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Modeling Tomorrow: Innovation for Sustainable Development Innovation Systems, Technological Capabilities, and Sustainability Transitions in Latin America and the Caribbean



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Modeling Tomorrow: Innovation for Sustainable Development

Innovation Systems, Technological Capabilities, and Sustainability Transitions in Latin America and the Caribbean

CHAPTER 1

I. Rethinking Innovation Systems and Ecosystems

Innovation Ecosystems and the Cluster as a Unit of Analysis: A Systematic Review with Perspectives for Latin American Industrial Clusters

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1. Introduction

Validating the appropriate use of strategies aimed at the continuous improvement of organizations opens possibilities for growth and for strengthening processes that favor better practices (Granstrand & Holgersson, 2020), thereby enhancing value creation and the performance of the initiatives undertaken (Yang, Yang, & Guo, 2024). Within this framework, various approaches have been developed toward building scenarios that sustain, over time, those firms seeking to generate added value, with innovation understood as a transversal feature that drives continuous improvement in market participation (Sun, Liu, & Huang, 2022). Investment in value generation and in meeting market needs should be a focus of research, provided that such investment does not drastically alter the firm's core mission (Peirone, Pereira, Leitão, & Nezghoda, 2024; Huang, Li, & Li, 2023). In this sense, the concept of the Innovation Ecosystem emerges as a strategic construct that fosters innovation through the involvement of actors who interact positively with one another, addressing emerging market needs (Wei, Ni, Zhang, & Duan, 2023; Carneiro, Isidro, & Criado, 2022).

Participation in Innovation Ecosystems enhances the acquisition of added value through the positioning that alliances and agreements between actors provide (Lee, 2020); in this regard, such alliances position small and medium sized organizations as relevant inflection points, given the nexus they establish for both internal and external value generation. The literature underscores the importance of State and academic involvement for the proper development of the ecosystem (Carneiro et al., 2022; Jalilian & Zanjirchi, 2023) and warns that the understanding of the concept may vary depending on the interests of each participating component (Ranga, Mroczkowski, & Araiso, 2017; Pellikka & Ali-Vehmas, 2016).

Several authors have validated the practicality of the concept in terms of the benefits it affords to participating organizations (Ferasso & Sztando, 2022; Zeng, Lo, & Chen, 2024); others regard innovation development as a key vector for administrative growth and market participation (Zheng, Huang, Qian, Xu, & Shen, 2022; Shih, Hu, & Chou, 2024; Darkwa, 2023; Antonelli, Brunori, Jawhar, Petruzzella, & Roma, 2020; Resende & Bravo, 2016), noting that the Innovation Ecosystem provides these benefits without necessarily entailing additional costs for firm-level innovation, provided the economic capacities of the organizational system are assessed beforehand (Kai, de Lima, & Benitez, 2024).

The relationships among State, academia, industry, and society fostered by the Innovation Ecosystem allow for a more balanced distribution of burdens and responsibilities (Zhao, Lyu, & Grimes, 2024; Glukhov, Lialina, Rozhkov, Vasiukova, & Kosolapov, 2016). This raises the need to weigh the returns owed to each participating actor, so that particular interests do not undermine the sound functioning of the ecosystem (Glukhov et al., 2016; Andersson & Lindlöf, 2023). Within this framework, open innovation models have emerged, allowing the participation of different actors, regardless of whether they share a common business core, while reducing the costs and risks associated with innovation through shared investment (Alkhazaleh, Mykoniatis, & Alahmer, 2022; Bańka et al., 2024).

Cooperation among entities with differing interests, oriented toward satisfying the needs of the market in which they participate, requires that value generation not produce conflicts among the bodies involved. The Innovation Ecosystem addresses this need by connecting the various institutional mandates without giving rise to conflicts of interest among participants.

This need to clarify the term Innovation Ecosystem, and to examine its applicability to business environments, is precisely what motivates the doctoral research from which this document originates. That research is being carried out within the PhD in Engineering, Industry and Organizations program at Universidad Nacional de Colombia, and is centered on the competitiveness of the metalworking cluster of Manizales, Colombia, with the cluster taken as its specific unit of analysis. The remainder of this document is organized as follows: Section 2 reviews the literature on the Innovation Ecosystem construct and its components; Section 3 describes the systematic review methodology applied; Section 4 presents the bibliometric and thematic findings, together with their discussion; and Section 5 sets out the concluding remarks and the next steps of the ongoing doctoral work.

2. Literature review

In this regard, Mercan and Göktaş (2011) note that the Innovation Ecosystem offers considerable potential, particularly in converting knowledge into added value for participating industries; although these industries depend primarily on contributions generated within their own environment, the ecosystem strengthens business competitiveness. Three key components and their potential applications are thus identified. Cluster development refers to the geographic concentration of firms, suppliers, and industries aimed at promoting innovation within their respective fields, encouraging the creation of new knowledge and technology that improves firms' market positioning (Martínez-Marín, Puello-Pereira, & Ovallos-Gazabon, 2020). University-industry collaboration comprises alliances between academic institutions and firms that strengthen Research and Development, enabling better application of technological and scientific advances according to the needs of the productive sector. Innovative culture is a crucial factor for the success of any Innovation Ecosystem; its adoption facilitates firms' commitment to innovation, ensuring an environment conducive to continuous and sustainable development. Some authors nonetheless caution against misusing the term “ecosystem,” warning against its

arbitrary application to collective phenomena that do not strictly correspond to the concept (Cuartas Torres & Marín Cardona, 2023).

Within the Latin American context, Martínez-Marín et al. (2020) have modeled cluster competitiveness through systems dynamics, offering a formal treatment of the cluster as a differentiated unit of analysis rather than a simple derivation of regional or sectoral studies. Cuartas Torres and Marín Cardona (2023) extend this line of reflection to entrepreneurship ecosystems from a practical and conceptual standpoint, cautioning that the ecosystem metaphor should not be applied indiscriminately to collective phenomena that do not meet its defining conditions of interdependence among heterogeneous actors. Taken together, these Latin American contributions and the broader international literature reviewed above provide the conceptual foundation on which the systematic review reported in this document was designed, and on which the doctoral project itself is being built.

3. Methodology

With the aim of clarifying the term Innovation Ecosystem and validating its application to industry, regardless of the specific business core involved and of the benefits it offers within the market in which the firm participates, a systematic literature review strategy was adopted, following the PRISMA methodology, which allows for the establishment of appropriate criteria for document selection through successive reductions and filters (Arango, Rincón, & Berrio, 2023; Haddaway, Page, Pritchard, & McGuinness, 2022).

The search equation applied, identically across both bibliographic resources, was as follows:

(Innovation) AND NOT (Animals OR Habitat OR Environment) AND (Ecosystem) AND ("Innovation Ecosystems" OR "Innovation network") AND (Industries) AND (Organization) AND (Cluster)

The search was conducted on October 31, 2024. Its application in Scopus yielded 267 records (2012 to 2024 period; 150 sources; annual growth rate of 34.64 percent), and in Web of Science, 157 records (2010 to 2024 period; 84 sources; annual growth rate of 26.2 percent), for a total of 424 identified documents. This initial pool was subjected to a two-stage deduplication process. First, 45 duplicate records shared between both databases were removed, identified through DOI matching and normalized-title matching. Second, 1 guest editorial was excluded for not constituting original research. The result was a total of 378 unique records, which constitute the final corpus included in this review.

The topical relevance of the corpus is guaranteed by the very design of the search equation, which requires, through the mandatory AND operator, the co-occurrence of the terms Industries, Organization, and Cluster alongside Innovation Ecosystems, thereby narrowing the scope of the search from its own formulation. The complete process was documented following the PRISMA

2020 reporting guidelines, and the bibliometric analysis was complemented with the Bibliometrix (Biblioshiny) tool.

4. Analysis of results

4.1 Overview of the corpus and thematic distribution

The Web of Science subset (n = 157) spans the 2010 to 2024 period across 84 sources, with 481 authors, an international co-authorship rate of 38.22 percent, 3.43 co-authors per document, and an average of 33.73 citations per document. The Scopus subset (n = 267) spans the 2012 to 2024 period across 150 sources, with 715 authors, an international co-authorship rate of 29.96 percent, and an average of 18.01 citations per document. Annual scientific production shows sustained growth from 2016 onward in both databases, peaking in 2023 (Web of Science) and 2024 (Scopus), confirming a growing and recent interest in the Innovation Ecosystem concept as applied to business environments. In both databases, the Management and Business categories concentrate the largest share of documents, consistent with the business-oriented focus of the search equation used. A complementary analysis of the deduplicated corpus (n = 378) allows for quantifying the presence of specific Innovation Ecosystem components beyond the general categories assigned by the databases. Table 1 presents this distribution.

Table 1. Thematic distribution of the deduplicated corpus (n = 378)

Component / theme	**% of corpus**
Governance and public-sector actors	44.2%
Sustainability / Sustainable Development Goals	25.1%
Evolutionary dynamics / lifecycle	23.5%
SMEs and entrepreneurship	20.9%
Digital transformation / Industry 4.0	14.0%
Value creation / co-creation	12.4%
Regional / urban ecosystems	6.6%
Health / biotechnology	6.6%
Knowledge management / technology transfer	6.1%
Triple / quadruple helix	5.6%
Clusters and agglomeration	**4.8%**

Note: a single document may address more than one theme; percentages do not sum to 100%. Source: own elaboration based on Bibliometrix/Biblioshiny output.

Table 1 shows that three thematic streams dominate literature on Innovation Ecosystems. The first, with the greatest relative weight (44.2 percent of the corpus), addresses the role of governance and public-sector actors, evidencing that the State does not act as a mere external regulator but as a structural component of the ecosystem (Carneiro et al., 2022). The second

stream, linked to sustainability and the Sustainable Development Goals (25.1 percent), reflects a recent shift in literature toward the articulation between innovation and environmental transition. The third, centered on the evolutionary dynamics of ecosystems (23.5 percent), suggests a growing consensus that Innovation Ecosystems are not static structures but systems that move through phases of emergence, consolidation, and eventual dissolution.

It is particularly noteworthy that the cluster and agglomeration component, the central unit of analysis for the doctoral research motivating this review, appears in only 4.8 percent of the reviewed corpus. This low representation is not confined to the Latin American context, already identified below as a geographic gap; it extends to the international literature as a whole, where the cluster as a specific organizational form of the Innovation Ecosystem receives less attention than other levels of analysis, such as the regional, urban, or sectoral. This dual gap, geographic and unit-of-analysis, reinforces the relevance of situated studies on specific industrial clusters, and suggests that their results could contribute not only contextualized evidence but also an underexplored case within the field's own conceptual architecture (Petchenko, Telnova, Yakushev, & Kuzminova, 2024).

4.2 Geographic distribution and highest-impact studies

The analysis of corresponding authors' countries evidences a marked geographic concentration of academic production: China leads by a wide margin, quadrupling its closest follower, followed by the United Kingdom and countries of continental Europe. No production from Latin American countries is identified among the top corresponding authors. This near-total absence of Latin American affiliations, confirmed in both Scopus and Web of Science, cannot be attributed to a methodological limitation of the search, given that the equation applied does not restrict geography or language. It follows, therefore, that this constitutes a genuine gap in academic output, consistent with what has been noted by Petchenko et al. (2024) regarding the scarcity of situated research in emerging contexts.

Consistent with the geographic concentration noted above, the most productive affiliations identified in the corpus are located at European and Asian universities, among them Tsinghua University, Vrije Universiteit Amsterdam, and Tampere University, with no Latin American institutions represented among the top ten most productive. Among the corpus items themselves, the most cited work, a 2010 paper by Adner and Kapoor, establishes that firm performance depends on the structure of upstream and downstream interdependence within the ecosystem, a framework taken up by later corpus items applying it to smart cities, agricultural innovation systems, and the external viability of ecosystem actors. These are reported here as descriptive findings of bibliometric analysis rather than as sources cited by the present authors and are accordingly not included in the reference list below.

5. Concluding remarks and next steps

Based on the systematic review conducted, distinct groups of interest are evidenced that promote and apply the Innovation Ecosystem as a generator of added value for industry; its application within the business environment directly drives the achievement of long-term sustainability objectives for the organizations involved. The establishment of appropriate keywords for this type of study directly contributes to the generation of useful material for future research, while also evidencing the field's recent consolidation in terms of publication output. A sustained increase in research associated with the Innovation Ecosystem is confirmed, validating the growing interest in clarifying its concept, application, and added value. Research interest in the term has emerged within the past fifteen years, with the earliest periods identified in Scopus and Web of Science dating to 2012 and 2010, respectively. A substantial gap is confirmed between research developed in the East, particularly China, and the limited academic interest in understanding this model within Latin American industrial culture, a gap that, as shown above, coexists with a second and largely independent one: the international underrepresentation of the cluster itself as a unit of analysis within the Innovation Ecosystem literature.

These two findings, taken together, constitute the point of departure for the doctoral research in progress, oriented toward examining the applicability of the Innovation Ecosystem framework to the metalworking cluster of Manizales, Colombia. As next steps, the doctoral project will advance along three complementary lines. First, it will articulate the Innovation Ecosystem framework with the postulates of General Systems Theory, in order to examine the applicability of its principles (totality, hierarchy, interdependence, homeostasis, entropy and negentropy, feedback, and equifinality) to the dynamics of the metalworking cluster. Second, it will gather primary information from the cluster's own actors (firms, academia, and public institutions) to empirically contrast the components identified in the literature, cluster development, university-industry collaboration, and innovative culture, against the reality of the Colombian case. Third, it will formulate a systemic competitiveness model applicable to industrial clusters in emerging economies, contributing to close the situated-knowledge gap identified in this review.

It is expected that these developments, informed by the training received within the NACLICS PhD Academy 2026, will provide evidence useful both to the academic community interested in Innovation Ecosystems and to the actors of the Manizales metalworking sector interested in strengthening their competitiveness.

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