

Triple Helix and Quintuple Helix Interactions in Innovation Ecosystems

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Abstract: This study analyzed the role of the Triple Helix and Quintuple Helix models in innovative ecosystems through an integrative literature review of publications indexed in the Clarivate Web of Science database. The research was based on the understanding that contemporary innovation depends on collaborative relationships among universities, industries, governments, society, and the environment, particularly in contexts characterized by digital transformation, sustainability, and regional development. Methodologically, the study was qualitative, descriptive, and exploratory, employing a Boolean search string applied to the Web of Science database. The initial search yielded 625 publications, which were subsequently reduced to 170 articles after applying open-access and publication-period filters (2021–2026). Following thematic screening, the selected articles were organized into three analytical categories: ecosystem governance and coordination; sustainability and socioecological transitions; and entrepreneurship, knowledge transfer, and innovative performance. The findings revealed that ecosystem governance constitutes a central element for institutional coordination and the strengthening of collaborative innovation networks. Furthermore, sustainability was found to broaden the analytical scope of helix models by incorporating social and environmental dimensions into innovation processes. In parallel, findings related to entrepreneurship and knowledge transfer demonstrated that innovative ecosystems rely on the articulation between scientific production, applied innovation, and institutional cooperation. The study concludes that the Triple Helix and Quintuple Helix models provide significant analytical capacity for understanding the dynamics of innovation, sustainability, and regional development within contemporary innovative ecosystems.

Keywords: Triple Helix; Quintuple Helix; Innovation Ecosystems; Sustainability; Governance; Knowledge Transfer.

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I. INTRODUCTION

Innovation has assumed a strategic role in contemporary economic, social, and technological development, particularly in contexts characterized by digital transformation, global competitiveness, and the need for sustainable solutions to complex challenges. In this scenario, innovative ecosystems have come to be understood as dynamic environments composed of multiple interdependent actors capable of promoting the generation, transfer, and application of knowledge through collaborative relationships among public, private, academic, and social institutions (Etzkowitz & Leydesdorff, 2000). Consequently, innovation is no longer perceived as an isolated organizational phenomenon but rather as a process that depends on systemic interactions among different institutional and social agents (Carayannis & Campbell, 2009).

From this perspective, the Triple Helix model has become one of the most influential theoretical approaches for understanding innovation processes and regional development. The model proposes the interaction among universities, government, and industry as the central mechanism for creating innovative and competitive environments (Etzkowitz & Zhou, 2017). Within this framework, universities assume an expanded role, moving beyond their traditional functions of education and scientific research to engage in entrepreneurship, innovation, and technology transfer activities. Simultaneously, governments contribute through the formulation of public policies and support mechanisms for science, technology, and innovation, while industries transform knowledge into economic and competitive applications (Leydesdorff & Ivanova, 2016).

However, contemporary social and environmental transformations have broadened discussions regarding the limitations of the Triple Helix model, particularly in light of the growing need to incorporate sustainability, social participation, and environmental preservation into innovation processes. In this context, the Quintuple Helix model emerged by extending the traditional Triple Helix framework to include civil society and the natural environment, recognizing that innovation processes should be aligned not only with economic growth but also with sustainable development and socio-environmental responsibility (Carayannis, Barth, & Campbell, 2012). As a result, innovative ecosystems are increasingly interpreted as complex and multidimensional systems in which diverse social actors share knowledge, resources, and capabilities to foster sustainable innovation.

The expansion of research on the Triple and Quintuple Helix models has significantly stimulated international scientific production, particularly in studies related to open innovation, sustainability, entrepreneurship, collaborative governance, and regional development. Nevertheless, a considerable portion of this research remains fragmented across different fields of knowledge, making it difficult to establish an integrated understanding of the contributions and applications of these models within innovative ecosystems (Galvão, Mascarenhas, Rodrigues, Marques, & Leal, 2019). Furthermore, many studies focus on specific regional or

sectoral contexts, highlighting the need to systematize and synthesize the main scientific findings available in the international literature.

In this regard, conducting an integrative literature review is justified as a means of gathering, analyzing, and synthesizing scientific studies concerning the role of the Triple and Quintuple Helix models in innovative ecosystems. The use of the Clarivate Web of Science database is supported by the relevance, comprehensiveness, and scientific rigor of its indexed publications, enabling a structured analysis of theoretical and empirical trends related to the topic. Moreover, the integrative review approach makes it possible to identify convergences, research gaps, and opportunities for further scientific advancement regarding the interactions among the institutional and social actors involved in innovation processes.

Against this background, the present study aims to analyze the role of the Triple Helix and Quintuple Helix models in innovative ecosystems through an integrative literature review.

II. MATERIALS AND METHODS

This study is characterized as an integrative literature review with a qualitative, descriptive, and exploratory approach, developed to understand the role of the Triple Helix and Quintuple Helix models in innovative ecosystems. The integrative review method was selected because it enables the synthesis and interpretation of scientific studies employing different methodological approaches, thereby facilitating a comprehensive understanding of complex phenomena related to innovation, sustainability, governance, and regional development. Furthermore, this method allows for the identification of theoretical trends, research gaps, and analytical patterns within the international scientific literature.

Data collection was conducted using the Clarivate Web of Science database, selected due to its academic relevance, multidisciplinary scope, and rigorous indexing standards for scientific journals. To operationalize the search process, the following Boolean search string was applied:

("Triple Helix" OR "Quintuple Helix")
AND ("innovation ecosystem*" OR "innovation systems" OR "entrepreneurial ecosystem*" OR "regional innovation")

AND
(innovation OR sustainability OR governance OR collaboration OR "knowledge transfer" OR "open innovation" OR entrepreneurship OR "regional development" OR "innovation policy")

The initial search returned 625 publications. Subsequently, filters related to Open Access availability and the publication period between 2021 and 2026 were applied, reducing the dataset to 170 articles. The selected studies then underwent a screening process and thematic relevance assessment based on their alignment with the research objective and the presence of discussions related to the Triple Helix and Quintuple Helix models, innovative ecosystems, sustainability,

governance, entrepreneurship, collaborative innovation, and knowledge transfer.

Following the thematic filtering stage, the selected articles were organized into analytical categories derived from recurring themes identified across the publications. For the analytical composition of the study, fifteen authors were selected and distributed across three categories: (i) ecosystem governance and coordination; (ii) sustainability, society, and socioecological transitions; and (iii) entrepreneurship, knowledge transfer, and innovative performance. This categorical organization enabled a systematic structure for the analysis, facilitating the interpretation of findings and the development of the theoretical discussion concerning the investigated phenomenon.

The selected articles were analyzed through interpretative reading and thematic content analysis, with the aim of identifying convergences, analytical patterns, institutional relationships, and contributions to the understanding of innovative ecosystems. Furthermore, the results were organized in an argumentative and narrative manner, highlighting the principal contributions identified in the selected studies. Consequently, the adopted methodological approach made it possible to understand how the Triple Helix and Quintuple Helix models have been employed to explain the dynamics of innovation, sustainability, and collaboration across different institutional and territorial contexts.

III. LITERATURE REVIEW

Innovation can be understood as the process of creating, implementing, and diffusing novelties capable of generating economic, social, institutional, or technological value. In contemporary approaches, innovation is no longer restricted to the business sector and is increasingly examined across different domains of the economy, including public organizations, universities, social institutions, and territorial arrangements. This perspective expands the classical concept of innovation by linking it to measurement, public policies, and institutional learning (Gault, 2018).

With the advancement of knowledge networks, innovation has become increasingly dependent on organizations' openness to external flows of ideas, technologies, and capabilities. Open innovation connects research, business practice, and public policy, emphasizing that innovative value creation emerges through interactions among different actors rather than solely within the internal boundaries of firms. This perspective lays the foundation for understanding innovation as a collaborative and interorganizational phenomenon (Bogers et al., 2018).

The concept of an innovation ecosystem emerged to explain environments in which multiple interdependent actors contribute to the creation, development, and appropriation of innovative value. This concept has gained relevance because it enables the analysis of relationships among firms, universities, governments, investors, intermediaries, users, and other agents that shape innovative environments. Consequently, the analytical focus shifts from the isolated organization to the

network of relationships that sustains innovation (Granstrand & Holgersson, 2020).

Recent literature also highlights that the concept of innovation ecosystems is broad, polysemic, and applied differently across the fields of strategy, innovation, and entrepreneurship. Therefore, its use requires clear conceptual delimitation, particularly in integrative literature reviews. This discussion is important because it prevents innovation ecosystems from being treated merely as synonyms for networks, clusters, or innovation systems (Gomes et al., 2018).

The transition from innovation systems to innovation ecosystems depends on public policies capable of fostering cooperation, reducing institutional barriers, and strengthening interactions among stakeholders. In this sense, innovation depends not only on scientific and business capabilities but also on public governance and institutional design. This stage of the theoretical framework brings together innovation, territory, and political coordination (Zheng & Cai, 2022).

Contemporary discussions further expand the concept of innovation by linking it to sustainability transitions. Within this perspective, innovation is assessed not only through its economic outcomes but also through its contribution to social, environmental, and institutional transformations. This aspect is particularly relevant because it prepares the conceptual foundation for the Quintuple Helix model, positioning innovation as a mechanism for addressing complex sustainability challenges (Krlev & Terstriep, 2022).

Within the specific field of helix models, the Triple Helix remains a central framework for understanding interactions among universities, industry, and government. Rather than treating these actors separately, the model examines how their relationships generate innovation, entrepreneurship, and regional development. Contemporary literature revisits this framework to discuss its limitations, updates, and future possibilities (Cai & Amaral, 2021).

The expansion from the Triple Helix to the Quadruple Helix introduces civil society, users, media, and culture as relevant dimensions of innovation. This transition demonstrates that innovation cannot be sustained solely through university–industry–government interactions, requiring social participation and public legitimacy. Consequently, the discussion moves toward more open and socially responsive innovation models (Cai & Lattu, 2022).

The Neo-Triple Helix model proposes the integration of the Triple, Quadruple, and Quintuple Helix frameworks to explain innovative ecosystems operating across multiple layers. In this approach, university–industry–government interactions represent the internal dynamics of innovation, while society and the natural environment extend the model to encompass social and ecological dimensions. This formulation directly connects innovation with social structures and environmental systems (Cai, 2022).

Finally, recent literature suggests that helix models function as governance frameworks for innovative ecosystems, particularly in urban, regional, and sustainability-oriented

contexts. The evolution from the Triple Helix to the Quintuple Helix reflects the broader expansion of the innovation agenda—from an initially economic and technological focus toward social, institutional, and environmental concerns. Consequently, the theoretical framework converges on the understanding of innovative ecosystems as collaborative arrangements oriented toward innovation, sustainability, and regional development (Taratori et al., 2021).

IV. DISCUSSION AND RESULTS

The analysis of the selected studies enabled the identification of recurring thematic patterns related to the role of the Triple Helix and Quintuple Helix models in innovative ecosystems. Based on a critical review of the literature, the studies were organized into three analytical categories: (i) governance and coordination of innovative ecosystems; (ii) sustainability, society, and socioecological transitions; and (iii) entrepreneurship, knowledge transfer, and innovative performance. This categorization made it possible to structure the discussion in an integrated manner, facilitating the understanding of how different institutional actors interact to promote innovation, sustainability, and regional development. Furthermore, the analytical framework supported the identification of theoretical convergences, empirical trends, and coordination mechanisms present within the innovative ecosystems examined.

➤ *Category 1 — Governance and Coordination of Innovative Ecosystems*

Governance within innovative ecosystems is associated with the need to coordinate multiple institutional actors, particularly in environments characterized by organizational interdependence and continuous knowledge sharing. In this context, innovation ceases to occur in isolation and becomes increasingly dependent on the articulation among universities, firms, governments, and other social actors. Moreover, coordination mechanisms become essential for sustaining resource circulation, strengthening collaborative networks, and enhancing the adaptive capacity of ecosystems in response to contemporary technological and economic transformations (Neto et al., 2024).

According to Bittencourt et al. (2021), the orchestration of ecosystem resources varies according to the developmental stage of the innovative environment. The authors indicate that emerging ecosystems are more dependent on institutional induction mechanisms, whereas mature structures tend to operate with greater relational autonomy among participants. Furthermore, strategic alignment directly influences the efficiency of collaborative interactions and the consolidation of innovation dynamics. Consequently, governance assumes an evolutionary role within ecosystem structures.

Dos Santos et al. (2022) conceptualize the coordination of innovative ecosystems as an “institutional choreography” characterized by continuous adjustments among actors, interests, and decision-making flows. Within this scenario, universities, firms, governments, and society operate in highly complex organizational environments that require constant negotiation and collective adaptation. The authors further

emphasize that ecosystem stability does not emerge from the absence of conflict but rather from the ability to achieve operational convergence among diverse participants. Thus, governance transcends a purely bureaucratic function and becomes a relational mechanism for collective coordination.

Supporting this perspective, Cai (2022) proposes an integrated architecture combining the Triple, Quadruple, and Quintuple Helix models to enhance the analytical capacity of contemporary innovative ecosystems. The author argues that innovation environments increasingly incorporate social and environmental dimensions into traditional technological development processes. Furthermore, the integration of multiple helices strengthens ecosystem adaptability in the face of economic transformation and sustainability challenges. In this sense, ecosystem governance acquires a multidimensional character within innovation dynamics.

According to Zheng and Cai (2022), the transformation of traditional systems into innovative ecosystems depends directly on enabling public policies. Governments play a fundamental role in creating institutional environments that foster cooperation among universities, firms, and society. In addition, innovation-oriented policies tend to be more effective when structured around collective objectives and long-term strategies. Therefore, public governance functions as a mechanism for strengthening ecosystem interactions and institutional coordination.

➤ *Category 2 — Sustainability, Society, and Socioecological Transitions*

Sustainability is associated with the expansion of the very logic of innovative ecosystems, particularly through the incorporation of social and environmental dimensions into traditional innovation processes. In this context, innovation is no longer exclusively linked to economic growth but increasingly encompasses issues related to socio-environmental responsibility, ecological transitions, and sustainable regional development. Furthermore, innovative ecosystems require broader institutional structures capable of integrating diverse social actors around collective goals of economic and environmental transformation (Felix et al., 2025).

According to Zeng et al. (2023), innovation ecosystems within the fashion industry demonstrate how creative sectors have increasingly incorporated sustainability and environmental adaptation agendas. The authors indicate that the transformation of production systems depends on the integration of innovation, collaboration, and continuous organizational reconfiguration. Moreover, organizational adaptability becomes a critical factor for maintaining competitiveness in environments characterized by rapid economic and social change. Consequently, sustainability emerges as a strategic dimension of contemporary innovative ecosystems.

Kääriäinen et al. (2023) argue that the sustainability of innovative ecosystems depends on the existence of physical, cognitive, and virtual structures capable of supporting long-term collaborative processes. The authors emphasize that

sustainable innovation extends beyond technological infrastructure, encompassing collective learning mechanisms and continuous knowledge sharing among institutions. Furthermore, robust collaborative environments tend to exhibit greater adaptive capacity when facing complex environmental and economic challenges. Thus, ecosystem sustainability becomes directly dependent on the articulation between institutional cooperation and knowledge circulation.

Corroborating this perspective, Chung et al. (2025) argue that open innovation ecosystems in the energy sector rely heavily on cooperation among multiple institutional actors. The authors highlight that challenges associated with energy transitions require collective solutions involving universities, firms, governments, and civil society. Moreover, open innovation strengthens ecosystems by expanding knowledge flows and accelerating technological transformation processes oriented toward sustainability objectives. In this context, sustainability ceases to be a complementary element of innovation and assumes a central position within ecosystem dynamics.

According to Zheng and Cai (2022), the transformation of traditional systems into sustainable innovative ecosystems depends directly on public policies oriented toward collective goals and long-term strategies. The authors emphasize that governments play a decisive role in creating institutional environments capable of integrating economic development, social inclusion, and environmental responsibility. In addition, effective innovation policies tend to strengthen collaborative mechanisms among social and institutional actors. Consequently, sustainability expands the normative density of helix models by incorporating environmental and social concerns into innovation processes.

➤ *Category 3 — Entrepreneurship, Knowledge Transfer, and Innovative Performance*

Entrepreneurship and knowledge transfer are associated with the capacity of innovative ecosystems to transform scientific production into applied innovation, economic development, and value creation. In this context, universities perform functions that extend beyond teaching and research, assuming a strategic role in connecting knowledge, entrepreneurship, and regional innovation. Furthermore, the intensity of interactions among universities, firms, and governments directly influences the ability of ecosystems to generate startups, strengthen collaborative networks, and improve the innovative performance of participating organizations (Johnson et al., 2026).

According to Vallejo-Imbaquingo and Robalino-López (2025), Latin American universities play a significant role in fostering academic entrepreneurship within innovative ecosystems. The authors indicate that integration among academic institutions, firms, and governments contributes to the creation of environments more conducive to innovation and knowledge-based business development. Furthermore, institutional policies that encourage entrepreneurship help reduce the gap between scientific research and economic application. Consequently, universities emerge as central actors in ecosystem articulation.

Iqbal et al. (2026) emphasize that science parks perform a strategic role in mediating the relationship between university research and innovation commercialization. According to the authors, these environments strengthen connections among universities, firms, and investors, facilitating greater knowledge circulation and applied technological development. Moreover, institutional proximity contributes to transforming scientific production into economically viable and competitive solutions. In this regard, intermediary structures become fundamental for strengthening innovative ecosystems based on the Triple Helix logic.

Supporting this discussion, Noya, Taneo, and Melany (2023) highlight that small and medium-sized enterprises embedded in collaborative ecosystems tend to achieve higher levels of performance, integration, and innovative capability. The authors argue that institutional cooperation expands organizational access to resources, specialized knowledge, and strategic relationship networks. Furthermore, collaborative environments foster greater organizational adaptability in dynamic and competitive economic contexts. Therefore, innovation ceases to be an exclusively individual outcome and becomes increasingly dependent on systemic articulation among institutional actors.

According to Khan et al. (2022), collaborative innovation in Industry 4.0 environments depends on value co-creation among actors possessing distinct competencies. The authors emphasize that innovation generation involves not only technological development but also continuous knowledge sharing, strategic alignment, and trust-building among organizations. Moreover, more integrated ecosystems tend to exhibit greater capacity for generating innovative solutions and strengthening entrepreneurial performance. Thus, helix models explain not only institutional interaction but also the capacity to transform cooperation into economic and technological value.

V. CONCLUSION

The present study aimed to analyze the role of the Triple Helix and Quintuple Helix models in innovative ecosystems through an integrative literature review based on articles indexed in the Clarivate Web of Science database. To achieve this objective, a structured search strategy was conducted, followed by the application of publication period and open-access filters, enabling the selection of studies aligned with the investigated phenomenon. Subsequently, the articles were organized into analytical categories focused on understanding the dynamics of governance, sustainability, entrepreneurship, and knowledge transfer within innovative ecosystems. This analytical structure made it possible to understand how different institutional actors interact in promoting systemic innovation and strengthening collaborative environments oriented toward regional and sustainable development.

The findings revealed that ecosystem governance represents one of the main structural elements of innovative environments, particularly due to the need for coordination among universities, firms, governments, and other social actors. Furthermore, sustainability was found to broaden the

analytical scope of helix models by incorporating social and environmental dimensions into innovation processes. In parallel, findings related to entrepreneurship and knowledge transfer demonstrated that innovative ecosystems strongly depend on the articulation between scientific production, applied innovation, and institutional cooperation. Consequently, the analytical categories developed in this study indicate that innovative ecosystems are sustained through collaborative relationships, governance mechanisms, and institutional structures capable of fostering learning, adaptation, and knowledge circulation.

It can therefore be concluded that the research objective was achieved, as the integrative review enabled the identification of the main contributions of the Triple Helix and Quintuple Helix models to the formation and strengthening of innovative ecosystems. The results indicate that helix models provide significant analytical capacity for understanding interactions among institutional actors, as well as the mechanisms associated with innovation, sustainability, and regional development. Moreover, the analyzed literature suggests that contemporary innovative ecosystems increasingly operate through collaborative, integrated, and long-term approaches aimed at addressing economic, social, and environmental challenges.

Despite these contributions, this study is limited by its exclusive reliance on publications indexed in the Web of Science database and by the adoption of an integrative review approach, which does not include empirical validation. Future research may expand the scope of analysis by incorporating additional databases, conducting bibliometric investigations, or developing empirical studies capable of examining the application of helix models in specific regional, sectoral, and institutional contexts. Such efforts may contribute to advancing the understanding of innovative ecosystems and their role in promoting sustainable and inclusive development.

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