startup embeddedness within EEs, emerging as one of the key platforms to channel venture capital and investor flows (Dalle et al., 2023). These dynamics increase the availability of innovation resources within regional EEs, attracting other key players, such as university spin-offs, seeking proximity to other firms and entrepreneurial actors (Rossi et al., 2023). As a result, universities also play a critical role in regional EE development (Fuster et al., 2019), along with spin-out companies burgeoning from multinational enterprise employees that become incubators for new waves of entrepreneurs (Ryan et al., 2021).

Among institutional actors, STPs are particularly influential in supporting the early development of academic spin-offs, strengthening the establishment of academic entrepreneurship practices within EEs (Franco-Leal et al., 2020). Entrepreneurs frequently locate their ventures near STPs and incubators to gain access to technological advancements, form alliances, and leverage shared infrastructure (Audretsch & Belitski, 2019, 2021; Cuvero et al., 2023). Moreover, STPs act as connectors with other regions, linking ecosystems in similar stages of development (Oliver et al., 2020). For this reason, both practitioners and scholars consider STPs as essential actors and components of EEs (Kanda et al., 2025; Mohammadi et al., 2025). Policymakers and governments are also increasingly looking to STPs tenants (e.g., universities or corporate firms) as crucial elements of the knowledge-based economy to foster regional competitiveness and contribute to the creation of EEs (Cumming et al., 2019; Theeranattapong et al., 2021).

Despite their relevance, the role of STPs in fostering regional EE growth remains underexplored compared to other intermediary organizations. The main contribution bridging EE and STP research is provided by Germain et al. (2023), who find that STPs can facilitate the creation of EEs by coordinating and supporting different stakeholders, though their effectiveness depends on regional characteristics and the success of ecosystem collaborations. However, this work employs a single-case study methodology, relying on a context that possesses unique characteristics, thereby making it difficult to extend and generalize its results. Moreover, the vast majority of EE literature analyzes intermediary organizations at the micro- and meso-levels, focusing on their effect on incubated firms or on regional economies. However, gaps exist regarding the role of networks of intermediary organizations in regional EE development, highlighting the need for a macro-level perspective on the topic. In light of these limitations, this paper aims to provide a comprehensive understanding of STPs from a systemic perspective. Rather than focusing on the role of individual STPs in isolation, we aim to investigate the broader network dynamics and their multiplier effect on the development of regional EEs. This approach allows us to longitudinally explore how interactions between multiple STPs contribute to innovation diffusion, knowledge creation, and economic growth at the regional level.

Based on the previous debate, we formulate the following research questions:
1. *"Do STP networks affect regional EE development?"*
2. *"What EE dimensions are impacted by participation in STP networks, and when does the effect become observable?"*

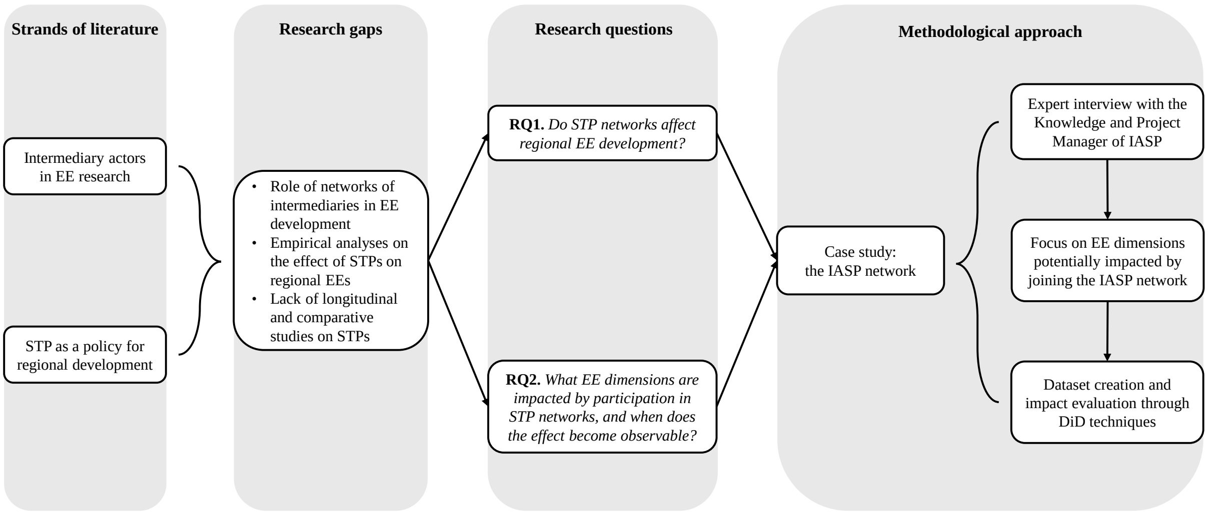
3.3 Research design

Through our analysis of the literature on STPs and EEs, we identified different research gaps within each field and at their intersection. In particular, EE studies largely overlook the role of intermediary networks in regional EE development, while STP research lacks longitudinal and comparative studies. Additionally, few works have examined STPs as intermediary actors within EEs and their contribution to regional entrepreneurial development. These gaps led us to formulate two main research questions, as outlined at the end of Section 3.2. To address these questions, we propose a multi-stage approach focusing on IASP, the largest global STP network. Specifically, we obtained access to data on STPs' entry and exit dynamics, enabling us to assess whether participation in IASP affects the regional EE in which a park is embedded through a longitudinal analysis spanning multiple countries.

As a first step, we conducted an expert interview with the Knowledge and Project Manager of IASP to gain insights into the association's membership mechanisms and selection criteria. During the interview, we introduced EE dimensions as defined by (Stam, 2015) and operationalized by (Leendertse et al., 2021). This discussion helped us identify which regional EE dimensions could be affected by IASP membership. Building on these insights, we collected data to monitor key regional EE dimensions over time and assess their relationship with STP participation in IASP. For this analysis, we employed a non-parametric generalization of the DiD estimator for TSCS data (Imai et al., 2023).

For clarity, our research design is summarized in Figure 3.1. The specific steps of our methodological approach are detailed in Sections 3.3.1 and 3.3.2.

Figure 3.1: Research design.



3.3.1 Case study: the IASP global network

Since its establishment in 1984, IASP has been recognized as a leading force in fostering collaboration and driving innovation on a global scale. The organization is dedicated to facilitating connections and knowledge exchange within a dynamic international network comprising STPs, areas of innovation, and innovation districts. By coordinating an active community of stakeholders, IASP promotes synergies at both national and international levels. Today, IASP boasts a diverse and extensive membership base, with over 350 members representing more than 115,000 companies across 80 countries. Its global presence is structured into six main regional divisions: Africa, Asia Pacific, Europe, Latin America, North America, and West Asia North Africa. In addition to its headquarters in Malaga, Spain, and a regional office in Beijing, China, the organization enhances its impact through global conferences and regional events, fostering cross-border collaboration and knowledge diffusion.

We selected the IASP global network as a case study to address our research questions for three main reasons. First, as the largest association of STPs worldwide, IASP provides a unique setting that enables analysis transcending the contextual limitations of traditional case studies. Its extensive membership network allows for investigating the role of STPs in regional EE development from multiple perspectives and across different geographical contexts, addressing current lacks of research in this regard (Germain et al., 2023). Second, the IASP's definition is widely referenced in key studies on STPs, as emphasized in Section 3.2.1, and is central to the discussion on their role in the development of regional EEs (Bellavista & Sanz, 2009; Cadorin et al., 2021; Etzkowitz & Zhou, 2018; Lecluyse et al., 2019). Third, the association provided us with access to a longitudinal dataset covering the period from 1985 to 2024. The availability of such data is particularly valuable, as the lack of longitudinal studies has been frequently cited as a major constraint in advancing research on STPs (Albahari et al., 2023; Audretsch & Belitski, 2019).

A summary of the IASP's characteristics is provided in Table 3.1.

Table 3.1: Key characteristics of the IASP case study.

Attribute	Description
Year of establishment	1984
Role	Leading network in fostering collaboration among STPs
Mission	Support STPs worldwide by catalyzing innovation, fostering growth, and facilitating cross-border collaboration
Community	Science and technology parks, areas of innovation, innovation districts
Membership size	Over 350 members representing more than 115,000 companies across 80 countries
Regional divisions	Africa, Asia Pacific, Eurasia, Europe, Latin America, North America, West Asia North Africa
Reasons for case study selection	(i) Largest association of STPs; (ii) widely referenced in STP research; (iii) access to a longitudinal dataset (1985–2024)

The expert interview

In the initial phase of our study, we conducted an expert interview with the Knowledge and Project Manager of IASP. This interview provided critical insights into IASP's internal operations, the broader dynamics of its global network, and its strategic objectives. The interview protocol was structured around three core themes:

- Operational mechanisms of the IASP global network — understanding how IASP facilitates connections among STPs, supports their activities, and influences their development through networking and collaboration.
- Assessment criteria and admission process for STP membership — clarifying the standards STPs must meet to join IASP and the evaluation process applied to new applicants.
- Selection of relevant variables from (Leendertse et al., 2021) — identifying key EE dimensions for the analysis to ensure methodological rigor and comprehensiveness in our study.

Therefore, the primary objectives of the expert interview were to deepen our understanding of IASP's internal processes, the mechanisms regulating relationships among members, and, most importantly, to identify the EE dimensions that IASP membership can potentially impact. In this context, expert interviews are crucial for refining knowledge production by offering privileged access to tacit knowledge and sector-specific expertise (Meuser & Nagel, 2009).

The interview took place in April 2024, lasted approximately one hour, and was conducted in English. To ensure accuracy, it was recorded, transcribed, and translated into the authors' native language. The insights gained significantly contributed to the design of our methodological approach, leading to two key outcomes:

- Ensuring coherence in STP characteristics and robustness of identification criteria for DiD estimators. The interview provided a clearer understanding of how IASP ensures consistency across its members, following a rigorous admission process including an in-depth assessment by the Executive Board that helps maintain high-quality standards within the global network. This selection process minimizes heterogeneity across STPs, reducing biases that typically arise when analyzing different types of parks (Albahari et al., 2017). As a result, our study benefits from a more reliable framework for applying DiD techniques, as discussed in the next section.

- Refining variable selection for assessing the impact of STP networks on regional EE development. The interview helped bridge two critical components of our research: the benefits of participating in IASP's global network and the EE dimensions most likely to be affected by IASP membership. By integrating these insights, we refined our variable selection, enhancing the study's relevance and methodological rigor. Specifically, the interview highlighted *intermediary services* (hereafter, "intermediaries") and *knowledge* as the most relevant EE dimensions for assessing the impact of STP membership[1]. This selection aligns not only with IASP's emphasis on fostering innovation and strengthening competitiveness among businesses and knowledge institutions but also with ongoing debate on the role of STPs at the micro- and meso-levels (Díez-Vial & Montoro-Sánchez, 2016; Etzkowitz & Zhou, 2018; Ng et al., 2022; Phongthiya et al., 2022).

Overall, this process minimized potential biases and enhanced the reliability of our analytical approach.

3.3.2 Methodology and data

The main objective of this paper is to analyze how participation in a global network of STPs affects the development of the regional EE where a park is embedded. Therefore, our units of analysis are NUTS-2 regions hosting one (or more) STPs belonging to IASP within the analyzed time window. In particular, we can benefit from an initial set of 221 STPs that joined (and, in some cases, exited) IASP between 1985 and 2024. We assess this effect by considering entrance into IASP as a treatment potentially stimulating EE dimensions, as introduced in Section 3.3.1. A popular way to estimate the effect of a policy or treatment on specific outcome variables is to compare treated and control units that share similar observed characteristics in the pre-treatment period. Two-way fixed effects (TWFE) regressions are among the most widely used methods in economics to estimate treatment effects (De Chaisemartin & d'Haultfoeuille, 2020). However, recent studies have proposed more accurate alternatives that account for treatment effect heterogeneity between groups and over time. This means that not all treated units in the sample receive the treatment simultaneously. In our case, STPs may join IASP in different years, meaning they are subject to staggered treatments. Moreover, we assume regional EE dimensions depend on past treatments (i.e., members who joined IASP earlier). Therefore, a method accounting for dynamic effects must be employed.

To this aim, we adopt a non-parametric generalization of the DiD estimator recently developed by (Imai et al., 2023), which has already been applied in economic geography studies (Celli et al., 2023), specifically for TSCS data. This type of data consists of repeated observations of the same units, which may receive the treatment multiple times, with the timing of the treatment varying across units. In general, DiD estimators compare the outcome trajectory (Y) from t_1 to t_2 between a treatment group a switching from untreated to treated and a control group b that remains untreated at both periods. Formally, a simple DiD can be written as:

$$\text{DiD} = Y_{a,2} - Y_{a,1} - \big(Y_{b,2} - Y_{b,1}\big). \tag{3.1}$$

Matching methods enhance the validity of causal inference by selecting control units that resemble treated ones and provide insights into the quality of returned matches (Stuart, 2010). They

[1] All other EE dimensions are also incorporated into our estimation model, as detailed in the following section.

help reduce the dependence of the treatment variable on observed confounders (Ho et al., 2007). (Imai et al., 2023) introduce a matching method for TSCS data, addressing limitations in prior studies that relied on linear regression models with fixed effects (Angrist & Pischke, 2009). While regression models remain popular, they suffer from strong parametric assumptions and difficulties in interpreting counterfactual estimates (Imai & Kim, 2021).

The methodology employed in this paper overcomes such limitations. In particular, following (Imai et al., 2023), we first select for each treated region a set of control regions that are not yet treated (i.e., regions that do not host an IASP member at the time of comparison). We use Mahalanobis distance matching, which assigns positive weights to control units with similar trends in the pre-treatment outcome and control covariates. This method performs well when the sample size is relatively small (Zhao, 2004) and has been used in STP studies to evaluate the effect on tenant firms (Liberati et al., 2016). Notice that not-yet-treated regions serve as valid control units in the absence of purely untreated units (Callaway & SantÁnna, 2021), as in our case. Our dataset includes entry and exit dynamics of parks that joined IASP over time, which also ensures comparability in IASP selection and membership criteria. We use lagged values of GDP per capita, percentage of employment, and population density as pre-treatment covariates to ensure socio-economic and demographic similarities. Additionally, we include lagged values of all EE dimensions[2], as they are interrelated (Leendertse et al., 2021). All variables employed, as well as available time spans and data sources, are listed in Table 3.2. By combining this set of variables with the entry and exit dynamics of STPs—aggregated at the NUTS-2 level based on their corresponding region—we obtain a set of 59 NUTS-2 regions hosting one or more STPs across 22 European countries that joined IASP between 2011 and 2024.

Then, for each treated region, we estimate the counterfactual outcome using the weighted average of three control units in the refined matched set. Different numbers of control units are tested for robustness (see Section 3.4.1). Finally, we estimate the average treatment effect among treated (ATT) by averaging the DiD estimates across all treated units.

To apply this methodology, we define F as the number of leads, representing the outcome measured F periods after treatment. We set $F = 3$ to capture the effect on the regional EE three years after an STP joins IASP. Additionally, we define $L = 3$ as the number of lags, ensuring matching based on pre-treatment trends up to three years before treatment. As in the regression approach, choosing L involves a bias–variance trade-off: higher values enhance the unconfoundedness assumption but reduce the number of potential matches. In our case, setting $L = 3$ results in a final dataset for our main analysis comprising 48 NUTS-2 regions across 19 European countries. The complete list of regions, along with the number of STPs and the years of treatment, is reported in Appendix C, Table C.1. Since the choice of L is arbitrary, we conduct robustness checks by varying it in Section 3.4.1. Once these parameters are defined, we compute the DiD estimate of the ATT for all treated units. Specifically, the ATT is defined as:

$$\delta(F, L) = E\Big\{ Y_{i,t+F}\big(X_{it} = 1, X_{i,t-1} = 0, \{X_{i,t-\ell}\}_{\ell=2}^{L}\big) - Y_{i,t+F}\big(X_{it} = 0, X_{i,t-1} = 0, \{X_{i,t-\ell}\}_{\ell=2}^{L}\big) \;\Big|\; X_{it} = 1, X_{i,t-} \tag{3.2}$$

where treated units are regions hosting an STP that joins IASP at time t ($X_{it} = 1$) and were

[2] Except finance-related variables, which were inaccessible.

Table 3.2: Variable selection (NUTS-2 level).

Variable	Description	Data source	Period
IASP membership	Treatment	IASP (confidential)	1985–2024
Percentage of employment in knowledge-intensive market services	EE dimension: Intermediary services	Eurostat	2008–2022
Intramural R&D expenditure as a percentage of GDP	EE dimension: Knowledge	Eurostat	2011–2021
Number of coordinators in FP7/H2020/Horizon Europe projects	EE dimension: Leadership	CORDIS	2011–2022
Births of new enterprises	EE dimension: Entrepreneurship culture	Eurostat	2008–2022
Quality of Government Index	EE dimension: Formal institutions	European Commission	2010–2022
Households with access to the internet at home	EE dimension: Physical infrastructure	Eurostat	2011–2022
Population aged 25–64 with tertiary education	EE dimension: Talent	Eurostat	2011–2022
Disposable income of private households	EE dimension: Demand	Eurostat	2012–2022
Innovative SMEs collaborating with others	EE dimension: Networks	Community Innovation Survey	2016–2022
Population density	Demographic context	Eurostat	2011–2022
GDP per capita	Socio-economic context	Eurostat	2011–2022
Employment rate	Socio-economic context	Eurostat	2011–2022

untreated before ($X_{i,t-1} = 0$). In this definition, $Y_{i,t+F}(\cdot)$ denotes the potential outcome under a given treatment path, while the rest of the treatment history $\{X_{i,t-\ell}\}_{\ell=2}^{L} = \{X_{i,t-2}, \ldots, X_{i,t-L}\}$ is set to 0 (no IASP member hosted in the pre-treatment window up to L). In our case, $\delta(3,3)$ represents the average causal effect of joining IASP on the regional EE three years after entry, conditioning on the treatment history up to three years before.

For each unit i treated at time t, we estimate the counterfactual outcome $Y_{i,t+F}(X_{it} = 0, X_{i,t-1} = 0, \{X_{i,t-\ell}\}_{\ell=2}^{L})$ using the weighted average of the control units in the refined matched set. Specifically, we define the non-negative weight $w_{it}^{i'}$, where i' refers to any control unit belonging to the matched sets, distributed uniformly in our main specification, i.e., $w_{it}^{i'} = 1/3$. We then average the DiD estimate of the ATT across all treated units. Formally:

$$\hat{\delta}(F, L) = \frac{1}{\sum_{i=1}^{N} \sum_{t=L+1}^{T-F} D_{it}} \sum_{i=1}^{N} \sum_{t=L+1}^{T-F} D_{it} \Big\{ (Y_{i,t+F} - Y_{i,t-1}) - \sum_{i' \in M_{it}} w_{it}^{i'} (Y_{i',t+F} - Y_{i',t-1}) \Big\}, \quad (3.3)$$

where $D_{it} = 1$ if unit i transitions from control to treatment at time t and has at least one matched control unit.

While this approach relies on a weaker set of assumptions compared to common methodologies for TSCS data—including TWFE, dynamic panel models, and other DiD estimators (Imai et al., 2023)—it still requires some conditions to hold. First, the parallel trend assumption after conditioning on the treatment, outcome, and covariate histories must hold. Specifically:

$$\begin{aligned} &E\big[Y_{i,t+F}(0,0,\{X_{i,t-\ell}\}) - Y_{i,t-1} \bigm| X_{it}=1, X_{i,t-1}=0, \{X_{i,t-\ell}, Y_{i,t-\ell}\}_{\ell=2}^{L}, \{Z_{i,t-\ell}\}_{\ell=0}^{L}\big] \\ =\ &E\big[Y_{i,t+F}(0,0,\{X_{i,t-\ell}\}) - Y_{i,t-1} \bigm| X_{it}=0, X_{i,t-1}=0, \{X_{i,t-\ell}, Y_{i,t-\ell}\}_{\ell=2}^{L}, \{Z_{i,t-\ell}\}_{\ell=0}^{L}\big], \end{aligned} \tag{3.4}$$

where Z_{it} is a vector of observed time-varying confounders for region i at year t. Thus, the conditioning set includes the treatment history, lagged outcomes, and covariate history. A key advantage of our matching approach is that it allows us to test parallel trends by inspecting covariate balance between treated and matched control units. Second, while the methodology accounts for some carryover effects (i.e., past treatments influencing future outcomes), it assumes no interference between regions, namely that the potential outcome of region i at time $t+F$ does not depend on the treatment status of other regions. This assumption is reasonable given typical time spans for knowledge spillovers at the micro-level (Díez-Vial & Fernández-Olmos, 2015). We therefore consider STP spillovers unlikely to extend beyond regional boundaries within our evaluation window.

Finally, unlike other recently introduced DiD estimators (e.g., Callaway & SantÁnna, 2021), our approach explicitly tests pre-treatment trend differences and does not rely on parametric assumptions. It also overcomes limitations of the synthetic control method (Abadie et al., 2010), which requires a long pre-treatment period to construct counterfactuals, and is particularly suitable when the number of treated units is small.

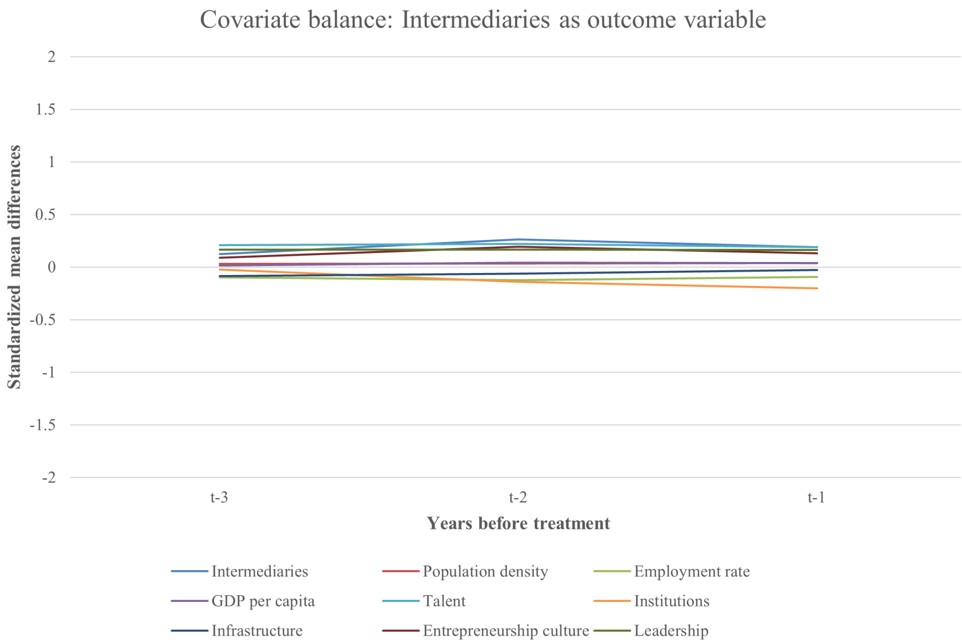
3.4 Results

Following the approach outlined in Section 3.3, we estimate the effects of STP networks on the intermediaries and knowledge dimensions of regional EEs. Our main specifications include all available variables for 48 NUTS-2 regions over a sufficiently long time window, allowing us to consider the number of lags and leads, as defined in Section 3.3. Specifically, when analyzing the impact on intermediaries, we include population density, employment rate, and GDP per capita as covariates from 2011-2022, along with the following EE dimensions available within the same time span: talent, institutions, infrastructure, entrepreneurship culture, and leadership. Similarly, when examining the impact on knowledge, we control for employment rate and GDP per capita from 2011-2021, as well as intermediaries, talent, institutions, infrastructure, entrepreneurship culture, and leadership within the same time span. All EE dimensions are operationalized as specified in Table C.1.

For completeness, we also conducted additional analyses using other EE dimensions as outcome variables (reported in Appendix C.2, Figure C.1 and Figure C.2). However, these yielded no significant results, reinforcing the validity of our variable selection based on the literature review and expert interview.

Before presenting our main estimates, we assess covariate balance between treated and matched control units in Figure 3.2. As discussed in Section 3.3, this test is fundamental to verify the parallel trend assumption when employing the non-parametric generalization of the DiD estimator (Imai et al., 2023), thereby strengthening the robustness of our empirical analysis. The plots indicate that all employed variables in both specifications remain stable over the three-year pre-treatment period within the standard deviation range of $(-0.5, 0.5)$, except for a slight imbalance in knowledge at $t-3$. These results suggest that the lagged values of both dependent variables and all covariates are well balanced between treated and control regions before treatment. This balance supports the plausibility of the parallel trend assumption after conditioning on treatment, outcome, and covariate histories, allowing us to attribute observed post-treatment differences causally to STPs' entry into IASP.

Figure 3.2: Covariate balance between treated and control regions with intermediaries (top) and knowledge (bottom) as outcome variables.



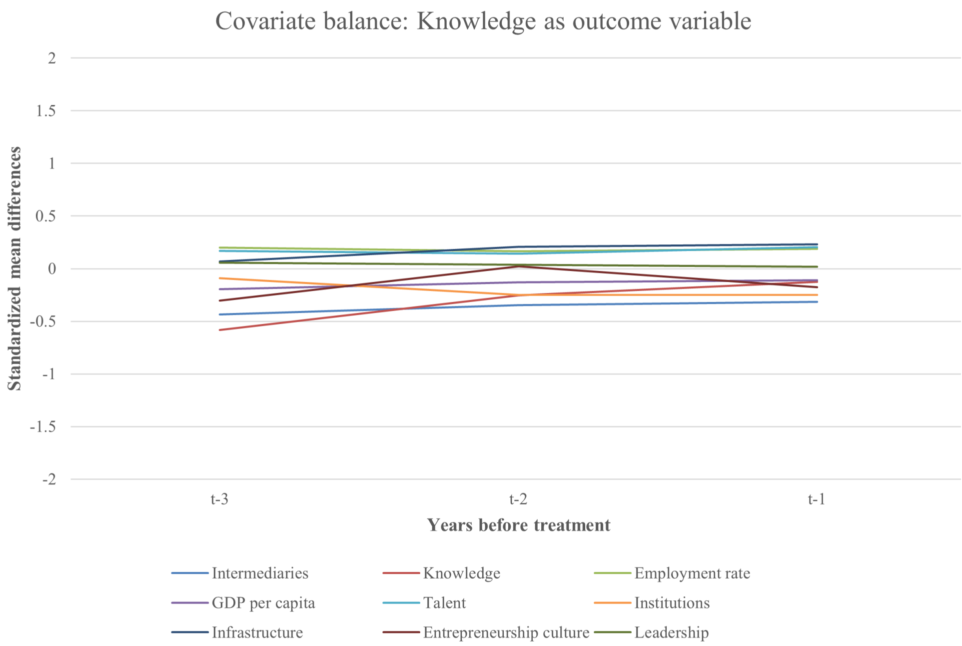
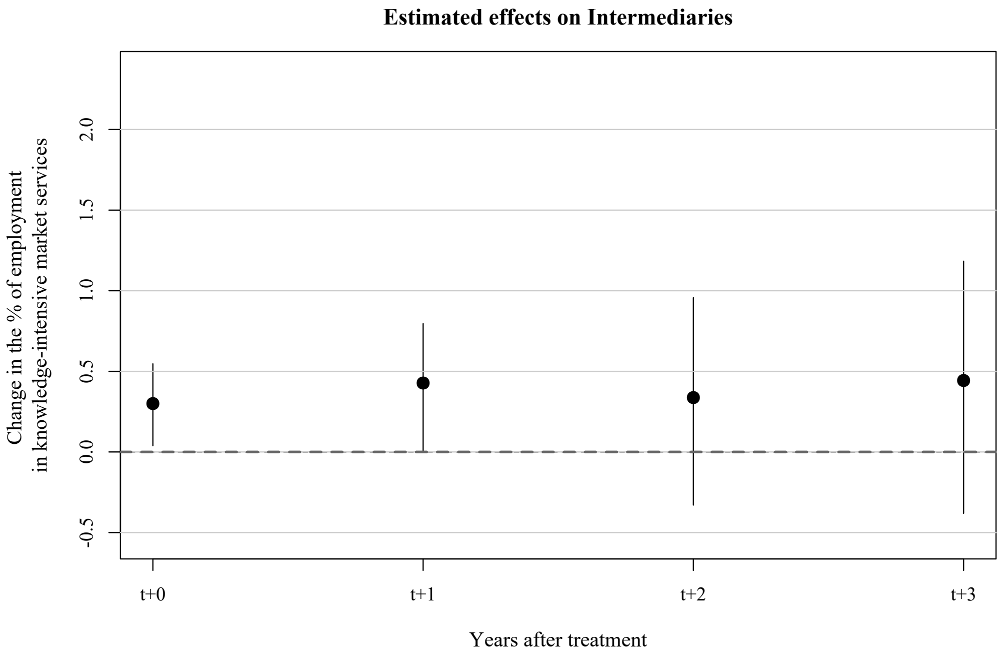
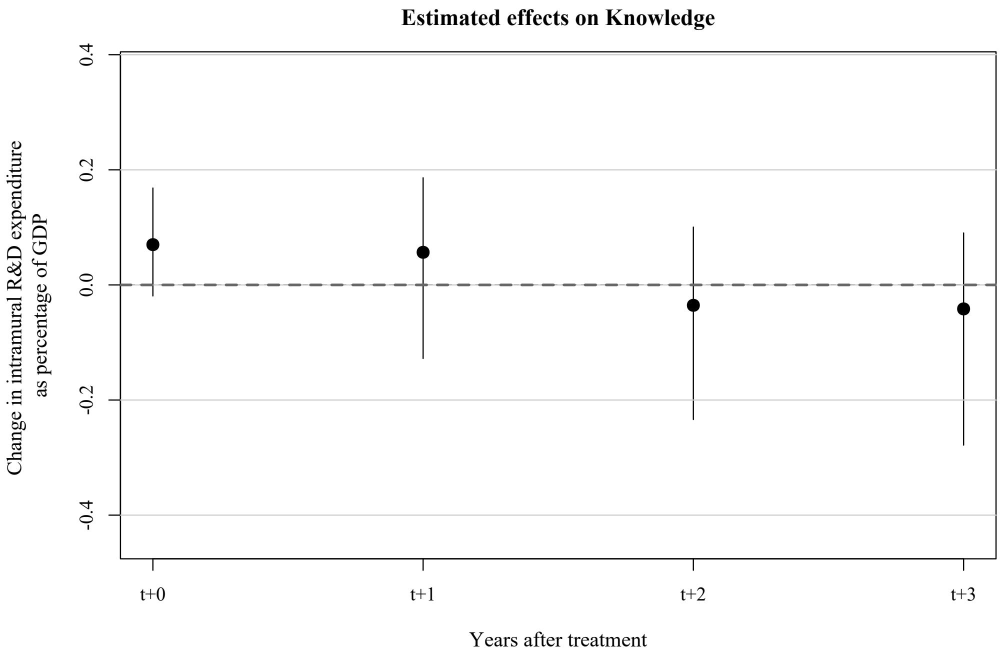


Figure 3.3 shows the estimated ATT for intermediaries and knowledge. In particular, the y-axis represents changes in the respective dimensions. Since both dependent variables are expressed as percentages, the estimated effects should be interpreted as direct percentage increases or decreases in (i) employment in knowledge-intensive market services and (ii) intramural R&D expenditure as percentage of GDP.

As it is possible to notice, STPs' entry into IASP leads to a statistically significant increase in

Figure 3.3: Estimated average treatment effect among treated (ATT) on intermediaries and knowledge with 95% confidence levels.





employment in knowledge-intensive market services by 0.30 and 0.43 percentage points in the year of treatment and the following year, respectively, within the regions hosting the newly affiliated STPs ($p < 0.05$). While the effect remains positive over the entire post-entry period, it loses statistical significance beyond the first year. This result suggests that STP networks contribute to the development of intermediary services in the regional EE where STPs operate. Specifically, this effect can be attributed to enhanced expertise, know-how, and networking capabilities of tenant firms, which benefit from being embedded not only in an STP but within a broader network of

STPs. This network effect may generate positive spillovers at the regional level.

In contrast, a distinct pattern emerges for intramural R&D expenditure, which shows a steady decline from the year of treatment until the third year post-entry, although the effect remains not statistically significant. The lack of significance is likely due to the smaller number of treated units in this specification (eight regions) compared to the analysis of intermediaries as the outcome variable (seventeen treated regions), given the shorter time window for data availability. Despite this limitation, the observed decline in this variable may be cautiously interpreted as consistent with the expected effects of joining an international network of STPs, which facilitates cross-border knowledge exchange and collaboration. Rather than indicating a negative impact of STP networks on knowledge-related EE dimensions, this trend aligns with the nature of the knowledge metric used in this study (and defined by Leendertse et al., 2021). Whether reaching statistical significance, the results would suggest that regions hosting IASP members decrease their intramural R&D expenditure, thereby opening up to external collaborative R&D beyond their regional boundaries.

3.4.1 Robustness checks

We test the robustness of our findings through three sensitivity analyses, with results presented in Table 3.3 alongside our main estimates. First, we assess the sensitivity of our analysis to the choice of the number of lags (L). As discussed in Section 3.3, selecting L involves a bias-variance tradeoff with higher values improving robustness while reducing the number of potential matches. Given the size of our sample, we re-estimate the ATT for intermediaries and knowledge by selecting $L = 2$ (instead of $L = 3$ in our main specification). Second, we vary the match set size, using 5 nearest neighbors rather than 3. Third, we employ a different matching method, replacing Mahalanobis distance with propensity score matching (PSM) (Rosenbaum & Rubin, 1983) to identify the set of control units for each treated region.

As for our main estimates, we first assess the covariate balance between treated and matched control units for each robustness check in Figure 3.4. While varying the number of lags and match sizes returns balanced matches within the accepted standard deviation range $(-1, 1)$, our main specifications provide the most balanced matching, confirming the robustness of our approach. In contrast, PSM results in less efficient covariate balance than Mahalanobis distance, consistent with previous studies (Liberati et al., 2016; Zhao, 2004).

Table 3.3 shows that most robustness check estimates align with our main analysis. The effect of STPs' entry into IASP remains positive and statistically significant for the intermediaries dimension of regional EEs in the year of treatment and the following year. In particular, the estimated impact on employment in knowledge-intensive market services increases by approximately 0.4 at $t+1$ and is statistically significant at the 5% level across all specifications (except for the PSM approach, which is less reliable due to covariate imbalance). The main difference concerns the year of treatment, where the estimated impact is lower and not statistically significant when using $L = 2$. When considering knowledge as the outcome variable, the effect consistently declines over time, becoming negative at $t + 2$, though it remains not statistically significant.

Figure 3.4: Covariate balance: intermediaries and knowledge as outcome variables. Robustness checks using (i) $L = 2$, (ii) Mahalanobis distance with 5 neighbors, and (iii) propensity score matching.

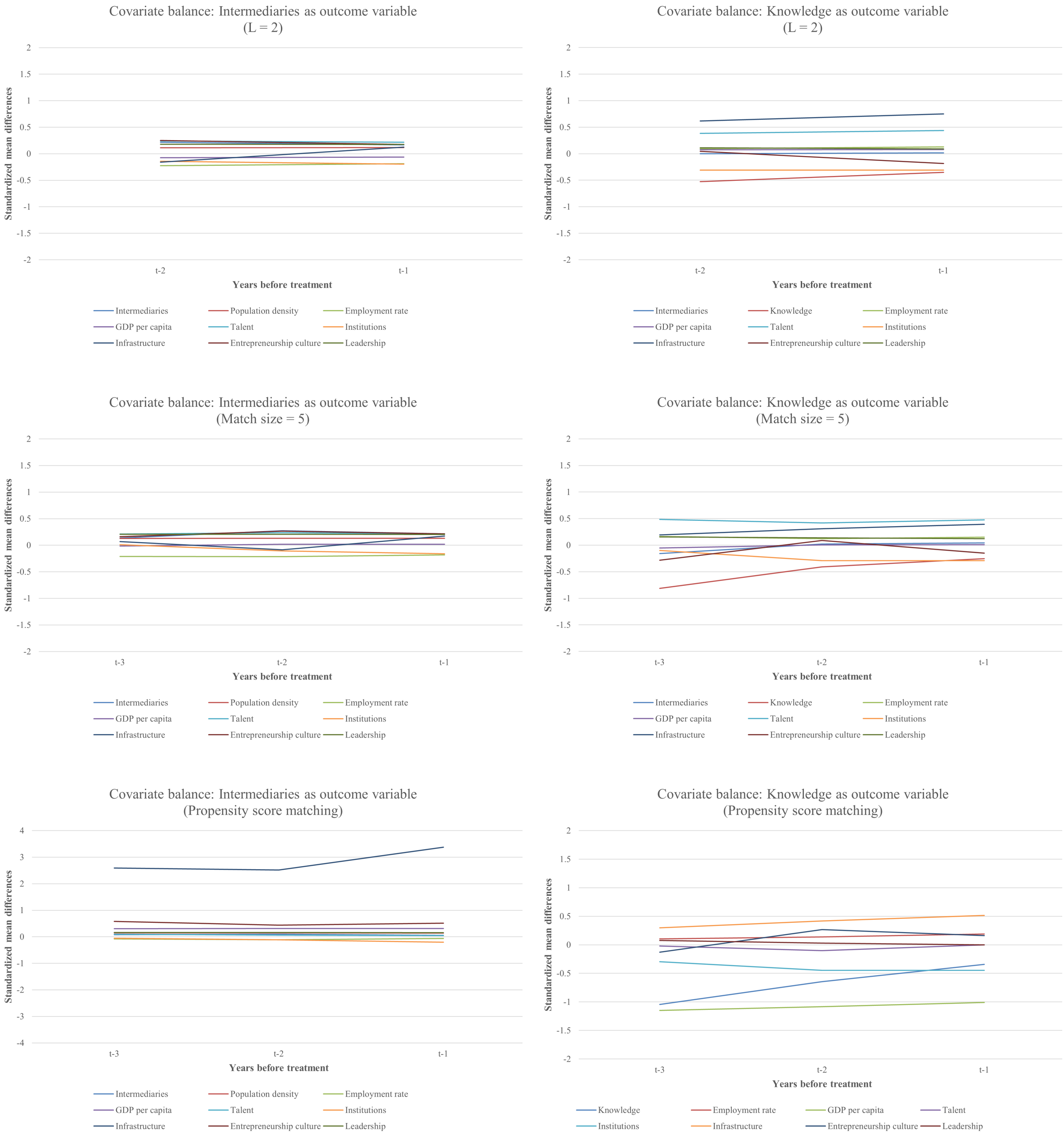


Table 3.3: Main estimates and robustness checks of the average treatment effect (ATT) on intermediaries and knowledge. Standard errors are computed with 1000 weighted bootstrap samples.

	Intermediaries				Knowledge			
	t+0	t+1	t+2	t+3	t+0	t+1	t+2	t+3
Main estimates	0.300**	0.427**	0.337	0.443	0.070	0.057	−0.035	−0.042
	(0.133)	(0.196)	(0.324)	(0.383)	(0.048)	(0.077)	(0.088)	(0.102)
$L = 2$	0.196	0.402**	0.399	0.495	0.077	0.065	−0.041	−0.074
	(0.123)	(0.181)	(0.306)	(0.354)	(0.051)	(0.070)	(0.080)	(0.120)
Mahalanobis with 5 neighbors	0.245**	0.427**	0.420	0.553	0.069	0.056	−0.029	−0.040
	(0.110)	(0.179)	(0.293)	(0.337)	(0.052)	(0.068)	(0.077)	(0.099)
Propensity score matching	0.259**	0.289	0.267	0.332	0.049	0.39	−0.050	−0.081
	(0.107)	(0.205)	(0.331)	(0.402)	(0.055)	(0.075)	(0.090)	(0.130)

Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

3.4.2 Heterogeneity tests

The effect of STPs' entry into IASP may also depend on the economic and geopolitical characteristics of the region. To explore potential heterogeneity in the impact of STP networks on regional EE development, we replicate our analysis – using the same set of parameters as in our main specification – while splitting regions based on GDP per capita and EU membership. Specifically, we conduct two heterogeneity tests. First, we divide regions into two groups based on the median GDP per capita among treated units in 2013 (the last common pre-treatment year for all treated regions). Second, we separate regions into EU and non-EU countries. The results are presented in Table 3.4.

Two key findings emerge from this analysis. Low-income regions experience an immediate increase in employment in knowledge-intensive market services (statistically significant at the 10% level) in the year of treatment. This effect likely stems from increased visibility, which helps these regions attract skilled workers who would otherwise migrate to more economically developed areas. However, the effect does not persist over time; although the ATT loses significance, it turns negative in the second and third years after treatment. In contrast, high-income regions benefit more from STPs' entry into IASP starting in the first year after treatment, with a statistically significant effect at the 10% level, increasing employment in knowledge-intensive market services by 0.46 percentage points. In terms of intramural R&D investments, no particular heterogeneous effects are observed based on GDP per capita.

More pronounced heterogeneity emerges when differentiating between EU and non-EU regions. Extra-EU regions exhibit a statistically significant increase ($p < 0.05$) in knowledge-intensive employment – typically made of highly specialized workers – with a rise of 0.75 and 0.98 percentage points in the year of treatment and the following year, respectively. This finding suggests that STP networks may act as complementary to EU policies in fostering cross-border knowledge transfers and resource sharing. Within the EU, such mechanisms are supported by the EU Research and Technological Development (RTD) policy, whereas STP networks appear to fulfill a similar role for extra-EU countries in the absence of such institutional frameworks. Finally, STPs' entry into IASP seems to stimulate R&D investments within extra-EU regions, significantly ($p < 0.05$) and positively affecting the knowledge dimension of the regional EE at the year of treatment. However, this effect reverses in the following years, becoming negative and not statistically significant.

Table 3.4: Heterogeneity effects. Standard errors are computed with 1000 weighted bootstrap samples.

	Intermediaries				Knowledge			
	t+0	t+1	t+2	t+3	t+0	t+1	t+2	t+3
GDP per capita above median	0.194	0.461^{*}	0.473	0.627	0.033	0.123	−0.022	−0.047
	(0.158)	(0.246)	(0.437)	(0.474)	(0.056)	(0.117)	(0.117)	(0.105)
GDP per capita below median	0.507^{*}	0.226	−0.247	−0.367	0.070	0.065	−0.032	0.005
	(0.274)	(0.395)	(0.410)	(0.613)	(0.059)	(0.088)	(0.108)	(0.133)
EU member	0.111	0.197	0.122	0.214	0.060	0.081	−0.029	−0.010
	(0.141)	(0.209)	(0.289)	(0.305)	(0.048)	(0.066)	(0.079)	(0.096)
Extra-EU	0.753^{**}	0.980^{**}	0.853	0.993	0.143^{**}	−0.117	−0.080	−0.267
	(0.345)	(0.419)	(0.895)	(1.105)	(0.071)	(0.221)	(0.221)	(0.204)

Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

3.5 Discussion

In this paper, we examine the role of STP networks in shaping regional EE development. To this aim, we develop a multi-stage approach to assess the effects of STPs' entry dynamics into global networks on EE dimensions, focusing on the regions in which these parks are located. Specifically, we address two main research questions: (i) "Do STP networks affect regional EE development?" and (ii) "What EE dimensions are impacted by participation in STP networks, and when does the effect become observable?". We focus on IASP – the largest global STP network – benefiting from data on entry and exit dynamics of STPs from the network. This longitudinal dataset, which spans multiple European regions, allows us to analyze whether participation in IASP determines changes in EE dimensions. Drawing on the EE framework developed by Stam (2015) and operationalized by Leendertse et al. (2021), we select two key EE dimensions that, based on an expert interview with the Knowledge and Project Manager of IASP, are most likely to be influenced by the association's activities: intermediary services (proxied by the percentage of employment in knowledge-intensive market services), and knowledge (proxied by intramural R&D expenditure as percentage of GDP). To estimate these effects, we employ a non-parametric generalization of the DiD estimator for TSCS data, which is particularly suitable when the number of treated units is small and when pre-treatment periods are short (Imai et al., 2023).

Our findings yield several interesting insights. First, STPs' entry into IASP leads to a statistically significant increase in employment in knowledge-intensive market services within their regions in the year of treatment and the subsequent year. This demonstrates that STP participation in global networks strengthens the intermediary services of regional EEs. Second, we observe a declining trend in intramural R&D expenditure from the year of treatment to the third year post-entry. Although not statistically significant due to the small number of treated units in this specification, this negative trend aligns with the idea that joining an international network of STPs promotes collaborative R&D extending beyond regional boundaries. Our covariate balance analysis confirms the comparability of treated and matched control units. Additionally, the robustness of our results is ensured by different sensitivity tests by varying the number of lags, match set size, and matching methods. Finally, we examine heterogeneity by GDP per capita level and EU membership. Differences emerge between low- and high-income regions in terms of the time in which the effect of STPs' entry in IASP is statistically significant. The former group experiences an immediate positive effect on intermediary services, potentially attracting skilled workers that might otherwise move toward more developed areas. In contrast, high-income regions show delayed effects that are significant in the first year post-entry. Heterogeneous effects are also observable when differentiating between EU and extra-EU regions. Specifically, extra-EU regions exhibit a statistically significant increase in knowledge-intensive employment in the year of treatment and the following year. These findings imply that STP networks may act as complements to EU integration policies by fostering cross-border knowledge transfer and collaborative R&D. Furthermore, extra-EU regions also demonstrate a significant rise in intramural R&D investment in the year of treatment, highlighting the value of global STP affiliations in enhancing regional knowledge production.

This study offers several theoretical contributions. First, it addresses calls for longitudinal, comparative, and dynamic approaches to STP research (Albahari et al., 2023), integrating previous studies that have largely considered STPs as static entities (Lecluyse et al., 2019). Second, it emphasizes the temporal evolution of STP networks' effects, showing their role in developing regional EEs over time. Third, while prior research has demonstrated that on-park firms tend to outperform off-park ones in terms of R&D efficiency (Siegel et al., 2003; Yang et al., 2009), we provide further understanding of these mechanisms by shifting the analysis at the macro-regional level. Specifically, our findings reveal that increased efficiency in R&D performance may be associated with a strategic reorientation of R&D activities toward international collaboration following entry into global STP networks. This is consistent with Minguillo et al. (2015), who found that on-park firms often establish collaborations beyond their regional context. In this vein, STP networks serve as multipliers of previously observed micro-level benefits, such as talent attraction and innovation performance. Fourth, we bridge STP and EE literatures, identifying the relevance of STP networks to key regional EE dimensions, extending recent contributions (Germain et al., 2023; Kanda et al., 2025; Mohammadi et al., 2025). Finally, our heterogeneous analysis highlights the importance of considering context-specific factors for EE measurement (Stam & Van de Ven, 2021) and cross-country STP effects (Lopes et al., 2025).

Besides theoretical contributions, our findings offer several practical implications for both policymakers and STP managers. The results suggest that regional authorities should not only support the establishment of STPs but also promote their participation into global networks, as such affiliations generate positive spillovers for the entire region. These outcomes reinforce the IASP mission to foster international partnerships and demonstrate how STP networks can lower barriers to entry into global innovation systems (IASP, 2025). For STP managers, the findings shed light on the value of actively participating in international networks to strengthen their regional intermediary role and to access external knowledge flows. Moreover, STP networks may serve as effective policy instruments for talent attraction and cross-border collaboration, especially in regions lacking cohesive policy frameworks – such as those European countries outside the EU – providing an alternative mechanism for cross-border knowledge exchange and collaboration.

This study presents some limitations. First, despite broadening the scope of prior research, our sample size is constrained by data availability on EE dimensions and regional socio-economic indicators. However, we mitigate this limitation by using a non-parametric DiD estimator suited to small sample settings. Second, some effects of STP networks may become more evident when analyzed locally (e.g., at the NUTS-3 level), highlighting the need for greater data granularity – an aspect that would be valuable to collect and integrate into future analyses (Hess, Wahl, & Johnson, 2025). Third, while we estimate the effects induced by STP network participation as average treatment effects, such benefits likely vary with parks' absorptive capacity and engagement levels. Future research should investigate this heterogeneity by conducting in-depth investigations through multiple case studies. Fourth, our findings stem from the analysis of IASP, the largest and most influential global association of STPs. Thus, the observed positive effects may, in part, reflect IASP's central position within the global STP landscape and may not fully extend to smaller or less integrated networks. Comparative studies involving other STP networks are thus essential to assess the generalizability of our findings. Finally, further research could incorporate social network analysis techniques to map global connectivity among STPs and assess their relational structures through centrality measures and network metrics.

Furthermore, some effects of STP networks may become more apparent when analyzed at a more localized level (e.g., NUTS-3), highlighting the need for greater data granularity—an aspect that would be valuable to collect and integrate into future analyses (Hess, Wahl, & Johnson, 2025).

3.6 Conclusions

This study examined how participation in global STP networks influences regional EE development, addressing key gaps in the literature by adopting a longitudinal and comparative approach that captures the dynamic and heterogeneous nature of ecosystem evolution. Drawing on a unique dataset of multiple European regions and employing a non-parametric generalization of the DiD estimator for TSCS data, the analysis revealed that STPs' entry into the IASP significantly strengthens the intermediary dimension of regional EEs, as reflected by increased employment in knowledge-intensive market services. This effect is both immediate and context-dependent, proving particularly relevant in low-income and extra-EU regions, where global networks act as complementary mechanisms to fragmented or underdeveloped policy frameworks. In these contexts, international affiliation enhances the absorptive capacity of regional actors, improves access to external expertise and markets, and facilitates the circulation of tacit and codified knowledge across geographical and institutional boundaries.

Conversely, a declining trend in intramural R&D expenditure suggests that joining international networks may lead to a structural reconfiguration of regional innovation processes. Rather than signaling a reduction in research intensity, this pattern indicates a shift from localized, firm-level R&D activities to cross-border collaboration and open innovation practices, consistent with the growing emphasis on distributed knowledge production within global innovation systems. By engaging in international networks such as IASP, STPs and their tenant firms can leverage shared research infrastructures, co-develop projects with transnational partners, and participate in broader value chains that transcend regional confines.

The findings advance STP research by reframing these organizations as dynamic, adaptive, and networked actors—rather than static policy tools—whose influence extends beyond local innovation promotion toward the orchestration of macro-regional knowledge flows. The study contributes to EE literature by identifying the specific ecosystem dimensions most affected by STP networking—namely intermediaries and knowledge—and by empirically linking micro-level innovation mechanisms (such as firm performance and collaboration) with macro-level regional development outcomes (such as employment in knowledge-intensive sectors). This bridging of analytical levels helps conceptualize STPs as "meso-level anchors" within multi-scalar innovation architectures, capable of translating global resources into regional capabilities.

From a theoretical standpoint, this work also highlights the temporal and contextual heterogeneity of ecosystem effects. Low-income and extra-EU regions experience an immediate impact following IASP membership, benefiting from increased visibility and legitimacy in the global innovation arena, while high-income regions exhibit delayed but more persistent effects as network participation consolidates existing innovation infrastructures. These differences emphasize the need to account for institutional thickness, absorptive capacity, and policy maturity when evaluating how global networks shape local ecosystems.

From a practical perspective, the results underscore that policies aimed solely at creating STPs are insufficient unless they also foster their integration into international knowledge networks. Encouraging participation in global associations such as IASP strengthens STPs' ability to mediate between academia, industry, and government, facilitating talent attraction, investment inflows, and cross-border R&D collaborations. For policymakers, promoting network participation can enhance regional competitiveness, reduce innovation disparities, and generate spillover effects that extend beyond individual parks. For STP managers, international engagement serves as a strategic lever to reinforce their intermediary and orchestration roles, providing access to shared infrastructures, global benchmarks, and collaborative platforms that accelerate innovation diffusion.

Ultimately, this study contributes to a broader understanding of how global STP networks function as connective tissue in the architecture of regional EEs, enabling regions to overcome local constraints and engage in international knowledge exchange. By demonstrating that global connectivity can amplify the developmental potential of regional ecosystems, the study reinforces the view that innovation-driven growth increasingly depends on the capacity of local systems to operate within global networks of collaboration and learning.

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Conclusions

This dissertation provides a comprehensive contribution to the study of ecosystems by examining how Innovation Ecosystems (IEs) and Entrepreneurial Ecosystems (EEs) can be conceptualized, connected, and operationalized in an era of rapid technological transformation, globalization, and digital convergence. Across three interconnected chapters, the work advances a unified perspective on ecosystems as interdependent, adaptive, and evolving systems of value creation, governed by relational, cognitive, and institutional logics.

The first chapter, developed within the framework of an industrial PhD in collaboration with FS Group and Eni, investigates how partnerships between distinct IEs can be effectively initiated and governed. By introducing the concept of Interconnected Innovation Ecosystems (IIEs), it offers one of the first empirically validated tools for partner selection across national and institutional boundaries. The tool operationalizes five dimensions—Partners' Maturity, Collaboration Readiness, Value Co-Creation, IP Management, and International Network—that integrate academic and practitioner insights through a design research approach. The chapter thus bridges theory and practice by reframing intellectual property as a relational and strategic asset and by demonstrating how design-driven methodologies can translate theoretical constructs into actionable managerial instruments.

The second chapter addresses one of the central conceptual challenges in the literature: clarifying the relationship between EEs and IEs. Through a scoping review and thematic synthesis of 48 peer-reviewed studies, it identifies four archetypes of nested configurations—startup ecosystems, entrepreneurial university ecosystems, entrepreneurial innovation ecosystems, and regional innovation ecosystems. These archetypes are mapped along two analytical dimensions: the dominant orientation (entrepreneurial versus innovation-driven) and the prevailing form of systemic complexity (bottom-up versus top-down). The contribution lies in redefining nestedness as a dynamic and functional relationship shaped by flows of resources, governance mechanisms, and complex system properties. The resulting typology provides both conceptual clarity and a policy-relevant framework for designing governance models that align with the intrinsic logic of each ecosystem configuration.

The third chapter advances this trajectory by translating the theoretical notion of nested interdependence into a macro-regional empirical analysis. It examines how Science and Technology Parks (STPs), as intermediary organizations, contribute to the development of regional EEs through participation in global networks, such as the International Association of Science and Technology Parks and Areas of Innovation (IASP). Using a longitudinal dataset and a non-parametric difference-in-differences estimator, the study shows that joining a global STP network significantly strengthens the intermediary and knowledge functions of regional ecosystems, especially in low-income and extra-EU regions. By demonstrating that cross-border connectivity enhances knowledge circulation and collaborative capacity, this chapter operationalizes the ideas of network orchestration and systemic interdependence developed throughout the dissertation. It bridges the literatures on STPs and EEs, revealing how intermediary infrastructures can amplify ecosystem performance through transnational collaboration.

The industrial PhD program has been crucial in guiding and shaping the trajectory of this dissertation, not only as an institutional context but as a methodological philosophy. Conducted at the intersection of academic research and organizational practice, this work demonstrates that genuine innovation arises when theoretical rigor and practical relevance advance in parallel. Rather than separating abstract theorization from applied experimentation, the industrial PhD model embraces their mutual reinforcement: theory informs practice, and practice continuously refines theory. Collaborations with partners such as FS Group and Eni enabled access to complex organizational ecosystems, allowing for the observation, co-design, and testing of tools in real contexts. This embeddedness fostered the development of frameworks that are scientifically robust and operationally useful, generating value not only for academia but also for the strategic management of innovation in firms and institutions. The experience highlights how research embedded in organizational contexts can produce both conceptual advancement and tangible impact, exemplifying a model of doctoral education that turns the university into a partner in transformation rather than a distant observer.

Future research should build upon this integrative foundation by embracing methodological hybridity—combining qualitative interpretation, quantitative modeling, and design experimentation—to address the growing complexity of contemporary innovation systems. The comparative evolution of hybrid ecosystems, such as those driven by artificial intelligence or sustainability transitions, requires approaches capable of capturing contextual dynamics while maintaining analytical rigor. Empirical validation of the proposed typology could be achieved through configurational methods such as fuzzy-set Qualitative Comparative Analysis (fsQCA), which can identify combinations of conditions that jointly enable ecosystem effectiveness, while predictive modeling of ecosystem outcomes could be explored through Artificial Neural Networks (ANN), enabling the anticipation of innovation trajectories and the identification of critical success configurations across contexts. Beyond technical sophistication, future ecosystem research must also develop practical, context-sensitive, and collaborative methodologies that engage organizations, policymakers, and researchers as co-producers of knowledge—ensuring that academic inquiry remains grounded in real-world challenges and contributes to actionable innovation.

This dissertation contributes to a more integrated, dynamic, and operational understanding of ecosystems, emphasizing how their effectiveness depends on the ability to connect, orchestrate, and evolve across organizational, institutional, and territorial boundaries. By bridging theoretical fragmentation and advancing actionable frameworks, it demonstrates how industrial PhD research can act as a conduit for value co-creation between academia and practice, fostering a virtuous cycle of theoretical refinement and practical innovation that enriches both domains and strengthens the collective capacity to design, manage, and sustain complex systems of innovation.

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Appendix A

Appendix to the Paper *"A Tool for Partner Selection for Innovation Ecosystems in National and International Settings"*

Table A.1: Proposed tool

Principle	Evaluation Question	Score	Level Description
Partners' Maturity	To what extent is the partner organization mature, structured, and aligned with strategic innovation areas?	1	New or informal entities lacking a legal structure and innovation experience. No strategic direction or operational processes in place.
		2	Small-scale actors with limited innovation history, unclear strategic positioning, and insufficient internal capabilities to support advanced collaborations.
		3	Mid-sized organizations with some innovation engagement; occasional alignment with strategic domains and moderate resource availability.
		4	Established players with clear strategic focus, recurring involvement in innovation projects, and well-structured internal innovation teams.
		5	Highly experienced and institutionally embedded partners, consistently engaged in high-impact innovation aligned with core strategic areas, supported by robust infrastructure and governance.

Table A.1: (continued)

Principle	Evaluation Question	Score	Level Description
Collaboration Readiness	How ready and capable is the partner to collaborate and transform innovation into marketable outcomes?	1	No collaboration mechanisms in place; innovation efforts are siloed and disconnected from both partners and the market.
		2	Initial openness to collaboration, though poorly structured and lacking dedicated personnel or procedures; weak market orientation.
		3	Partial collaboration experience with some defined procedures; growing ability to engage in structured joint innovation.
		4	Established collaboration pathways with documented experience in co-innovation; good integration with market timelines and partner workflows.
		5	Fully institutionalized and mature collaboration systems with proven ability to manage complex multi-actor initiatives leading to marketable outcomes.
Value Co-creation	What is the level of mutual engagement and strategic value generated through joint innovation initiatives?	1	No co-creation activity; innovation processes are internal and closed to external actors, with negligible mutual benefits.
		2	Sporadic or pilot co-creation attempts with minimal knowledge sharing and unclear outcomes.
		3	Structured co-innovation processes established in selected initiatives; mutual benefit begins to emerge.
		4	Strong and active engagement in co-design and co-development, including shared responsibilities and value capture strategies.
		5	Deep, long-term co-creation integration with the partner, embedded in governance, shared IP, and joint strategic objectives with measurable mutual value.

Table A.1: (continued)

Principle	Evaluation Question	Score	Level Description
IP Management	How does the partner manage intellectual property, and to what extent is there a strategy for protection and monetization?	1	No awareness or use of IP protection mechanisms; innovation is unprotected and vulnerable to appropriation.
		2	Basic awareness of IP but no formal strategy; reactive approach to protection with limited legal or technical support.
		3	Initial development of IP protocols; isolated patent filings or ad-hoc legal arrangements present.
		4	Operational IP strategy in place with regular filings, internal capabilities for IP handling, and use of exclusivity rights.
		5	Advanced IP portfolio with monetization strategies, licensing models, cross-border protections, and legal enforcement structures.
International Network	To what extent does the partner operate in international innovation networks and possess global innovation capabilities?	1	Entirely local operations with no foreign engagement or visibility in international innovation scenes.
		2	Ad-hoc participation in international events or short-term projects with limited institutional follow-up.
		3	Moderate engagement in international collaborations; involved in networks but not as a strategic actor.
		4	Consistent participation in international innovation programs and partnerships with cross-border infrastructure.
		5	Globally embedded organization with leadership roles in international platforms, long-term global presence, and proven innovation export capacity.

Appendix B

Appendix to the Paper *"Entrepreneurial and innovation ecosystems: a scoping review on the complexity of nested configurations"*

Table B.1: Full list of selected articles.

Authors	**Year**	**Title**	**Source**
Abreu and Grinevich	2024	The entrepreneurial university: strategies, processes, and competing goals	The Journal of Technology Transfer
Alam et al.	2024	Success Components of University Entrepreneurial Ecosystem: A Multimethod Exploration	IEEE Transactions on Engineering Management
Ancona et al.	2023	Network-based principles of entrepreneurial ecosystems: A case study of a start-up network	Small Business Economics
Audretsch et al.	2023	Sustainable orientation management and institutional quality: Looking into European entrepreneurial innovation ecosystems	Technovation
Autio et al.	2014	Entrepreneurial innovation: The importance of context	Research Policy
Baloutsos et al.	2020	Identifying contradictions in an incumbent–startup ecosystem – an activity theory approach	European Journal of Innovation Management
Berger and Kuckertz	2016	Female entrepreneurship in startup ecosystems worldwide	Journal of Business Research

Table B.1: (continued)

Authors	**Year**	**Title**	**Source**
Bramwell et al.	2019	Growing entrepreneurial ecosystems: Public intermediaries, policy learning, and regional innovation	Journal of Entrepreneurship and Public Policy
Carayannis et al.	2017	The ecosystem as helix: an exploratory theory-building study of regional co-opetitive entrepreneurial ecosystems as Quadruple/Quintuple Helix Innovation Models	R&D Management
Cooke	2016	The virtues of variety in regional innovation systems and entrepreneurial ecosystems	Journal of Open Innovation: Technology, Market, and Complexity
Corvello et al.	2023a	Building start-up acceleration capability: A dynamic capability framework for collaboration with start-ups	Journal of Open Innovation: Technology, Market, and Complexity
Corvello et al.	2023b	Start-up collaboration units as knowledge brokers in Corporate Innovation Ecosystems: A study in the automotive industry	Journal of Innovation & Knowledge
Eslamloo et al.	2025	Successful commercialisation in startup accelerator programmes: How different startup ecosystems matter	Journal of Innovation & Knowledge
Farinha et al.	2018	Regional innovation systems and entrepreneurial embeddedness	European Planning Studies
Ferreira et al.	2023	The role of entrepreneurial ecosystems in technological and social challenges	R&D Management
Freire-Gibb and Gregson	2019	Innovation systems and entrepreneurial ecosystems: Implications for policy and practice in Latin America	Local Economy
Fu and Qian	2023	Building innovative capacity in regional entrepreneurship and innovation (eco)systems: Startups versus incumbent firms	Growth and Change
Guerrero and Martínez-Chávez	2020	Aligning regional and business strategies: Looking inside the Basque Country entrepreneurial innovation ecosystem	Thunderbird International Business Review
Guerrero et al.	2020	Entrepreneurial university ecosystems and graduates' career patterns: do entrepreneurship education programmes and university business incubators matter?	Journal of Management Development

Table B.1: (continued)

Authors	Year	Title	Source
Haines	2016	Developing a Startup and Innovation Ecosystem in Regional Australia	Technology Innovation Management Review
Johnson et al.	2019	Entrepreneurial dynamism and the built environment in the evolution of university entrepreneurial ecosystems	Industrial and Corporate Change
Kraus et al.	2021	The role of innovation and knowledge for entrepreneurship and regional development	Entrepreneurship and Regional Development
Krishnan and Krishna	2024	Introduction: Start-ups and innovation ecosystems	Science, Technology and Society
Kwong et al.	2022	How entrepreneurial are social entrepreneurship education providers? The role of universities' entrepreneurial ecosystems in the provision of elective social entrepreneurship courses to business students	Studies in Higher Education
Lahikainen et al.	2018	Challenges to the development of an entrepreneurial university ecosystem: The case of a Finnish university campus	Industry and Higher Education
Leceta and Könnölä	2019	Fostering entrepreneurial innovation ecosystems: Lessons learned from the European Institute of Innovation and Technology	Innovation: The European Journal of Social Science Research
López-Rubio et al.	2020	Regional innovation system research trends: toward knowledge management and entrepreneurial ecosystems	International Journal of Quality Innovation
Marcon and Duarte Ribeiro	2021	How do startups manage external resources in innovation ecosystems? A resource perspective of startups' lifecycle	Technological Forecasting and Social Change
Marcon et al.	2024	How the interplay between innovation ecosystems and market contingency factors impacts startup innovation	Technology in Society
Markkula and Kune	2015	Making Smart Regions Smarter: Smart Specialization and the Role of Universities in Regional Innovation Ecosystems	Technology Innovation Management Review
Motoyama and Knowlton	2017	Examining the connections within the startup ecosystem: A case study of St. Louis	Entrepreneurship Research Journal
Nieth et al.	2018	Embedding entrepreneurial regional innovation ecosystems: reflecting on the role of effectual entrepreneurial discovery processes	European Planning Studies

Table B.1: (continued)

Authors	Year	Title	Source
Ojaghi et al.	2019	A synthesized framework for the formation of startups' innovation ecosystem: A systematic literature review	Journal of Science and Technology Policy Management
Ozkan et al.	2023	The Next Generation of Innovation	Technology & Innovation
Pidorycheva et al.	2020	A Conceptual Framework for Developing of Regional Innovation Ecosystems	European Journal of Sustainable Development
Primario et al.	2024	Peer innovation as an open innovation strategy for balancing competition and collaboration among technology start-ups in an innovation ecosystem	Journal of Innovation & Knowledge
Prokop	2021	University entrepreneurial ecosystems and spinoff companies: Configurations, developments and outcomes	Technovation
Radziwon et al.	2017	Creating and capturing value in a regional innovation ecosystem: A study of how manufacturing SMEs develop collaborative solutions	International Journal of Technology Management
Saccol Filho et al.	2023	A measurement tool for the competitiveness of startups' innovation ecosystem	Journal of the Knowledge Economy
Schaeffer et al.	2021	Mutualism in ecosystems of innovation and entrepreneurship: A bidirectional perspective on universities' linkages	Journal of Business Research
Shashlo et al.	2018	Determinants of integration interaction among the subjects of the entrepreneurial innovation ecosystem of macro region	Amazonia Investiga
Singh et al.	2019	Analyzing the startup ecosystem of India: A Twitter analytics perspective	Journal of Advances in Management Research
Tejero et al.	2019	Analysis of the Dynamism in University-Driven Innovation Ecosystems Through the Assessment of Entrepreneurship Role	IEEE Access
Thomas et al.	2020	Universities as orchestrators of the development of regional innovation ecosystems in emerging economies	Growth and Change

Table B.1: (continued)

Authors	Year	Title	Source
Thomas et al.	2018	Linking entrepreneurial and innovation ecosystems: The case of AppCampus	Entrepreneurial Ecosystems and the Diffusion of Startups
Vargas and Arias	2022	The entrepreneurial ecosystem of Guadalajara, Jalisco, Mexico: Its technology-based and fast-growing startups and entrepreneurial-employees	Journal of Technology Management & Innovation
Vettik-Leemet and Mets	2024	Entrepreneurship and Innovation—Process Overlap or the Same? Systematic Overview and Converging Process-Dynamic Model	Administrative Sciences
Ziakis et al.	2022	Start-Up Ecosystem (StUpEco): A conceptual framework and empirical research	Journal of Open Innovation: Technology, Market, and Complexity

Appendix C

Appendix to the Paper *"Fostering regional entrepreneurial ecosystem development: the role of science and technology park networks"*

C.1 Final dataset

The dataset used for our main analysis builds on information regarding the entry and exit dynamics of 221 Science and Technology Parks (STPs) that joined (and, in some cases, exited) the International Association of Science and Technology Parks and Areas of Innovation (IASP) between 1985 and 2024. We aggregated this information at the NUTS-2 regional level, based on the geographic location of each park, and integrated it with the variables listed in Table 2 of the paper. This process yielded a panel of 59 NUTS-2 regions across 22 European countries that hosted one or more STPs affiliated to IASP between 2011 and 2024. To ensure consistency in our difference-in-differences (DiD) estimates, we set the pre-treatment window to $L = 3$, meaning that only regions with STPs entering IASP from 2014 to 2024 are retained for analysis. This restriction led to a final sample of 48 NUTS-2 regions across 19 European countries. The complete list of regions, along with the number of STPs and their treatment windows, is reported in Table C.1. In cases where multiple STPs operate within the same region, the treatment window is defined as the union of their individual membership periods. The number of IASP members reported per region reflects the cumulative count within the relevant time span and does not imply simultaneous membership. Regions that are classified as never treated include those that hosted STPs joining IASP during the final years of our observation period (i.e., 2023–2024). These regions are retained as potential control units, along with regions that remain untreated at different points in time.

Table C.1: Final dataset. In case of multiple parks within the same region, the treatment window corresponds to the union of the distinct membership periods. The number of IASP members is cumulative within the indicated time span and does not necessarily represent simultaneous memberships.

NUTS-2 region	Country	Number of IASP members	Treatment window
BG41	Bulgaria	1	2014-2022
FRF2	France	1	2014-2022
SK04	Slovakia	1	2014-2022
ES61	Spain	2	2014-2022
TR10	Turkey	3	2014-2022
TR31	Turkey	2	2014-2021
IS00	Iceland	1	2015-2022
ES11	Spain	2	2016-2022
FRE1	France	1	2016-2022
ITC3	Italy	1	2016-2021
RS11	Serbia	1	2017-2022
TR22	Turkey	1	2017-2022
ES62	Spain	1	2017-2022
SE31	Sweden	2	2018-2022
ES51	Spain	1	2018-2022
FRY4	France	1	2019-2022
ES30	Spain	1	2019-2022
UKI4	United Kingdom	1	2019-2022
RS12	Serbia	1	2020-2022
DE40	Germany	1	2020-2022
ITC1	Italy	1	2020-2022
RS22	Serbia	1	2020-2022
PT11	Portugal	2	2020-2022
TR42	Turkey	1	2020-2022
ES70	Spain	1	2020-2022
FRD2	France	1	2021-2022
BE22	Belgium	1	2022
CZ06	Czech Republic	1	2022
HU32	Hungary	1	2022
NL21	Netherlands	1	2022
NL22	Netherlands	1	2022
PL63	Poland	1	2022
TR41	Turkey	1	2022
ES52	Spain	1	2022
UKF1	United Kingdom	1	2022
UKM8	United Kingdom	1	2022
PT17	Portugal	0	Never
DE12	Germany	0	Never
BE21	Belgium	0	Never
FRL0	France	0	Never
LU00	Luxembourg	0	Never
PL92	Poland	0	Never
SE33	Sweden	0	Never
CH04	Switzerland	0	Never

Continued on next page

Table C.1 – *Continued from previous page*

NUTS-2 region	Country	Number of IASP members	Treatment window
UKH1	United Kingdom	0	Never
ITI4	Italy	0	Never
UKI3	United Kingdom	0	Never
UKI7	United Kingdom	0	Never

C.2 Further analyses

In our main analysis, we evaluate the effect of Science and Technology Park (STP) participation in the International Association of Science Parks and Areas of Innovation (IASP) on two specific entrepreneurial ecosystem (EE) dimensions: intermediary services and knowledge. These dimensions were selected from the framework proposed by Stam (2015), based on both an extensive review of the literature and an expert interview with the Knowledge and Project Manager of IASP. Specifically, the expert interview contributed to bridging two critical components of our research design: the expected benefits of participation in IASP's global network and the EE dimensions most likely to be affected by such participation. By integrating these insights, we refined our variable selection, enhancing the study's relevance and methodological rigor.

For completeness, we conducted additional analyses using other EE dimensions as outcome variables, operationalized as reported in Table 2 of the paper: talent, entrepreneurship culture, formal institutions, physical infrastructure, demand, and network. We followed the same estimation strategy as in our main specifications, setting $L = 3$ for the pre-treatment window (except for the network dimension, for which we used $L = 2$ due to a more limited number of observations). For matching treated and control regions, we applied Mahalanobis distance matching using the three nearest neighbors.

As shown in Figure C.1, covariate balance was successfully achieved across all models – except for the network dimension, which may be affected by the smaller sample size – confirming the robustness of our approach. However, as evident from Table C.2, none of the additional outcome variables yielded statistically significant treatment effects. Although this result may partially reflect the higher incidence of missing data for some EE dimensions in the regions under study, it ultimately reinforces the validity of our variable selection and the paper's focus on intermediary services and knowledge as the EE dimensions most likely impacted by STP network membership.

Figure C.1: Covariate balance: talent, entrepreneurship culture, formal institutions, physical infrastructure, demand, and network as outcome variables.

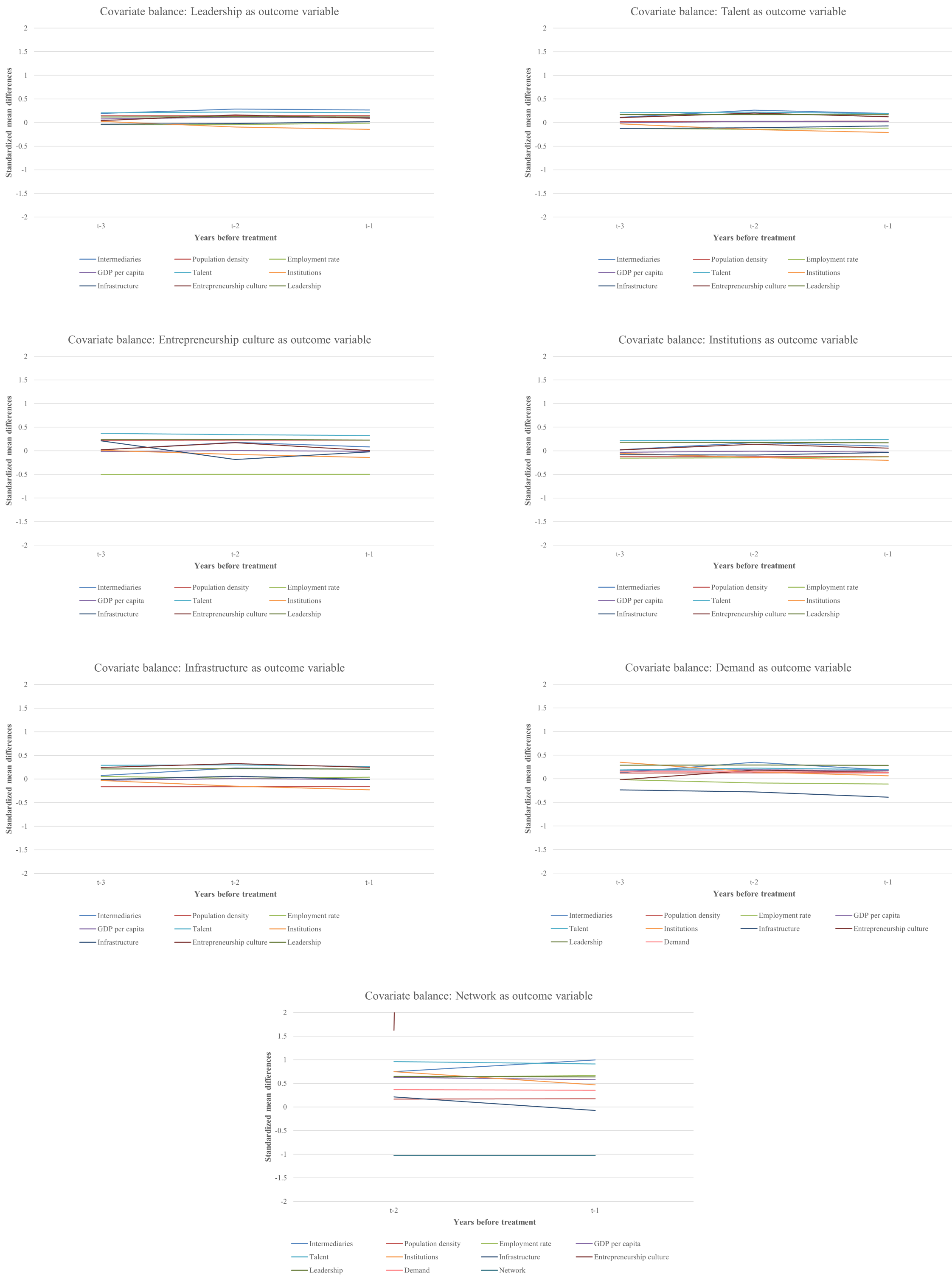

Table C.2: Main estimates of the average treatment effect (ATT) on leadership, talent, entrepreneurship culture, formal institutions, physical infrastructure, demand, and network. Standard errors are computed with 1000 weighted bootstrap samples.

	Post-treatment period			
EE dimension	$t+0$	$t+1$	$t+2$	$t+3$
Leadership	1.137	-11.510	-23.098	-23.176
	(3.482)	(34.742)	(37.519)	(38.442)
Talent	0.198	0.306	0.276	0.243
	(0.398)	(0.633)	(0.984)	(1.231)
Entrepreneurship culture	866.111	-1200.704	-1995.037	-983.037
	(1662.534)	(2481.809)	(2353.844)	(2809.599)
Formal institutions	0.029	0.016	0.044	0.044
	(0.095)	(0.107)	(0.120)	(0.120)
Physical infrastructure	0.053	-0.297	-1.733	-0.788
	(1.620)	(3.106)	(4.678)	(5.423)
Demand	427.437	-2.560	-69.763	680.060
	(1432.452)	(1806.732)	(2907.284)	(4630.220)
Network	5.108	-1.294	-10.953	5.569
	(8.661)	(21.936)	(14.817)	(21.404)

Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

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