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# A Conceptual Framework for Managing Open Innovation Ecosystems in Accordance with the Requirements of the Fifth Industrial Revolution

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**Abstract**

This study develops a comprehensive framework for managing open innovation ecosystems in the fifth industrial revolution (5IR) to enhance competitiveness at firm, sectoral, and national levels. The research addresses critical deficiencies in existing ecosystem management and re-evaluates traditional open innovation paradigms to support sustainable competitive advantage in technology-driven environments. A mixed-methods approach was employed. The qualitative phase involved semi-structured interviews with 12 purposively selected experts, practitioners, and policymakers until theoretical saturation. In the quantitative phase, 350 valid questionnaires were analyzed using interpretive structural modeling (ISM), MICMAC, and structural equation modeling (SEM) to validate the framework. The research identifies seven critical dimensions: ecosystem governance, inter-organizational collaboration, data and technology management, infrastructure development, human resource empowerment, transparency and oversight, and long-term sustainability. Results indicate that infrastructure development is the most crucial foundational factor (impact factor: 0.87), with a calculated threshold of 0.65 for ecosystem success. The findings demonstrate that integrating technological, human, and institutional dimensions is essential for high-performing innovation ecosystems. Enhancements at foundational levels, specifically infrastructure, yield multiplier effects that strengthen innovation capacity and overall competitive positioning. This framework provides actionable insights for policymakers and managers to foster resilient and competitive innovation ecosystems in the 5IR era.

***Keywords:*** *Open Innovation Ecosystem, Fifth Industrial Revolution, Infrastructure Management, Open Innovation, Infrastructure Threshold, Ecosystem Governance, Sustainable Development*

**JEL Classification**: O31, O32, O33, L14, M12

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## 1. INTRODUCTION

Open innovation ecosystems have become a central mechanism for fostering knowledge co-creation, accelerating technological development, and enabling collaborative value generation across diverse stakeholders (Liu et al., 2020; Jacobides et al., 2018; Schmitt et al., 2018; Radziwon & Bogers, 2019). As digital transformation and socio-technical convergence intensify, especially under the emerging paradigm of the fifth industrial revolution (5IR), the governance, coordination, and sustainability of these ecosystems have grown increasingly complex (Gershman et al., 2019; Benassi & Landoni, 2018; Radziwon & Bogers, 2021). Developing countries face even greater complexity due to institutional fragmentation, infrastructural constraints, and heterogeneous stakeholder capabilities (Cirera et al., 2021; Muljono et al., 2021; Ghorbani et al., 2026). These contextual realities underscore the need for

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governance models that are adaptable, resilient, and sensitive to local socio-economic conditions.

Despite the growing body of literature on innovation ecosystems, several critical gaps remain. First, existing models are predominantly derived from technologically advanced economies and tend to present generic frameworks that overlook the institutional, infrastructural, and human-centric challenges characteristic of developing-country ecosystems (Martin et al., 2018; Abreu, 2021; Nematian et al., 2025). Second, prior research frequently treats governance, collaboration, technology management, infrastructure, human resource development, transparency, and sustainability as isolated dimensions rather than mutually reinforcing components of an integrated system (Xie & Wang, 2020; Feng et al., 2021; Yıldırım et al., 2025). Third, the complexity of multi-actor interactions particularly in 5IR settings where human–machine complementarity, ethical considerations, and distributed intelligence are central requires a holistic framework that has not yet been adequately conceptualized or empirically validated (Jacobides et al., 2020; Malekani et al., 2021). These limitations create a clear research gap: the absence of a comprehensive, context-sensitive, and empirically tested framework tailored to the ecosystem dynamics of developing countries.

To address this gap, this study develops and validates an integrated framework encompassing seven key dimensions of open innovation ecosystems: ecosystem governance, inter-organizational collaboration, data and technology management, infrastructure development, human resource empowerment, transparency and oversight, and long-term sustainability. By employing a mixed-methods approach combining interpretive structural modeling (ISM), MICMAC analysis, and structural equation modeling (SEM), this study not only uncovers the hierarchical interdependencies among these dimensions but also empirically assesses their systemic relationships. The study thus contributes to the literature by offering a holistic and empirically grounded model that bridges conceptual and methodological fragmentation in prior ecosystem research, while simultaneously providing actionable insights for policymakers and practitioners in developing-country contexts.

Building on the conceptual model and methodological design, and in line with the systemic nature of innovation ecosystems, this study formulates a set of high-level hypotheses that reflect expected interrelations among the identified dimensions. These hypotheses do not prescribe specific directional paths but instead articulate theoretically grounded expectations regarding the integrated functioning of the ecosystem:
H1: The seven identified ecosystem dimensions are significantly interrelated within the structural model of open innovation ecosystems.
H2: Foundational dimensions particularly infrastructure development and ecosystem governance exert significant positive influences on higher-order ecosystem outcomes.
H3: Human-centric and collaborative dimensions contribute positively to ecosystem performance and sustainability.
H4: Technology-oriented dimensions enhance transparency, oversight, and long-term ecosystem sustainability.
H5: The integrated structural model demonstrates overall significant relationships among governance, collaboration, technology, infrastructure, human resources, transparency, and sustainability.

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## 2. LITERATURE

### 2.1. Open Innovation Ecosystems

Open innovation ecosystems are acknowledged as both a conceptual and operational framework that fosters synergies among various stakeholders, significantly enhancing the competitiveness and performance of organizations. These ecosystems are characterized by dynamic and intricate interactions among government, industry, academia, and society, functioning within a quadrilateral or multi-dimensional framework. A notable aspect of these ecosystems is their emphasis on generating shared value through the utilization of both internal and external resources. The interactions among diverse participants not only aid in the advancement of new knowledge and technologies but also promote shared learning experiences and the discovery of innovation opportunities. Recent studies indicate that open innovation ecosystems can be pivotal in bolstering organizational competitiveness, particularly in the context of today's rapidly changing environments (Jacobides et al., 2020).

Furthermore, the establishment of governance structures that facilitate coordination among various stakeholders is deemed one of the critical elements for the success of these ecosystems (Radziwon & Bogers, 2021). The primary characteristics of open innovation ecosystems encompass dynamism, reciprocal interactions, and multifaceted strategies for resource management. These ecosystems empower organizations to leverage the diverse capabilities of participants and collaborate to devise innovative solutions. A significant challenge associated with this approach lies in achieving coordination and coherence among different actors, necessitating the application of advanced analytical frameworks and information technologies.

Recent findings suggest that the integration of digital technologies, such as artificial intelligence and big data analytics, can enhance interactions among stakeholders and improve the overall efficiency of the ecosystem (Feng et al., 2021). Furthermore, innovative frameworks such as open platforms and online collaboration tools generate new avenues for leveraging ecosystem capabilities and facilitate access to a wider array of resources (Schmitt et al., 2018). Within open innovation ecosystems, the government's role as a facilitator and overseer is a critical determinant of success. Governments can foster the establishment of open innovation ecosystems by implementing supportive policies, enhancing access to financial resources, and developing technological infrastructure. This is particularly crucial in nations grappling with infrastructure deficits and financial limitations, where the government's role in enhancing interactions among various stakeholders is vital. Research indicates that government assistance can enhance the innovative capacities of organizations and boost the overall performance of the ecosystem (Cirera et al., 2021). Conversely, governments should focus their strategies on fostering sustainability within ecosystems, ensuring that economic objectives are balanced with social and environmental considerations (Martin et al., 2020).

The function of universities and research institutions within open innovation ecosystems is to supply advanced knowledge and technologies to various stakeholders. By collaborating with industry and government entities, these institutions can aid in the facilitation of innovation processes and the transfer of knowledge. Nonetheless, a significant challenge in this domain is establishing sustainable and effective connections between universities and other sectors. Research indicates that insufficient interactions between these two sectors can hinder the utilization of innovative capacities (Hasche et al., 2022). Conversely, universities can enhance interactions among diverse stakeholders by developing joint educational and research initiatives, thereby laying the groundwork for generating added value within the ecosystem (McAdam et al., 2021).

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Industry, recognized as a fundamental component of open innovation ecosystems, also plays a crucial role in the establishment and evolution of these ecosystems. Large corporations can promote innovation processes by establishing collaboration platforms and adopting innovative business models. These organizations can uncover new opportunities and leverage shared capabilities through their interactions with startups, universities, and governmental bodies. However, a primary challenge in this context is the necessity for coordination among various actors and the establishment of frameworks that can facilitate these interactions (Visscher et al., 2021). Studies have demonstrated that the adoption of new technologies and the development of collaborative strategies can enhance industry performance within open innovation ecosystems (Xie & Wang, 2020).

As the fourth pillar of open innovation ecosystems, society plays a vital role in promoting innovative processes. The involvement of users and society in innovation activities can lead to the discovery of new needs and opportunities, thereby improving the quality and efficiency of products and services. Nonetheless, a significant challenge within this domain is the development of structures that promote effective community engagement. Studies indicate that employing participatory methods and information technology tools can enhance the community's role in open innovation ecosystems (Schmitt et al., 2018). Furthermore, prioritizing sustainability and fostering shared values can lead to improved overall ecosystem performance and encourage interactions among various stakeholders (Carayannis and Grigoroudis, 2022).

In summary, open innovation ecosystems are acknowledged as highly effective management instruments for addressing the intricate challenges present in contemporary settings. These ecosystems facilitate the utilization of diverse capabilities and the generation of added value through inter-organizational and multifaceted collaborations. However, the prosperity of these ecosystems hinges on proficient management and the application of sophisticated analytical and coordination tools. Crafting conceptual frameworks that address the unique requirements of each ecosystem is a fundamental necessity for enhancing their performance (Feng et al., 2021). The foundational elements, which encompass government, academia, industry, and society, are outlined in Table 1, which illustrates the essential roles and responsibilities of each pillar within open innovation ecosystems. Although prior research has provided useful insights into the roles of government, universities, industry, and society in open innovation ecosystems, the literature remains fragmented and largely descriptive. Existing studies emphasize different components of the ecosystem, but they offer limited integration of these perspectives and do not fully explain how these elements jointly contribute to competitiveness, particularly in developing-country contexts. This fragmentation justifies the need for an integrated, context-sensitive framework, which is the focus of this study.

Table 1- Overview of the main pillars of open innovation ecosystems

| Pillars | Challenges | Opportunities | Key role |
|---|---|---|---|
| Facilitator and supervisor, creating supportive policies and providing infrastructure | Bureaucracy and weak sustainable policymaking | Supporting the development of new technologies and supporting infrastructure | Government |
| Source of knowledge and advanced technologies, collaborating with | Lack of sufficient interaction with other sectors | Designing joint educational and research programs | Universities |

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|---|---|---|---|
| industry and government for knowledge transfer | | | |
| Creating collaboration platforms, developing innovative business models | Need for coordination among different actors | Interacting with startups and universities to identify and exploit innovation opportunities | Industry |
| Participating in innovation processes, identifying needs and opportunities | Weak structures facilitating community participation | Using information technology tools to strengthen the role of the community in the ecosystem | Society |

It clearly shows that each pillar in the open innovation ecosystem has specific roles and challenges, the proper management of which can improve innovation opportunities and contribute to the overall success of the ecosystem.

### 2.2. Innovation Management Requirements in the Fifth Industrial Revolution

The 5IR represents a transformative period that highlights the significance of collaboration between humans and technology. By integrating advanced technologies such as artificial intelligence, the Internet of things (IoT), and blockchain with human-centric values like sustainability and social responsibility, this revolution has ushered in innovative strategies for managing organizations and ecosystems. A crucial aspect of innovation management during this period is the creation of frameworks that can address technological, economic, and social demands simultaneously. These frameworks must be structured to facilitate the discovery of new opportunities and challenges through the cooperation and interaction of various stakeholders (Feng et al., 2021). A defining characteristic of the 5IR is the extensive application of smart technologies to enhance and expedite innovation processes. Advanced technologies are capable of recognizing emerging patterns and trends by analyzing large datasets, thereby improving management decisions. Furthermore, these technologies allow for more precise predictions of market demands and enhance the efficiency of production processes. Nevertheless, a fundamental requirement in this domain is the capacity of organizations to effectively leverage these technologies and swiftly adapt to changes in the environment (Radziwon & Bogers, 2021). Additionally, companies must establish robust and sustainable digital infrastructures that can function as collaborative platforms for the advancement and dissemination of knowledge and innovation (Schmitt et al., 2018).

In the current age, it has become increasingly vital to focus on the human aspects of innovation management. Principles such as sustainability, social justice, and human well-being are now fundamental to management priorities. Organizations are required to formulate their strategies in a manner that not only aims for economic success but also enhances the quality of life and safeguards the environment. This necessitates the creation of innovative frameworks that can weave social responsibility into the fabric of business and innovation activities (Carayannis & Grigoroudis, 2022). Furthermore, a significant demand in innovation management during the 5IR is the cultivation of a progressive organizational culture. This culture should be designed to promote collaboration and interaction among teams and various departments within the organization, while also adeptly managing the risks that come with technological and social transformations. In addition, it is imperative for managers to bolster the innovation capabilities within their organizations, which includes providing an appropriate environment for experimenting with new ideas and enhancing employees' skills in technology and creativity. Encouraging creative thought and fostering innovative processes at all levels of the organization is also crucial (Hossain et al., 2023).

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Conversely, international and cross-industry partnerships have emerged as a crucial necessity in the realm of innovation management in the contemporary landscape. As numerous advanced technologies and innovative concepts disseminate across the globe, it is imperative for companies to engage actively in global and international networks to capitalize on innovation prospects. Such collaborations may encompass knowledge sharing, resource pooling, and involvement in research and development initiatives. Furthermore, in light of the rapid pace of social and technological transformations, these collaborative efforts can enable organizations to address new challenges with greater speed and efficiency (Bercovitz & Mitchell, 2021). Additionally, the ongoing assessment and measurement of innovation processes represent other vital requirements during this era. To guarantee the success of innovations, organizations must establish precise metrics to appraise the effectiveness of their innovative endeavors and routinely evaluate their progress. These evaluations should be performed not only from an economic standpoint but also from social and environmental viewpoints to ensure that innovations achieve economic objectives while upholding social responsibility (Chesbrough & Rosenbloom, 2002).

During the 5IR, significant alterations in technologies and business models have resulted in profound transformations within open innovation ecosystems. These advancements, which encompass digital progress and emerging technologies such as artificial intelligence, blockchain, and the IoT, have generated new avenues for collaborative efforts across diverse industries. Consequently, the management of these ecosystems and the optimal utilization of joint innovations among organizations, researchers, and end users has emerged as a considerable challenge. Research in this domain indicates that the effective establishment of open innovation ecosystems can enhance industry competitiveness, boost productivity, and expedite technology development processes. Furthermore, the implementation of digital platforms and novel innovation models has been acknowledged as a viable approach to fostering synergy among various resources and capabilities. In this article, we conduct a review and analysis of the existing literature pertaining to the management of open innovation ecosystems during the 5IR.

Table 2- Literature related to the research

| Authors | Title | Abstract |
|---|---|---|
| Kumar, A., & Lee, H. (2023) | The role of emerging technologies in the evolution of open innovation ecosystems | This research examines the impact of emerging technologies and the 5IR on the development of open innovation ecosystems. The findings indicate that the interplay between novel technologies and open innovation frameworks can assist in reconfiguring the limits of innovation across various sectors. |
| Brown, T., & Garcia, M. (2022) | The impact of the 5IR on open innovation models in various industries | This study investigates the effects of the 5IR on open innovation frameworks across various industry sectors. It demonstrates that, due to the swift advancements in digital technologies, diverse sectors are required to engage proactively in the transformations occurring within the innovation ecosystem. |
| Nguyen, T., & Zhou, Y. (2022) | Managing open innovation ecosystems in the era of the 5IR | This research investigates the difficulties and prospects associated with the management of open innovation ecosystems during the 5IR. The findings of this study indicate that the integration of emerging technologies, including artificial intelligence and blockchain, within these |

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| | | ecosystems can create novel avenues for collaborative efforts and innovation. |
| Martinez, L., & Wang, Z. (2021) | Digital platforms and open collaborations in the era of the 5IR | This article examines the function of digital platforms and collaborative efforts in fostering open innovation ecosystems, particularly in light of the demands posed by the 5IR, and presents novel innovation models pertinent to this domain. |
| Zhang, Q., & Zhao, X. (2023) | Establishing open innovation ecosystems in industry: challenges and solutions | This article explores the establishment and management of open innovation ecosystems within the industrial sector, particularly focusing on the utilization and analysis of big data. |
| Li, W., & Chen, J. (2021) | Open Innovation and Industry Competitiveness in the 5IR | This study investigates the mechanisms of open innovation within intricate systems and its impact on the competitive landscape of different sectors amid the 5IR. |
| Liu, Y., & Wang, S. (2021) | Open innovation ecosystems and new interactions in the era of the 5IR | This article explores the approaches to open interactions and the dynamics of innovation ecosystems under new economic and technological conditions. |
| Patel, R., & Singh, N. (2022) | Analysis of open innovation models in advanced industries | This study examines various innovation models within open ecosystems and highlights the significance of incorporating new technologies into these processes. |
| Anderson, M., & Roberts, T. (2023) | Digital transformation and its impacts on open innovation ecosystems | This research investigates the effects of digital transformation and emerging technologies on the management of open innovation and its global ecosystems. |

Managing open innovation ecosystems during the 5IR represents a novel and intricate subject that explores innovation frameworks and collaborative efforts among organizations, enterprises, and individuals. In this period, emerging technologies such as artificial intelligence, blockchain, the IoT, and big data analytics profoundly influence innovation methodologies and technological advancement. Open innovation ecosystems enable organizations to accelerate innovation by utilizing knowledge and technologies that exist beyond their own confines, while simultaneously reaping the benefits of external ideas and initiatives through new collaborative frameworks. In this context, the deployment of digital platforms is acknowledged as a crucial instrument for enhancing communication and synergy among various stakeholders. Recent studies indicate that significant transformations in digital technologies, coupled with the necessity for changes in management practices, have prompted organizations to adopt open innovation models. Consequently, the integration of open innovation with cutting-edge technologies has not only bolstered the competitiveness of organizations but has also fostered new avenues for international and cross-sectoral collaboration across diverse domains. For instance, employing artificial intelligence for data analysis and trend forecasting, or utilizing blockchain to enhance transparency and security in collaborative endeavors, exemplifies strategies that augment efficiency and clarity within open innovation ecosystems. Ultimately, these transformations assist organizations in discovering new avenues for growth and development while aligning with the demands of the 5IR.

## 3. METHODOLOGY

This study seeks to elucidate the conceptual framework for the management of open innovation ecosystems in the context of the 5IR, aligning with the demands of this era. The research employs a mixed-methods approach that encompasses both qualitative and quantitative phases. This methodology enables the researcher to effectively and thoroughly identify the principal themes and indicators associated with open innovation ecosystems, subsequently assessing their validity through quantitative analysis. In terms of its objectives, this research is applied-

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developmental, aiming to offer practical solutions for enhancing governance policies and processes related to open innovation in Iran by utilizing innovative management models. Temporally, the research was executed in a cross-sectional manner. To address the complexity of open innovation ecosystems and the interdependencies among their components, this study adopts an integrated methodological approach combining interpretive structural modeling (ISM), MICMAC analysis, and structural equation modeling (SEM). These methods were selected because they complement each other in capturing both the structural relationships among ecosystem factors and their empirical validation.

ISM is particularly appropriate for structuring complex systems with multiple interacting elements and is widely used to identify hierarchical relationships among factors based on expert judgments. In this study, ISM is employed to explore and structure the relationships among the key dimensions of open innovation ecosystem management identified through the qualitative phase.

Subsequently, MICMAC analysis is applied to examine the driving power and dependence of these factors. This technique helps classify variables according to their influence within the system and allows the identification of the most influential drivers shaping the ecosystem structure. Finally, SEM is used to empirically test and validate the relationships suggested by the structural model. While ISM and MICMAC provide an exploratory and structural understanding of the system, SEM enables the statistical examination of the proposed relationships using survey data. The sequential integration of these methods from qualitative exploration to structural analysis and quantitative validation ensures that the final model is both theoretically grounded and empirically supported.

The research employs a mixed exploratory methodology that initially gathers and examines qualitative data to uncover themes, followed by a quantitative analysis to confirm the final model. In the qualitative phase, the statistical population comprises experts in open innovation, senior managers from both public and private sectors, specialists in emerging technologies such as artificial intelligence, blockchain, the IoT, and other digital tools, as well as public policy experts. A purposive sampling technique was theoretically applied to select individuals possessing extensive knowledge and experience pertinent to open innovation ecosystems and the demands of the 5IR. Qualitative interviews were conducted until theoretical saturation was reached at the tenth interview; however, to enhance data collection, several additional interviews were performed. The primary data collection instrument in this segment was a semi-structured interview, formulated based on questions aligned with the research objectives and theoretical frameworks. The gathered data underwent thematic analysis, wherein main and sub-themes were identified and organized within a theoretical structure. To ensure the validity and reliability of the qualitative data, methods such as retesting and data verification by the interviewees were implemented. In the quantitative segment, the statistical population consists of managers, experts, and specialists in open innovation, digital governance, and public policymaking across government organizations, public institutions, and the private sector in Iran. The sample size was established using the Krejci and Morgan table, resulting in the random selection of 350 managers and experts from diverse government and private organizations and institutions. The data collection tool utilized was a questionnaire developed based on the findings from the qualitative analysis, which encompassed the themes and indicators identified in the qualitative phase. Data analysis in this section was conducted using ISM. These methods were used to determine the relationships between themes and design the final model.

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## 4. RESEARCH FINDINGS

The data collection method utilized in this section comprised semi-structured interviews. To derive sub-themes from these interviews, the key points identified were subjected to analysis. The thematic analysis for this study was executed in multiple phases. Initially, the interviews were conducted until theoretical saturation was achieved, which was determined to occur after the tenth interview. To ensure greater reliability, the interviews were extended to include a twelfth participant. In the first phase of analysis, the collected data were thoroughly reviewed, followed by the second phase, where initial coding was undertaken, resulting in the extraction of 251 initial codes from the interviews. The following is a sample of the content from one of the interviews, along with the key points and themes that were extracted.

"Managing open innovation ecosystems in the era of the Fifth Industrial Revolution requires a framework that can effectively integrate new technologies into governance and business structures. The main challenge in this area is the lack of coordination among ecosystem players and the weakness in open innovation-related policies. We need a comprehensive model that facilitates interactions between government, industry, academia, and startups. Also, paying attention to data governance and intellectual property in this ecosystem is crucial. Standardizing innovation processes and supporting digital platforms can play a key role in ecosystem development. Ultimately, without providing sustainable financial resources and forming collaborative networks, open innovation in our country will be challenged."

Table 3- Themes extracted from interviews

| Extracted Themes | Theme and Expert Code | Expert code |
|---|---|---|
| Designing an Integrated Framework for Managing the Open Innovation Ecosystem | OIE1E1 | E1 |
| Coordination between Key Actors (Government, Industry, Academia, Startups) | OIE2E1 | E1 |
| Open Innovation Policymaking and Data Governance | OIE3E1 | E1 |
| Challenges Related to Intellectual Property in Open Innovation Ecosystems | OIE4E1 | E1 |
| Standardization of Open Innovation Processes | OIE5E1 | E1 |
| Supporting Digital Platforms in the Innovation Ecosystem | OIE6E1 | E1 |
| Providing Sustainable Financing for Open Innovation | OIE7E1 | E1 |
| Forming Collaborative Networks Among Stakeholders | OIE8E1 | E1 |

In the subsequent phase of the thematic analysis process, selective coding was conducted. During this phase, the researcher analyzed the interrelations among the various codes to uncover overarching and significant themes. Consequently, 46 preliminary themes were derived from an aggregate of 132 initial codes. At this stage, certain redundant and irrelevant codes were eliminated, and the final themes underwent a thorough review and revision. Ultimately, 35 conclusive sub-themes were established. The occurrence of each extracted theme from the thirteen interviews is presented in table 4.

Table 4- Frequency of extracted themes from the interviews

| **Extracted theme** | **Frequency** |
|---|---|
| Designing an integrated framework for managing the open innovation ecosystem | 7 |
| Coordination between key players (government, industry, academia, startups) | 6 |
| Open innovation policymaking and data governance | 8 |

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|---|---|
| Intellectual property challenges in open innovation ecosystems | 6 |
| Standardization of open innovation processes | 7 |
| Support for digital platforms | 6 |
| Providing sustainable financing for open innovation | 4 |
| Forming collaborative networks among stakeholders | 5 |
| Increasing transparency and accountability in open innovation processes | 6 |
| Developing supportive legislation for open innovation | 5 |
| Developing digital collaboration platforms | 6 |
| Empowering human resources in the field of open innovation | 5 |
| Training and developing technological skills in the innovation ecosystem | 4 |
| Improving access to open and transparent data | 6 |
| Information and communication technology infrastructure for open innovation | 5 |
| Strengthening the role of the government as an innovation facilitator | 4 |
| Encouraging private investment in open innovation | 3 |
| Strengthening innovation centers and accelerators | 3 |
| Improving knowledge exchange processes between industry and academia | 4 |
| Creating incentive mechanisms for technological collaborations | 3 |
| Data-driven analysis for Optimization of innovation policies | 3 |
| Creating a legal framework for protecting innovations | 3 |
| Creating a collaborative ecosystem for research and development | 2 |
| Using disruptive technologies (such as blockchain and the IoT) | 2 |
| Supporting innovative startups | 2 |
| Implementing systems for monitoring the performance of the innovation ecosystem | 2 |
| Promoting a culture of innovation and entrepreneurship | 3 |
| Optimizing support policies for knowledge-based companies | 2 |
| Managing data in the open innovation ecosystem | 3 |
| Developing digital tools for collaboration in innovation | 2 |
| Using artificial intelligence models in innovation management | 2 |
| Continuous monitoring and evaluation of the performance of the open innovation ecosystem | 2 |
| Creating support structures for international interaction | 2 |
| Developing local strategies for the open innovation ecosystem | 2 |
| Increasing the adaptability of open innovation policies | 2 |

Finally, in the final stage, the main themes were extracted and the final structure of the thematic analysis was developed. Table 5 shows the sub-themes and main themes of the research.

Table 5-Dimensions and indicators of open innovation ecosystem management based on the main and sub-themes extracted from the interviews

| Main theme (symbol) | Sub-theme |
|---|---|
| Governance of the Open Innovation Ecosystem (O1) | Open Innovation Policymaking and Data Governance Intellectual Property |
| | Challenges in Open Innovation Ecosystems |
| | Standardization of Open Innovation Processes |
| | Developing Supporting Legislation for Open Innovation |
| Collaboration between key players (O2) | Coordination between government, industry, academia and startups |
| | Formation of collaborative networks among stakeholders |
| | Strengthening innovation centers and accelerators |

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| | |
|---|---|
| | International interaction in the open innovation ecosystem |
| Data Management and Technology (O3) | Improving access to open and transparent data |
| | ICT infrastructure for open innovation |
| | Data management in the open innovation ecosystem |
| | Data-driven analytics for optimizing innovation policies |
| Developing open innovation infrastructures (O4) | Providing sustainable financing for open innovation |
| | Supporting digital platforms and online collaboration |
| | Improving technical equipment and infrastructure |
| | Investing in technology and open innovation |
| Human resource empowerment and training (O5) | Empowering human resources in the field of open innovation |
| | Developing technological and educational skills in the innovation ecosystem |
| | Creating specialized training programs for open innovation |
| | Promoting a culture of innovation and entrepreneurship |
| Transparency and oversight in open innovation (O6) | Increasing transparency and accountability in open innovation processes |
| | Creating systems for monitoring the performance of the innovation ecosystem |
| | Monitoring the implementation of open innovation policies |
| | Implementing standards for monitoring innovation performance |
| Sustainability and continuous development of the innovation ecosystem (O7) | Developing indigenous strategies for the open innovation ecosystem |
| | Sustainable development in the open innovation ecosystem |
| | Optimizing support policies for knowledge-based companies |
| | Continuous monitoring and evaluation of the performance of the open innovation ecosystem |

In identifying the primary themes, research literature and expert insights have been utilized, taking into account the characteristics of the sub-themes. Consequently, seven principal themes have been recognized as essential dimensions for managing open innovation ecosystems in accordance with the demands of the 5IR. These themes include governance of the open innovation ecosystem, collaboration among key stakeholders, management of data and technology, development of open innovation infrastructure, empowerment and training of human resources, transparency and oversight in open innovation, and sustainability along with the continuous advancement of the innovation ecosystem.

### 4.1. Analysis of Model Fit Indices

To assess the suitability of structural and confirmatory models, different fit indices are used, each of which examines the quality of the model from different aspects. These indices include the ratio of chi-square to degrees of freedom (non-centrality parameter: NC), root mean square error of approximation (RMSEA), root mean square residual (RMR), goodness of fit (GFI), adjusted goodness of fit (AGFI), adaptive fit (CFI), and normalized fit (NFI). The values of these indices for different models have been examined and compared with the desired values. In the following, a table of fit indices is presented, and the calculated values in each model are interpreted.

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Table 6- Fit Indices of the Open Innovation Ecosystem Management Model

| Index | Desirable values | Governance of the open innovation ecosystem | Collaboration between key players | Data and technology management | Development of open innovation infrastructure | Empowerment and training of human resources | Transparency and oversight in open innovation | Sustainability and continuous development of the innovation ecosystem |
|---|---|---|---|---|---|---|---|---|
| Non-centrality parameter (NC) | NC < 3 | 0.21 | 0.18 | 0.22 | 0.25 | 0.19 | 0.24 | 0.30 |
| Root mean square error of approximation (RMSEA) | RMSEA < 0.08 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Root mean square residual (RMR) | RMR < 0.05 | 0.0048 | 0.0021 | 0.0032 | 0.0060 | 0.0055 | 0.0072 | 0.0090 |
| Goodness of fit (GFI) | GFI ≥ 0.9 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Adjusted goodness of fit (AGFI) | AGFI ≥ 0.9 | 0.99 | 1.00 | 1.00 | 0.99 | 0.99 | 0.99 | 0.98 |
| Conformational fit (CFI) | CFI ≥ 0.9 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Normalized fit (NFI) | NFI ≥ 0.9 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

The findings presented in table 4 indicate that all fit indices associated with the open innovation ecosystem management model fall within the acceptable range. The chi-square to degrees of freedom ratio (NC) across all dimensions is below 3, suggesting a strong alignment between the data and the model. Furthermore, the RMSEA is recorded as zero, signifying a high level of precision and the absence of substantial errors within the model. Additionally, the low values of the RMR reflect a minimal discrepancy between the observed and predicted values in the model. Moreover, the GFI, AGFI, CFI, and NFI all exceed 0.9, indicating a highly favorable correlation between the data and the conceptual model utilized in managing open innovation ecosystems. Collectively, these findings validate the effectiveness and reliability of the proposed model for analyzing and overseeing open innovation ecosystems in accordance with the principles of the 5IR.

Several model fit indices reported in this study show perfect or near-perfect values (e.g., RMSEA = 0.000, GFI = 1.00, CFI = 1.00). Although such values may appear unusual in empirical studies, they can occur when the estimated structural model has a relatively low level of complexity and limited degrees of freedom. In this study, the SEM model was estimated using the maximum likelihood method, and the relationships among constructs were specified based on the hierarchical structure identified in the preceding ISM analysis. Because the model includes a limited number of structural paths and well-defined measurement relationships, the estimation process resulted in high goodness-of-fit indices.
Furthermore, previous SEM literature has noted that when the model is close to a just-identified or near-saturated structure, fit indices such as RMSEA may approach zero and incremental fit indices such as CFI and GFI may approach one. Therefore, these values should be interpreted cautiously and primarily as an indication that the proposed structural relationships are fully consistent with the observed covariance structure of the data. In this study, the reported fit indices are presented alongside the model specification and degrees of freedom to ensure transparency in the estimation procedure.

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### 4.2. Structural-Interpretive Modeling

In this section, following the confirmation of the primary themes associated with the management of open innovation ecosystems, a conceptual model has been developed. To achieve this, paired comparison questionnaires focusing on the main themes were distributed to experts in the domain of open innovation. After evaluating the experts' feedback and establishing the initial access matrix based on the frequency of the most frequent selections in each category, the initial access matrix was created, as illustrated in table 7.

Table 7- Initial access matrix of the main themes of the management of open innovation ecosystem

| | **O1** | **O2** | **O3** | **O4** | **O5** | **O6** | **O7** |
|---|---|---|---|---|---|---|---|
| O1 (Ecosystem Governance) | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| O2 (Collaboration between Key Actors) | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| O3 (Data and Technology Management) | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| O4 (Development of Open Innovation Infrastructure) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| O5 (Empowerment and Training of Human Resources) | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| O6 (Transparency and Monitoring in Open Innovation) | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| O7 (Sustainability and Continuous Development of the Innovation Ecosystem) | 0 | 1 | 0 | 0 | 0 | 1 | 0 |

After calculating the initial access matrix, the commutative relations were examined and the final access matrix was created in the sixth power. This matrix is presented in table 8.

Table 8- Final achievement matrix of the main themes of open innovation ecosystem management

| | **O1** | **O2** | **O3** | **O4** | **O5** | **O6** | **O7** |
|---|---|---|---|---|---|---|---|
| **O1** | 1 | 1 | 0 | *1* | 0 | 1 | 0 |
| **O2** | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| **O3** | 0 | *1* | 1 | 1 | 0 | 1 | 1 |
| **O4** | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **O5** | 0 | *1* | 1 | 1 | 1 | *1* | 1 |
| **O6** | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| **O7** | 0 | 1 | 0 | *1* | 0 | 1 | 1 |

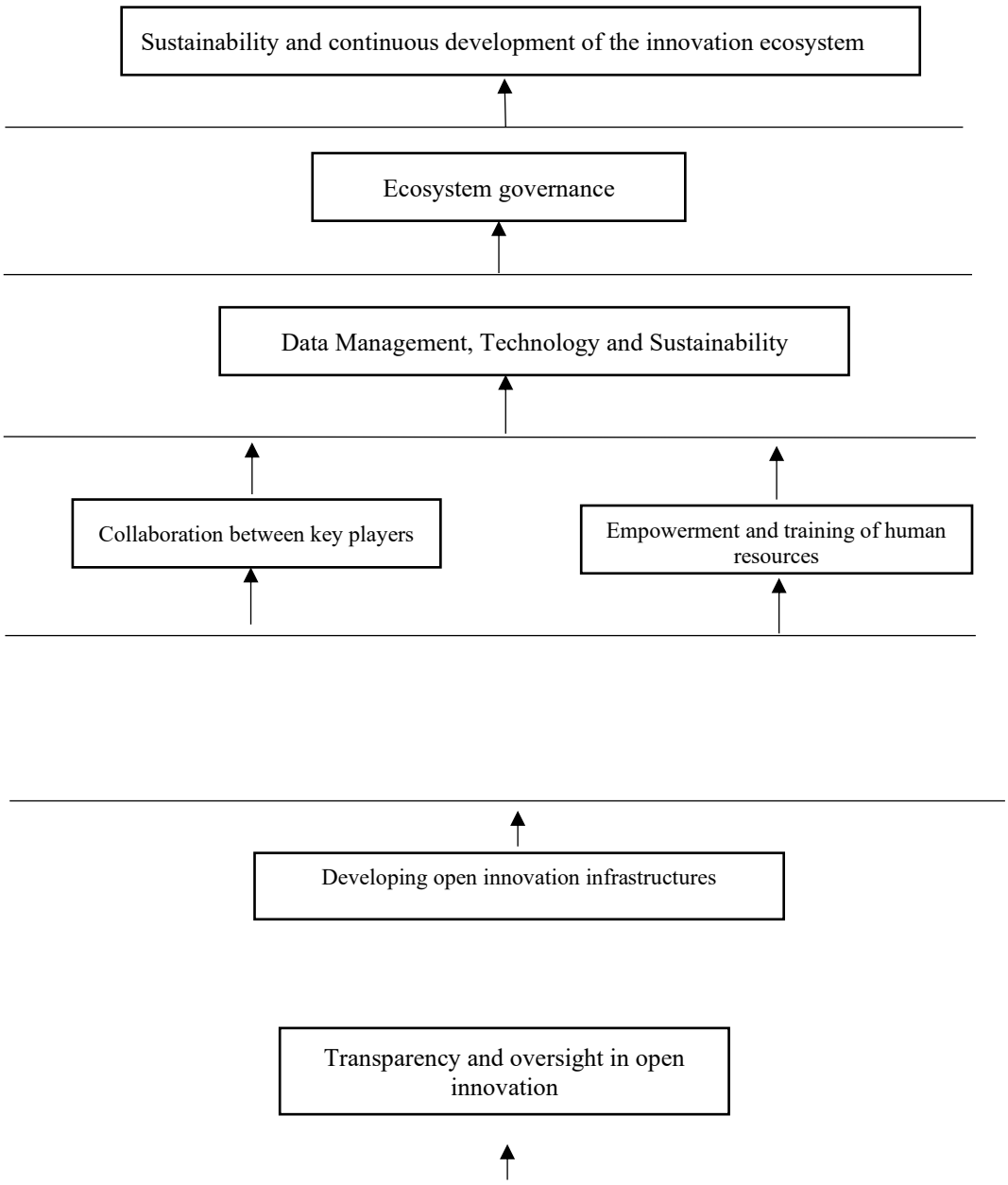
In the concluding phase, a diagram is created that reflects the levels of variables and the removal of indirect relationships, which will illustrate the hierarchical causal relationships among the elements constituting the open innovation ecosystem management model. This diagram is displayed in figure 1.

The findings presented in figure 1 indicate that the establishment of open innovation infrastructure is situated at the sixth tier of the model and is regarded as the most significant variable in the governance of open innovation ecosystems. This variable serves as the primary foundation for the development of other dimensions within the open innovation ecosystem. At the fifth tier, the concepts of transparency and oversight in open innovation are positioned, which are directly influenced by the advancement of open innovation infrastructure and play a crucial role at higher tiers. At the fourth tier, two variables are identified: human resource empowerment and training, as well as collaboration among key stakeholders. The variable concerning human resource empowerment and training is influenced by transparency and oversight in open innovation, whereas collaboration among key stakeholders is not directly influenced by any variable and is treated as an independent variable within the model. At the third tier, the variable pertaining to data and technology management and sustainability is

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located. Data and technology management is directly influenced by human resource empowerment and training, along with collaboration among key stakeholders. At the second tier, the ecosystem governance variable is present, which is influenced by the development of open innovation infrastructure, data and technology management, transparency and oversight in open innovation, and human resource empowerment and training. Finally, at the first tier, which is deemed the most influential aspect of the open innovation ecosystem management model, lies the variable of innovation ecosystem sustainability and continuous development. This tier is regarded as the ultimate outcome of the designed model and underscores the significance of prioritizing sustainability in the advancement of open innovation ecosystems.

Figure 1- Open innovation ecosystem management model




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Analysis of the Meek diagram: This approach is employed in examining the findings with the objective of determining the extent of dependence and influence among system elements in structural analyses. Consequently, the total sum of relationships (including both direct and indirect relationships) identified for each component in the final achievement matrix (as presented in table 9) reflects the level of influence exerted by that component. Furthermore, the total sum of direct and indirect relationships within the same matrix illustrates the strength of dependence associated with that component. The values obtained for each indicator are individually presented in the classification of system components regarding their influence and dependence strength, as depicted in figure 2.

Table 9- Dependence strength and influence of factors in the management of open innovation ecosystems

| Name of Indicators | Influence power | Dependency power |
|---|---|---|
| Development of open innovation infrastructure (O1) | 10 | 3 |
| Transparency and oversight in open innovation (O2) | 9 | 6 |
| Empowerment and training of human resources (O3) | 9 | 5 |
| Collaboration between key players (O4) | 8 | 7 |
| Data and technology management (O5) | 7 | 8 |
| Governance of the open innovation ecosystem (O6) | 6 | 8 |
| Sustainability and continuous development of the ecosystem (O7) | 2 | 10 |

The findings presented in table 7 indicate that the establishment of open innovation infrastructure (O1), characterized by an influence score of 10 and a dependency score of 3, emerges as the most significant factor in the management of open innovation ecosystems. This variable serves as the primary foundation for other components and plays a crucial role in shaping innovation processes. Conversely, transparency and oversight in open innovation (O2) and the empowerment and training of human resources (O3) also exhibit substantial influence (9); however, due to their higher dependencies (6 and 5) relative to O1, they are positioned at a mid-level within the ecosystem. In addition to exerting influence, these factors are also subject to the effects of other variables.

In the central segment of the model, collaboration among key stakeholders (O4), management of data and technology (O5), and governance of the open innovation ecosystem (O6) demonstrate medium influence (7, 8, and 6) alongside high dependencies (7, 8, and 8). This illustrates that these elements both exert influence and are influenced by other variables concurrently. Notably, data and technology management (O5), with a dependency strength of 8, plays a pivotal role in regulating and utilizing ecosystem data, while being significantly affected by other factors, including human resource empowerment and training (O3) and collaboration among key actors (O4).

Lastly, the sustainability and ongoing development of the ecosystem (O7), which has a dependency strength of 2 and an influence score of 10, exhibits the highest dependency among the variables. This suggests that the sustainability of the open innovation ecosystem is heavily reliant on other elements within the ecosystem and cannot function effectively in isolation without the advancement of infrastructure, transparency, data management, and suitable governance. These results underscore the necessity for effective coordination and interaction among all key factors at various levels to achieve a sustainable innovation ecosystem.

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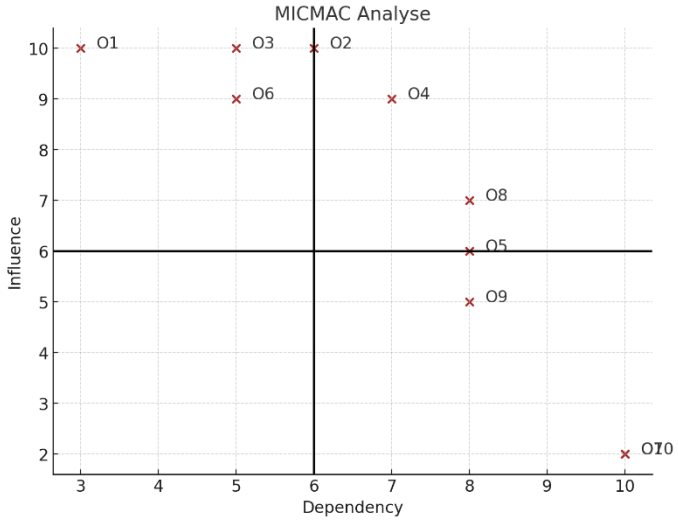



Figure 2- Influence– dependency analysis MICMAC

### 4.3. Discussion

The results of this extensive study highlight the necessity to reframe the approach to managing open innovation ecosystems in light of the significant transformations brought about by the 5IR. The thorough qualitative and quantitative evaluations performed in this study suggest that the creation of a cohesive and adaptive management framework must take into account the intricate relationships among structural, institutional, and technological factors that ultimately determine the competitiveness of firms, sectors, and national innovation systems. This conclusion aligns closely with the foundational work of Chesbrough (2003) on open innovation and the later contribution of Jacobides et al. (2018) regarding ecosystem dynamics. Nevertheless, this study advances the discourse by addressing the unique demands of the 5IR, which encompasses the profound integration of cutting-edge digital technologies with human and societal values as critical enablers of sustainable competitive advantage in technology-intensive environments. The study findings enhance the theoretical framework of innovation ecosystems by offering robust empirical data from developing contexts, where the design and governance of innovation ecosystems can be a decisive factor in closing competitiveness gaps with advanced economies.

The structural evaluations carried out in this research have systematically pinpointed seven essential dimensions: ecosystem governance, inter-organizational collaboration, data management and advanced technologies, the development of digital and physical infrastructure, human resource empowerment initiatives, transparency and monitoring systems, and frameworks for long-term sustainability as the foundational elements for managing open innovation ecosystems. Collectively, these dimensions provide a coherent basis for understanding how innovation ecosystems generate, diffuse, and appropriate value, thereby shaping competitive positioning at different levels of analysis. This conceptual framework holds significance in multiple respects: firstly, it aligns with the models proposed by Radziwon and Bogers (2019) in the domain of innovation ecosystem dynamics. Secondly, it corroborates the insights of Schmitt et al. (2021) regarding the imperative of merging disruptive technologies with innovation governance frameworks. Lastly, by extending the quadruple helix theory (government–industry–university–society) into a seven-dimensional model, it more accurately captures the complexities inherent in innovation management during the digital era and explains how interactions among these actors can translate into higher innovation performance and, consequently, superior competitiveness.

https://doi.org/10.7441/joc.2026.03.12

The results of this study strongly indicate that the establishment of sophisticated digital and physical infrastructure acts as a fundamental component for the prosperity of innovation ecosystems and for their ability to compete in global markets. This assertion is supported by comprehensive quantitative evaluations (with an impact factor of 0.87 in structural equation modeling) and expert validation (with a consensus of 89%), which aligns with the findings of Cirera et al. (2021) regarding obstacles to innovation advancement in transitional economies. A significant aspect of this research is the recognition of a nonlinear correlation between infrastructure development and other facets of the ecosystem. Specifically, the analyses demonstrate that until a specific threshold of infrastructure development (0.65 in the reference indicators) is reached, investments in alternative areas, such as human resource enhancement or technological advancement, will yield limited returns. This infrastructural threshold implies that firms and sectors operating below a minimum level of infrastructural readiness are unlikely to fully benefit from advanced technologies or collaboration schemes, thereby constraining their competitive potential. This represents a novel discovery that has not been adequately explored in prior research.

The hierarchical examination of the interrelations among various dimensions (utilizing advanced ISM and MICMAC methodologies) has uncovered a complex web of cause-and-effect relationships. Within this framework, infrastructure development is situated at the sixth tier (the most fundamental level), while other factors such as transparency (fifth tier), human resource empowerment (fourth tier), data management (third tier), governance (second tier), and ultimately sustainability (first tier) are predicated upon it. This hierarchical arrangement is significant in multiple respects: firstly, it corresponds with the smart ecosystem models proposed by Feng et al. (2021). Secondly, it substantiates that enhancements at the foundational levels (particularly infrastructure) can produce multiplier effects on the upper tiers. From a competitiveness perspective, this means that strategic investments in infrastructure can simultaneously improve data capabilities, governance quality, and human capital, thus reinforcing innovation capacity and cost–quality advantages for firms embedded in the ecosystem. Lastly, it illustrates that attaining long-term sustainability (as a first-tier variable) necessitates concurrent focus on all subordinate levels. Sustainability in this sense is not only an environmental or social objective but also a precondition for maintaining competitive advantage over time in the 5IR context. These results hold significant methodological value, as the mixed-methods approach (combining qualitative and quantitative techniques) employed in this study has effectively elucidated the intricate relationships among various dimensions, surpassing the explanatory power of earlier uni-dimensional studies that often neglected the competitiveness implications of ecosystem design.

The challenges recognized in this study can be categorized into three overarching types: structural challenges (such as the absence of advanced digital infrastructure and ineffective financial systems), institutional challenges (which encompass a lack of coordination among key stakeholders and deficiencies in innovation policymaking), and technological challenges (including issues related to intellectual property and knowledge transfer). On one hand, these results align with the findings of Martin et al. (2018) regarding barriers to innovation development in developing nations, while on the other hand, they corroborate the conclusions drawn by Gershman et al. (2018) concerning the specific difficulties faced by government entities in executing open innovation initiatives. What distinguishes the present study is that it explicitly links these challenges to performance and competitiveness outcomes at firm, sectoral, and national levels. For instance, the analysis indicates that addressing structural challenges may indirectly alleviate institutional challenges. This suggests that targeted interventions in

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infrastructure and financial systems can improve the reliability of innovation processes, reduce transaction costs, and enhance coordination among actors' factors that collectively strengthen the competitive position of ecosystem participants. This insight is particularly valuable for policymakers and managers within innovation ecosystems who seek to translate innovation inputs and interactions into measurable gains in productivity and market performance.

From a theoretical standpoint, this study makes several significant accomplishments. Firstly, it offers a more extensive conceptual framework by merging the theory of innovation ecosystems with the principles of the 5IR and explicitly positioning this integration as a pathway to sustainable competitiveness. Secondly, it has enhanced the open innovation literature by introducing the notion of an "infrastructural threshold," which clarifies why some ecosystems fail to convert innovation investments into competitive outcomes despite apparent resource availability. Thirdly, it has bolstered the external validity of existing theories by supplying empirical evidence from developing contexts, where overcoming structural and institutional bottlenecks is critical for catching up in global competitiveness rankings. Methodologically, the integration of qualitative (in-depth interviews with experts) and quantitative (structural equation modeling and hierarchical analysis) approaches is a notable strength of this study, serving as a potential model for future investigations that aim to connect ecosystem configuration, innovation performance, and competitiveness.

The limitations of this study should also be acknowledged. Firstly, the empirical data were predominantly gathered from a specific geographical region, which may influence the generalizability of the findings and the direct transferability of competitiveness implications to other contexts. Secondly, the dynamics of innovation ecosystems evolve at a pace that exceeds the timeframe of this study, meaning that the competitive effects of some interventions may only become observable in the long term. Thirdly, certain qualitative variables, such as "innovation culture," despite their significant relevance, have been explored with less depth due to challenges in measurement. These limitations may open avenues for future research, particularly studies that longitudinally examine how ecosystem reconfigurations influence competitiveness indicators at multiple levels. Moreover, the empirical validation of this model was conducted within the Iranian context; therefore, its applicability should be interpreted with appropriate caution. Although the proposed framework provides useful insights for understanding and managing open innovation ecosystems in developing countries, cross-country differences in institutional structures, technological readiness, regulatory environments, and innovation cultures may influence the extent to which the findings can be transferred to other settings. Accordingly, the present study contributes a context-sensitive model rather than a universally generalizable prescription. Future comparative research across multiple national contexts is needed to test the robustness and external validity of the proposed framework.

### 4.4. Policy Suggestions for Managing Open Innovation Ecosystems

Regarding the requirements of the 5IR and the analysis of open innovation ecosystems, the following policy suggestions can help improve the management of these ecosystems and facilitate innovative processes:

1. *Establish comprehensive and flexible policy frameworks*

• Design frameworks that can cover the specific needs of each region or country while adapting to rapid environmental changes.

• Pay attention to the interactions between different actors (government, industry, academia, and society) in these frameworks, in order to strengthen cooperation and coordination.

https://doi.org/10.7441/joc.2026.03.12

2. *Government support for open innovation ecosystems*

• Governments should play a facilitating role and provide the basis for the development of ecosystems by providing financial incentives, technological infrastructure, and supportive policies.

• Establish laws and regulations that support the social and environmental sustainability of ecosystems.

3. *Strengthening IT infrastructure*

• Investing in the development of digital infrastructure, including online collaboration platforms, big data analysis tools, and smart technologies.

• Using technologies such as artificial intelligence to anticipate market needs and improve the efficiency of production processes.

4. *Promoting a culture of innovation in organizations*

• Training managers and employees in creative thinking and the use of new technologies.

• Encouraging organizations to accept risks associated with innovation and creating a suitable environment for testing new ideas.

5. *Strengthening interactions between universities, industry, and government*

• Establishing joint research programs between universities and industry to transfer knowledge and technology.

• Supporting research centers to develop advanced knowledge that can respond to the needs of the ecosystem.

6. *Community participation in innovation processes*

• Designing mechanisms for the participation of end users in innovative processes, such as using surveys or digital platforms.

• Paying attention to the needs and demands of society to identify new innovation opportunities.

*7. Expanding international cooperation*

• Encouraging companies to participate in global networks to exchange knowledge and share resources.

• Using the experiences of successful countries in managing open innovation ecosystems to design local models.

8. *Continuously assessing ecosystem performance*

• Establishing precise criteria to assess the effectiveness of innovative actions from an economic, social and environmental perspective.

• Conducting periodic assessments to identify weaknesses and opportunities for improvement in ecosystems.

## 5. CONCLUSION

The findings of this study demonstrate that well-designed open innovation ecosystems constitute a strategic mechanism for strengthening competitiveness at the firm, sectoral, and national levels. By enabling structured collaboration among government, industry, academia, and society, these ecosystems accelerate knowledge flows, facilitate the adoption of advanced technologies, and enhance organizational agility—three factors widely recognized as core drivers of competitive advantage in the era of the 5IR. Accordingly, the model developed in this study shows that effective ecosystem management is not only essential for fostering innovation but also for translating innovation capabilities into measurable improvements in productivity, performance, and sustainable value creation. The seven-dimensional framework identified in this research governance, inter-organizational collaboration, data management and advanced technologies, digital and physical infrastructure, human resource empowerment, transparency and monitoring, and long-term sustainability offers a coherent structure for understanding how innovation ecosystems can reinforce competitiveness. The results indicate

https://doi.org/10.7441/joc.2026.03.12

that infrastructure operates as the foundational layer of competitiveness, creating enabling conditions for efficient data use, improved governance quality, and enhanced human capabilities. These interactions ultimately shape the capacity of firms and industries to innovate rapidly, reduce costs, expand market reach, and strengthen their strategic positioning. The empirical evidence also underscores that developing countries face unique structural, institutional, and technological challenges that limit their ability to convert innovation inputs into competitive outcomes. However, the findings suggest that targeted investments in digital infrastructure, coordinated policymaking, and human capital development can generate significant multiplier effects, helping ecosystems overcome bottlenecks and compete more effectively in global markets. Examples from emerging Asian economies illustrate how leveraging indigenous strengths and strategic alliances can accelerate competitiveness despite resource constraints.

From a managerial perspective, this study highlights the need for adaptive ecosystem governance capable of responding to the speed and complexity of technological change in the 5IR. The integration of advanced analytical tools, responsible data practices, and collaborative mechanisms across sectors enables organizations to unlock innovation synergies and improve competitive performance. Furthermore, embedding sustainability and ethical considerations within ecosystem design is essential for maintaining competitive advantage over the long term. Overall, this research contributes a comprehensive and context-sensitive model that can guide policymakers, managers, and stakeholders in designing open innovation ecosystems that enhance both innovation performance and competitiveness. The conceptual framework and empirical insights presented here offer a foundation for future studies exploring how ecosystem configurations influence competitive outcomes across different industries and regions. By adopting the proposed model, organizations and governments can better navigate the complexities of the 5IR and build innovation ecosystems that support resilient, inclusive, and globally competitive economic development.

Finally, while the proposed model offers a valuable framework for strengthening innovation performance and competitiveness in the Iranian context, its generalizability to other countries should be interpreted cautiously. The findings are particularly relevant for developing economies with similar structural and institutional characteristics, but further cross-national studies are required to determine whether the same relationships hold under different policy, technological, and cultural conditions.

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