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LEVEL OF COLLABORATION AND KNOWLEDGE TRANSFER AMONG ACTORS OF THE INNOVATION ECOSYSTEM: THE PROPOSITION OF AN ANALYTICAL MODEL

NÍVEL DE COLABORAÇÃO E TRANSFERÊNCIA DE CONHECIMENTO ENTRE ATORES DO ECOSSISTEMA DE INOVAÇÃO: A PROPOSIÇÃO DE UM MODELO ANALÍTICO

NIVEL DE COLABORACIÓN Y TRANSFERENCIA DE CONOCIMIENTO ENTRE ACTORES DEL ECOSISTEMA DE INNOVACIÓN: LA PROPOSICIÓN DE UN MODELO ANALÍTICO

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Abstract

Objective of the study: This study aimed to investigate how collaboration between actors in the innovation ecosystem is related to the transfer of knowledge between institutions.

Methodology/Approach: The study units were the innovation hubs of the Federal Institutes of Education, Science and Technology in Brazil accredited by Embrapii. The methodological approach of the research was qualitative; the method employed was the multiple-case study; the data collection was conducted through semistructured interviews with representatives from academia, company, government, and society; and the results were obtained via content analysis.

Originality/Relevance: Based on the findings of this research, it was possible to elaborate an analytical model to relate the level of collaboration and transfer of knowledge between agents of the innovation ecosystem.

Main Results: The main results indicated that the collaboration between the actors was related to the transfer of knowledge through the creation and expansion of the established partnerships as well as the management of the facilitators and difficulty of this relationship.

Theoretical/ Methodological Contributions: The theoretical contribution was the proposition of an integrated analytical model of collaborative relations and knowledge transfer between members of the innovation ecosystem.

Management/Social Contributions: The managerial contribution of the study was the identification of key aspects to improve the collaborative relationship between the actors of the innovation and knowledge transfer ecosystem. The social contribution consists of the possibility of collaboration expansion and knowledge transfer by enhancing the facilitating factors and minimizing the difficulties identified in the researched innovation ecosystems.

Keywords: Knowledge management. Innovation ecosystem. Knowledge transfer. Level of collaboration.

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Resumo

Objetivo do estudo: Este estudo teve como objetivo investigar como a colaboração entre atores do ecossistema de inovação está relacionada à transferência de conhecimento entre instituições.

Metodologia/Abordagem: As unidades de estudo foram os polos de Inovação dos Institutos Federais de Educação, Ciência e Tecnologia credenciados pela embrapii. A abordagem metodológica da pesquisa foi qualitativa; o método empregado foi o estudo de casos múltiplos; a coleta de dados foi realizada por meio de entrevistas semiestruturadas com representantes da academia, empresa, governo e sociedade; e os resultados foram obtidos por meio da análise de conteúdo.

Originalidade/Relevância: Com base nos achados desta pesquisa, foi possível elaborar um modelo analítico para relacionar o nível de colaboração e transferência de conhecimento entre os agentes do ecossistema de inovação.

Principais Resultados: Os principais resultados indicaram que a colaboração entre os atores estava relacionada à transferência de conhecimento por meio da criação e ampliação das parcerias estabelecidas, bem como a gestão dos facilitadores e dificuldades desse relacionamento.

Contribuições Teóricas/ Metodológicas: A contribuição teórica foi a proposição de um modelo analítico integrado de relações colaborativas e transferência de conhecimento entre membros do ecossistema de inovação.

Contribuições Gerenciais/ Sociais: A contribuição gerencial do estudo foi a identificação de aspectos-chave para melhorar a relação colaborativa entre os atores do ecossistema de inovação e transferência de conhecimento. a contribuição social consiste na possibilidade de expansão da colaboração e transferência de conhecimento, potencializando os fatores facilitadores e minimizando as dificuldades identificadas nos ecossistemas de inovação pesquisados.

Palavras-chave: Gestão do conhecimento. Ecossistema de inovação. Transferência de conhecimento. Nível de colaboração.

Resumen

Objetivo del estúdio: Este estudio tuvo como objetivo investigar cómo la colaboración entre actores en el ecosistema de innovación se relaciona con la transferencia de conocimiento entre instituciones.

Metodología/Enfoque: Las unidades de estudio fueron los polos de innovación de los institutos federales de educación, ciencia y tecnología de Brasil acreditados por embrapii. El enfoque metodológico de la investigación fue cualitativo; el método empleado fue el estudio de casos múltiples; la recolección de datos se realizó a través de entrevistas semiestructuradas con representantes de la academia, la empresa, el gobierno y la sociedad; y los resultados se obtuvieron a través del análisis de contenido.

Originalidad/Relevancia: A partir de los hallazgos de esta investigación, fue posible elaborar un modelo analítico para relacionar el nivel de colaboración y transferencia de conocimiento entre agentes del ecosistema de innovación.

Principales Resultados: Los principales resultados indicaron que la colaboración entre los actores estuvo relacionada con la transferencia de conocimiento a través de la creación y ampliación de las alianzas establecidas así como la gestión de los facilitadores y dificultad de esta relación.

Aportes Teóricos/ Metodológicos: El aporte teórico fue la propuesta de un modelo analítico integrado de relaciones colaborativas y transferencia de conocimiento entre los miembros del ecosistema de innovación.

Contribuciones a la gestión/ Sociales: La contribución gerencial del estudio fue la identificación de aspectos clave para mejorar la relación colaborativa entre los actores del ecosistema de innovación y transferencia de conocimiento. la contribución social consiste en la posibilidad de ampliación de la colaboración y transferencia de conocimiento potenciando los factores facilitadores y minimizando las dificultades identificadas en los ecosistemas de innovación investigados.

Palabras-clave: Gestión del conocimiento. Ecosistema de innovación. Transferencia de conocimiento. Nivel de colaboración

1 Introduction

In a knowledge-based era, replacing the era of industrial society, advanced knowledge is increasingly translated into practical uses owing to its theoretical and practical nature (Etzkowitz & Zhou, 2017). This change affects the organization of work; instead of the social predominance of the industrial worker, there will be a predominance of the knowledge worker (Amatucci, 2000).

In this context, universities gain special relevance as they have the potential to contribute to the generation of new knowledge at a regional level and the knowledge that can be explored through the transfer of technology to entrepreneurs and companies in the region (Cunningham & O'Reilly, 2018). This process can produce positive economic results insofar as it contributes to the improvement of regional economic performance.

Piirainen et al. (2010) stated that the knowledge transfer process based on triple helix – TH (University–Industry–Government) – contributes to the increase in the "internalization" or isolation of knowledge instead of the promotion of broader opportunities for innovation. Faced with this limitation, the theoretical model was rethought by adding a fourth helix (society) to the innovation ecosystem. Carayannis et al. (2012) and Leydesdorff (2012) argued that the fourth helix proposes the recognition of the growing role that end users play in regional project-based innovations. In essence, these end users generate demand for innovation, and this can represent effective open innovation opportunities (E. G. Carayannis & Rakhmatullin, 2014).

Carayannis et al. (2012) argued that the environment is now considered in the innovation ecosystem, appearing as the fifth helix. It is assumed that human beings are impacted by the natural environment but are not passive insofar as they interfere with the course of activities involving knowledge and innovation (Alhassan et al, 2019).

Scholars defend that there is still a shortage of investigations aimed at the operationalization of quadruple and quintuple helices (Mineiro et al., 2018). Galvão et al. (2019) justified that academia has exhaustively discussed the university–industry–government relationship within the triple helix, addressing aspects such as policies aimed at knowledge and innovation, entrepreneurial universities, innovation and business strategies, agents involved in innovation and knowledge, and aspects of regional development.

Bacon, Williams, and Davies (2019) stated that although the results of some research (Meng, Li, & Rong, 2019; Miller et al., 2016; Secundo et al., 2019) have supported the creation of structures favoring the knowledge transfer, the limitations of recent studies can be summarized in the following items: (1) the authors fail to distinguish the different actors that make up the innovation ecosystem, (2) the authors do not explore the empirical data related to successful cases of knowledge transfer, and (3) the authors do not determine the existing interrelationships between the factors leading to knowledge transfer. Therefore, it is intended to supply the lack of investigations whose objectives are oriented

toward understanding the participation of actors and the factors involved in the process of transferring knowledge from these interactions.

Based on the above, this research aimed to investigate how the collaboration between the agents of the innovation ecosystem is related to the knowledge transfer.

In this article, a qualitative methodological approach is adopted, and the resources that characterize the multiple-case study method are explored more specifically. The object of study is the units of the Federal Network of Education, Science and Technology accredited by the Brazilian Industry for Industrial Research and Innovation – Embrapii. The research *corpus* consists of managers of the innovation hubs, representing academia, entrepreneurs with projects developed in partnership with the hub, an innovation superintendent linked to the government, and, finally, a president of an incubator with broad representation in society. Faced with the need to gather different sources of evidence, typical elements of bibliographical, documental and field research are combined. Field research is intensive, with semistructured interviews.

The practical contribution of the investigation is the identification of fundamental aspects (facilitators and barriers) in the collaboration between university–industry–government, society, and the environment, considering the privileged social units of study. As for the social contribution, it is expected that by knowing the facilitators and barrier aspects existing in the collaboration between the investigated actors, it will be possible to intervene with the maximization of the facilitator's aspects and the reduction of the barriers that act in the knowledge transfer.

Finally, the theoretical contribution is the design of an analytical model based on the theories of knowledge management and the innovation ecosystem, as it seeks to relate the level of collaboration and knowledge transfer between the agents of the innovation ecosystem.

2 Theoretical backgrounds

Based on a literature review, the framework used in this study develops the theoretical lenses that supported the elaboration of the collection instrument and the exercise of data interpretation.

2.1 Knowledge management theory

Nonaka and Takeuchi (1995) distinguished individual from collective knowledge; the individual is created according to beliefs, attitudes, opinions, and factors influencing the formation of your personality. In turn, social knowledge resides in the collective actions of a group, involving norms that guide intragroup communication and coordination. For the authors, in the organizational environment, it is essential to transform individual knowledge into collective knowledge, and the conversion of knowledge (SECI model) happens in four ways: from tacit to tacit knowledge, socialization; from tacit to explicit knowledge, externalization; from explicit to explicit knowledge, combination; and from explicit knowledge to tacit knowledge – internalization.

Through interactions between members of the organization and between these members and the environment where they live, the process of knowledge creation contributes to the improvement of the interaction between individuals, institutions, and society, as it expands the conversion of tacit into explicit knowledge (Nonaka, Toyama & Hirata, 2008).

Oliva (2014) stated that knowledge management techniques can be important to formalize tacit knowledge through written procedures that should guide the sequence of repetitive activities. For the author, the formalization of knowledge allows continuous improvement in processes.

At the same time, knowledge is recognized as a critical resource insofar as its effective management and the information transferred between ecosystem partners are crucial to the innovation process (Bacon et al., 2019). Knowledge derives from a complex construction, which involves different organizational and motivational models, which can be identified in the effort to understand the process of knowledge generation and transfer (Alexander & Martin, 2013).

The knowledge transfer to the industry can occur through intentional and unintentional flows that generate developments in basic research or through interactions mediated by the market, such as signed contracts and collaborative research (D'Este, Guy, & Iammarino, 2013; Maietta, 2015). Etzkowitz (2008) ensured that the flow of people can also favor the circulation of ideas from one sphere to another, leading to collaborative projects and promoting understanding between institutions. This continuous innovation requires a well-planned knowledge management system that makes the organization stand out in knowledge creation (Popadiuk & Choo, 2006).

Knowledge transfer can also be impeded by the weak protection of intellectual property rights; the difficulty of disseminating knowledge, both nationally and internationally; the costs incurred in integrating innovations that may originate in different places from co-creation models (Del Giudice, Carayannis, & Maggioni, 2017).

In an effort to align knowledge, partner characteristics, and appropriate governance, Milagres and Burcharth (2019) recommended that managers carefully consider which transfer processes to implement, without disregarding routines, training, visits, and informal social interactions. Chesbrough (2003), in turn, reinforced the importance of knowledge transfer and to achieve success in this process; he recommended the creation of a favorable scenario for the establishment of cooperative relationships between knowledge generators and users.

Alexander and Martin (2013) clarified that each knowledge transfer channel, such as the sharing of laboratories between academia and industry, licensing, and patents, has a dominant form of governance that moves between relational and transactional. The channels follow the quintuple evaluation criteria: a) formal interaction vs. informal, b) geographic proximity translated by the degree of face-to-face interaction, c) transferred knowledge considering the degree of explicitness, d) mode of conflict resolution (internally vs. third party intervention), and e) relational incorporation expressed by engagement in new partnerships (Alexander & Martin, 2013).

According to Schartinger et al. (2002), the formality of a relationship is evidenced when the interaction that takes place between the parties is delimited by agreements or contracts. In the second criterion, the degree of face-to-face interaction suggests that the focus on communications generates trust and relational integration, which, in turn, are important attributes in university–industry knowledge transfer relations (Clinton, Merritt, & Murray, 2009).

The third criterion is a reference to the ability of a channel to transfer knowledge. According to Perkmann and Walsh (2008), tacit knowledge transfer occurs more effectively in channels of a more relational nature, and explicit knowledge is transferred more effectively in transactional channels.

The fourth criterion refers to attempts to control or mitigate risks through a contractual approach, such as meeting established deadlines, financial disbursements, etc. However, it is impossible to define *a priori* all contractual clauses relating to possible conflicts. To reduce this potential risk, a complex contractual approach may be employed, or alternatively, a third party may be appointed to resolve any disputes (Williamson, 1985). Dispute resolution, when it occurs internally, reflects relational governance, whereas third party resolution is recurrent in transactional forms of governance.

The last criterion refers to the previous involvement between the partners, being a measure of reliability for the establishment of partnerships, both potential and future. Some consider trust and relational integration fundamental to contractual governance (Uzzi, 1997).

In addition to the knowledge management theory, this research also uses as a theoretical basis the concept of ecosystem that has its origins in Biology. According to Shaw and Allen (2018, p. 90), ecosystem can be defined as: “The process of recycling nutrient flows along pathways constituted by subsystems organized into process-oriented functions; connects living and non-living subsystems; energy gradients of scarce nutrients.”

2.2 Knowledge collaboration models

In the most cited models in the literature to explain the relationships between the actors of the innovation ecosystem involved in the creation of knowledge;it can be seen that the models evolved from the most individualized to the most participatory forms.

Initially, the linear approach proposed by Bush (1945) is observed, in which the innovation process is “pushed” from the knowledge generated in the laboratories and not induced by market demand. Going through the gradual increase in the participation of other actors in the generation of knowledge, sometimes with the role of government as advocated by the Sábato Triangle (Sábato & Botana, 1968), sometimes with a focus on the singularities of a national innovation system (Freeman, 1987).

Leydesdorff and Etzkowitz (1998) recognized the centrality of the entrepreneurial university to foster the innovative process. In the view of Chesbrough (2003), it is open innovation that expands the boundaries of the firm and provides added value for customers. Finally, the most recent knowledge

creation models bring the active participation of society (E. G. Carayannis & Campbell, 2010) and the environment (Carayannis; Barth & Campbell, 2012), further expanding the participation of the ecosystem in the generation of new knowledge.

However, in this work, due to the characteristics of the research corpus, the models are analyzed from the triple helix (Leydesdorff & Etzkowitz, 1998) to the fourth and fifth helices, cited by Carayannis et al. (2006, 2010, 2012). Next, the selected models will be described in detail.

2.2.1 Triple Helix

The triple helix is one of the most referenced models in the theoretical field of approach and characterization of cooperation formed by the interrelationships between university–business–government. The design of the model defends the effective interaction between the functions of these three spheres through the creation of networks of communication and dissemination of knowledge, as well as an environment that stimulates innovation and, consequently, economic and social development (Etzkowitz, 2003; Leydesdorff & Meyer, 2006 ; Leydesdorff, L.; Etzkowitz, 2003).

In the triple helix, the knowledge that flows between institutions is increasingly complex, partially overlapping and breaking boundaries between institutional spheres (Etzkowitz, 2003; Leydesdorff & Meyer, 2006; Etzkowitz & Leydesdorff, 2000). The interactions promoted between agents contribute to the companies' competitive advantage by identifying new functions and organizational needs (Leydesdorff & Meyer, 2006).

Carayannis et al. (2021) stated that the academic research focuses on basic research, commonly in reference to academic disciplines, and without a particular interest in the practical use of knowledge or innovation. The organizing principle of the triple helix is the expectation that the university will assume entrepreneurial responsibility in society. The entrepreneurial university maintains the academic tradition, in addition to assuming a leading role in economic and social development through the transfer of knowledge. For Etzkowitz (2003), investing in the entrepreneurial university does not correspond to the commercialization of the university but to the recognition of the university as being responsible for the generation and transfer of knowledge, integration of teaching and research, and underpinning of the innovation process.

In the context of the knowledge-based economy, Carayannis et al. (2012) valued the triple helix for recognizing the centrality of higher education to the innovation process. For Carayannis and Grigoroudis (2016), the weakness of the triple helix lies in the absence of the public sphere, that is, the society that is often the end user of innovation and, therefore, exerts a strong influence on the generation of knowledge and technologies *via* user demands is not represented in the model. Thus, the quadruple helix expands the triple helix paradigm by incorporating the social function, which serves as a source for understanding the circulation of knowledge and technology for the diffusion and application of innovation.

2.2.2 Quadruple Helix

Carayannis and Campbell (2009) proposed the quadruple helix model as an extension of the triple helix model. The authors added the fourth helix as the public, based on the media and culture of civil society, that is, the fourth helix is associated with elements of the media, creative industry, culture, values, lifestyles, and art. Along this path, cooperation among government, companies, academia, and society is necessary to build the foundations of a strong national industry (Afzal et. al, 2018)

Carayannis and Grigoroudis (2016) stated that the most important constituent element of the quadruple helix, in addition to civil society, is the knowledge that circulates between social subsystems, influencing innovation, and development in a society.

The quadruple helix model emphasizes cooperation for innovation, in particular the dynamically intertwined processes of coopetition, coevolution, and cospecialization within and across regional and sectoral innovation ecosystems, which could serve as the basis for diverse development strategies (Carayannis & Grigoroudis, 2016).

From the perspective of Schoonmaker and Carayannis (2013), despite the pressure exerted by the national innovation policy, most universities continue to operate according to triple helix structures, without being able to develop the expected levels of collaboration with the industry and end users. However, the effective and fully functioning quadruple helix requires universities to adopt more open models of knowledge transfer, in which industry and end users are involved at all levels of the process (Miller et al., 2014). According to Alexander et al. (2015), the involvement of the university with the industry depends on a series of actors – the commercial relations teams and the technology transfer office, among others – however, the authors warn, the academic is the protagonist of this process.

With the need to interact in a complex open innovation ecosystem, the knowledge transfer processes of universities are in a state of transition (Alexander et al., 2012; Miller et al., 2014). In this context, there is a lack of a more accurate understanding of how knowledge can be effectively transferred between universities and members of the quadruple helix, especially when considering the context of open innovation (Carayannis & Rakhmatullin, 2014).

2.2.3 Quintuple Helix

According to Carayannis and Campbell (2010), the quintuple helix is a model that takes into account the set of social and academic interactions in a given environment, with the objective of promoting and visualizing the cooperation of the knowledge and innovation system for a more sustainable development. For the authors, the quintuple helix supports the formation of a “win–win” situation between ecology, knowledge, and innovation, creating synergies between economy, society, and democracy.

In this model, by definition, the complexity of the quintuple helix structure implies a complete and analytical understanding of all helices and requires the continuous involvement of the entire

disciplinary spectrum, from the natural sciences (due to the nature and environment) to the social sciences and human (for committing to the interests of society and strengthening democracy and the economy) (Carayannis & Campbell, 2010).

Carayannis et al. (2012) stated that the quintuple helix allows the visualization of collective interactions, as well as knowledge exchanges beyond the four subsystems of the quadruple helix (educational system, economic system, the media and culture, and the political system). Perspective in which the natural environment is decisive for sustainable development capable of strengthening natural capital (flora, fauna, biodiversity, water resources, etc.). Although not typically conceptualized as an actor, the natural environment is in a similar relationship to the four helices, as humans are impacted by the natural environment and modify it in the course of knowledge generation and innovation activities (Alhassan et al., 2019).

The quintuple helix goes beyond the natural environment of society, considering the socio-ecological relationship as a challenge for a future development roadmap (Carayannis; Campbell, 2010; Carayannis; Rakhmatullin, 2014).

For Baaziz (2018), the quintuple helix is an appropriate structure for solving problems in a context marked by complexity. The success and limitations of this enterprise are due to the multiplicity of actors and interests involved when there are expectations of collaboration between companies, startups, public institutions, universities, researchers, and other individuals. The objective that brings them all together lies in the interest of identifying investment opportunities in sustainable development, developing new technologies, and creating new products and services.

2.3 Innovation ecosystem

Jacobides et al. (2018) defined ecosystem as a set of actors with different degrees of multilateral complexity and non-generic complementarities, which are not hierarchically controlled but united by the aggregation of existing value in collective investments. The authors identify three types of ecosystem-related approaches: 1. Business ecosystem is centered on the industry and its environment. In this approach, the ecosystem is conceived as an economic community of actors in which everyone interacts through their activities. Teece (2007) stated that the business ecosystem represents the environment in which the industry must monitor and react as it affects its dynamic capabilities, hence its ability to create sustainable competitive advantage. 2. Platform ecosystem translates the way in which actors organize themselves around a platform or technology. In this view, the ecosystem comprises the platform sponsor and all providers that make the platform more valuable to consumers (Ceccagnoli et al., 2012). 3. Innovation ecosystem is focused around a specific innovation or new value proposition and the actors that support it. The emphasis is on understanding how interdependent actors interact to create and market innovations that benefit the end customer (Adner, 2006).

Gomes et al. (2018) argued that, in part, the concept of the innovation ecosystem was formulated as a reaction to the value capture and competitive focus prevailing in the preexisting literature on the business ecosystem. Furthermore, the innovation ecosystem concept places more emphasis on value creation and collaboration. Adner (2006, p.2) explained that innovation ecosystems are "the collaborative arrangements through which companies combine their individual offerings in a coherent way, with a customer-oriented solution." Adner (2017) stated that the ecosystem is based on two axes, whereas ecosystem as an affiliation corresponds to communities of associated actors, defined by their networks and platform associations; ecosystem as structure recognizes ecosystems as configurations of activities defined by a value proposition.

The innovation ecosystem brings together several actors insofar as it favors the exchange of information, consequently involving multiple agents, namely, universities, research institutes, funders, government, and small and medium-sized companies, in addition to large corporations. In this environment, driven by the objective of facilitators the exchange of knowledge across organizational boundaries, organizations are increasingly attracted by the possibility of establishing external partnerships (Carayannis & Campbell, 2009).

The objective of collaboration between the actors of the innovation ecosystem is the production and sharing of knowledge, operations that translate into the process of co-creating knowledge, here understood as the development of new knowledge that results from the collaboration between the participating actors (Carayannis et al., 2014).

According to Granstrand and Holgersson (2020), an innovation ecosystem corresponds to a set of actors, activities, and artifacts in evolution, institutions, and relationships, including complementary (collaboration) and substitute (competition) relationships, important for the innovative performance of an actor or of a population of actors.

From the perspective of this definition, the actors correspond to companies, universities, government, and other institutions that make up the innovation ecosystem. The activities are the processes resulting from the relationships established in this ecosystem, and the artifacts include tangible products and services, intangible resources, technological and non-technological resources, sources, and other types of system inputs and outputs, including innovations.

3 Methodologies

In this research, a qualitative, exploratory approach is adopted. Minayo (2012) explained that qualitative research understands the reality experienced socially, realizes the possibility of building knowledge, and gathers the requirements and instruments to be considered as a scientific construct. Coherent not only with the choice of approach but also with the theme and research problem, the multiple-case study method is adopted. In addition to enabling the establishment of comparisons between the social units of study, it contributes to the obtainment of more robust results when compared

with the single-case study (Yin, 2001). The research combines a bibliographic survey, fundamental in the construction of theoretical lenses, documental survey, and field research, with semistructured interviews. The collected data were treated with the support of the categorical content analysis technique. This type of analysis allows, through the breakdown of the text into thematic categories, the investigation of issues that have gained centrality in the narrative of interlocutors. The multiple-case study method requires the selection and characterization of the social units of study, with the concern of highlighting the qualitative representativeness of each one of them, in light of what is being investigated (Yin, 2001). The choice of representatives of the Federal Network of Scientific and Technological Professional Education (RFEPCT) accredited by the Brazilian Industry for Research and Industrial Innovation (Embrapii) is due to the fact that the program has among its main goals the encouragement of technological research and innovation through the interaction between innovative companies and society.

RFEPCT was inaugurated in 1909, when the then President of the Republic, Nilo Peçanha, invested in the creation of 19 schools for Apprentices and Craftsmen. These later gave rise to the Federal Centers for Professional and Technological Education (Cefets) and in 2008 to the Federal Institutes for Professional and Technological Education. In 2020, the federal network already has 644 units distributed across all states of the federation, involving about one million enrollments and 60.000 public agents (BRASIL - MEC, 2019)

Embrapii, in turn, was created in May 2013, as a result of a government initiative. Its objective is to encourage, promote, and finance applied research projects aimed at the industrial sector in the country. Established as a nonprofit civil association under private law, Embrapii was qualified by the federal government as a social organization in September 2013. In December of the same year, the management contract was signed with the Ministry of Science, Technology, Innovation and Communications (MCTIC) and the Ministry of Education (MEC) (Embrapii, 2019).

Considering the research conducted, with the concern of preserving representativeness in the social units of study, the following selection criteria were adopted: a) centers with distinct expertise, b) located in different geographic regions, c) varying levels of cooperation between actors in the innovation ecosystem, d) consolidated partnership with Embrapii, and e) different maturity levels, represented by the time of implementation of the center and the number of contracts signed. This led to the selection of the Campos dos Goytacazes (Rio de Janeiro), Florianópolis (Santa Catarina), Fortaleza (Ceará), and Southern Minas Gerais (Minas Gerais) centers.

Ten semistructured interviews were carried out, with a high degree of depth. The interviews took place between April and October 2020, due to physical mobility restrictions resulting from the COVID-19 pandemic that took place in the country; they were carried out virtually using Zoom Meetings. With the consent of the interlocutors, all of them were recorded, and the audio was transcribed. Furthermore, with the aim of systematizing the treatment and analysis of the material, each

respondent was represented by a code. The first block of interviews was carried out with the managers of the selected innovation poles; within the scope of the research, they represent the university's helix (EA1 to EA4). Then, representatives of companies that developed one or more projects in partnership with Embrapii (EE1 to EE4) were interviewed. The third and last block of interviews included a government representative involved in activities related to the promotion of innovation (EG1); finally, typifying the fourth helix of innovation, a member of society recognized to be involved with the innovation ecosystem (ES1) was interviewed.

Categorization and content analysis were performed with the support of the NVivo software. It should be elucidated that during the interviews, the researcher's perceptions were the subject of written records, useful for understanding the investigated phenomenon.

As presented in Table 1, the interviews were analyzed in two blocks: collaboration of the innovation ecosystem and knowledge transfer. Thus, evidencing of the categories and subcategories that stood out from the bibliographic survey was carried out.

Table 1

Deductive analysis categories

Block	Authors	Category	Subcategory
Innovation Ecosystem Collaboration	Etzkowitz, (1998); Etzkowitz (2003) Leydesdorff and Meyer (2006); Carayannis and Campbell (2006); Carayannis and Grigoroudis (2016); la Vega, Puente and Sanchez, (2019); (Mcadam, Miller and Mcadam, (2016); Miller; et al., (2016)	Triple helix	Entrepreneurial University
			Knowledge economy
		Quadruple helix	Social elements
			Elements of cooperation
		Quintuple helix	Certifications
			Environment and sustainability
Knowledge transfer	Nonaka; Takeuchi,(1995); Alexander and Martin (2013); (Dell'ano and Del Giudice, (2015) ; Miller et al. (2016); Schartinger et al. (2002); Clinton et al. (2009); Williamson (1985); Perkman and Walsh (2008); Uzzi (1997)	Relational governance	Tacit knowledge
			Relational embedding
			Geographic proximity
			Informal interaction
			Internal conflict resolution
		Transactional governance	Explicit knowledge
			Geographic distance
			Formal interaction
			External conflict resolution

Source: Elaborated by the authors.

The process of selecting the inductive categories emerged from the research objectives and the contributions proposed in this work. Therefore, the factors that contributed the most and hindered the

collaboration and knowledge transfer between the actors of the researched innovation ecosystems were identified with the interlocutors. The subcategories identified as facilitators of the process are supporters, credibility, qualified labor, and the existence of graduate programs. The barrier factors of the process, in turn, are communication failures, bureaucracy, financial aspect, management, and ideological issues. Table 2 brings together the categories and subcategories that emerged from the field.

Table 2

Inductive categories of analysis

Block	Category	Subcategory
Innovation Ecosystem Collaboration Knowledge Transfer	Facilitators	Supporters
		Credibility
		Skilled labor
		Graduate programs
	Barriers	Communication Failures
		Bureaucracy
		Financial
		Management
		Ideology

Source: Elaborated by the authors.

Throughout the empirical research, it was noticed that the factors facilitators and barriers are indistinctly related to both the innovation ecosystem collaboration block and the knowledge transfer block. All categories will be properly described and discussed in the Results section.

4 Results

After the organization and presentation of the data resulting from the interviews conducted with representatives of academia, companies, government, and society, this section will be dedicated to the exercise that moves between interpretation and analysis, supported by the theoretical lenses previously constructed. A comparative analysis among cases was conducted, deepening the aspects related to knowledge management in collaboration between actors in the innovation ecosystem and in the knowledge transfer.

According to Alexander and Martin (2013), knowledge is a complex construction that combines different organizational and motivational models. If you want to understand the knowledge generation and transfer process, these models can be identified. For EE1, “the knowledge transfer took place from the beginning, with meetings with researchers, in the exchange of experiences and from the results generated, whether they were within expectations or not.” That is, the respondent highlights the exchange of tacit knowledge, carried out through the existing partnership.

According to Perkmann and Walsh (2008), tacit knowledge transfer occurs more effectively in more relational channels, and explicit knowledge is transferred more effectively in transactional channels. EA4 makes a point of explaining the relevance of transparency between project partners when it stated that, "our cost spreadsheet is open, the partner looks and knows where every penny of the project is going." Another indication of relational integration was brought by EA2 when elucidating that "they did not know what the Federal Institute did, nor what the professional did. When the student went to work on the project, there at the industry they saw a very interesting possibility of hiring and training people." In this case, the trust resulted from a joint work and was achieved with the coexistence required by carrying out the work required by the project – a collaborative work.

The transactional aspect can also be observed when interviewees are asked about ways to resolve any conflicts. EE4 stated that, "when there is a conflict, then you go to your contract, you need to be provided with how to undo the partnership, how to return money, how to compensate. Then you call the legal department." A similar view is identified in the narrative of EA3, for whom "you need to try to visualize what could bring a problem, which could delay the project and leave it agreed in the contract, so that we can solve it." The concern lies in calibrating the expectations between the parties aiming at the elimination of possible conflicts in the future. Williamson (1985) argued that to reduce this potential risk, a complex contractual approach can be applied, or alternatively, a third party can be appointed to resolve any disputes.

Considering the category of analysis Collaboration of the Innovation Ecosystem, it is possible to affirm that the subcategories related to the triple, quadruple, and quintuple helices are present in the data extracted from the interviews. In the extracts from the narratives that follow, there are characteristics of the entrepreneurial university that, in the view of Etzkowitz (2003), corresponds to an environment conducive to innovation as it creates conditions that favor the knowledge transfer to the productive sector.

Although there is no consensus, there is a group of academics who defend the importance of university research responding to social and market needs (Carayannis et al., 2018). In the words of one of the interviewees, "basic research is extremely important for the country, but innovation is only done with applied research" (ES1). An idea equally emphasized by EA3 when he assured that "the pole allows for a complementary education that we don't have in the classroom, it is the experience in the market." Furthermore, the projects generate scholarships, and by being favored with these scholarships, students are pressured to complete master's degree within the deadline. By associating the completion of the master's degree with a project of interest to the productive sector, the master's student develops skills appreciated by the labor market, and this translates into job opportunities in their area of interest. In this sense, attention is drawn to what EA1 states: "... for those researchers who had projects at the center, it was the guarantee that the student would have the scholarship and would have the project defended

within the deadline." He adds that "in many cases, this student was taken advantage of by companies and already left the course employed."

Carayannis and Campbell (2006) argued that networking and the creation of knowledge clusters are central elements in the adoption of new strategies for the development of a competitive environment and a knowledge society. For this, EA4 clarifies, with visible pride, that it has "... a database of registered specialists which basically contains all the information of that researcher, relating, in addition to academic knowledge, his practical experience in the industry." However, this is only possible because "there is a very strong partnership with the Federal University here, including all researchers here at the institute can work on projects at the university and vice versa" (EA3).

The fully functioning and effective quadruple helix requires universities to adopt more open models of knowledge transfer, in which industry and end users are involved at all levels (Miller et al., 2014). ES1 reinforces this idea when it stated that, "partner companies often do not have research centers, equipment, or professionals to carry out the tests carried out here at the pole": therefore, it is crucial to promote the interaction between them and the pole, particularly with regard to investment in activities involving research and development (R&D).

When EA4 invests in new partnerships, including exchanges between researchers from "competing" educational institutions, it adopts an attitude of coopetition, that is, cooperation between competitors. Although these institutions often apply for the same public notices and compete for the same resources, throughout the R&D process, they can work together as a means of adding value.

According to Baaziz, (2018), the fifth helix refers to an appropriate structure to solve tasks in a complex context because companies collaborate with each other, with startups, government, universities, researchers, and other individuals, guided by the objective of prospecting investment opportunities in sustainable development. In the researched poles, it is clear that there is a discourse focused on the importance of the environmental issue; however, there is a lack of initiatives to promote effective actions among the actors of the innovation ecosystem aiming at sustainable development. "We have been developing technologies here that have repercussions on the environmental issue, (...) but it is not something that is systematized, or that has a certification behind it, no" (EG1).

Carayannis et al. (2021) argued that ecology, ecological sensitivity, and environmental protection are not only a necessity for humanity's survival but that they must also be considered as engines for the greater production of knowledge and development of innovation. In this research, it is observed that the commitment to the environmental issue varied so much between poles, according to the expertise of each one of them being or not directly linked to this theme, and intra-pole, given the divergent perception of the relevance of the environmental aspect, revealed mainly in the speeches of representatives of academia and companies. For this, EA1 clarifies that "we are creating technologies to minimize the energy and water impact here in the building and then think about showing it to companies and seeing if they are interested in investing." The aspect of sustainability also reverberates

in the speech of EA3, for whom "most of the companies that we work for here at the center are committed to the issue of sustainability." However, the interviewee EE3, who works in partnership with this same pole (represented by EA3), shows the lack of harmony with the academic discourse when he stated that, "the environment is not something that is there as a main concern of the industry (...) the sustainability business is a bit tricky because it has a strong commercial appeal" [EE3]. The government representative stated that although environmental responsibility is relevant, he admitted that, "it was not a requirement in the notices we launched, but we have actors extremely committed to it" [EG1].

Environmental certifications also correspond to another challenge mentioned in the survey. In Sul de Minas, for example, initiatives related to product certification are not a requirement of the innovation pole; it happens through direct actions between producers and the consumer market. The representative of the academy (EA2) justified that in the coffee sector, companies certifying quality and good environmental practices have lost space; the producer sells not only the product but also the identity of his region and his explicit commitment to the environment. However, the sector entrepreneur (EE2) confirms that at the beginning of the project, there was no environmental concern on his part: "when we started, we did not have the vision we have today, this environmental vision of the business, this ecological footprint" [EE2]. Although only the Rio de Janeiro hub has recognized environmental certifications, as mentioned by EA4 – "the issue of sustainability permeates all our work with innovation, including our hub is certified as a physically sustainable unit" – the managers of the other units recognize the need for adaptation certification standards in a short period of time.

With regard to the inductive categories (Table 2), the factors that facilitate the process of collaboration and knowledge transfer are highlighted in the interviews. The first factor highlighted is the existing geographical proximity between the sensu stricto graduate programs, as both students and their advisors can prospect and conduct projects. For Dell'ano and Del Giudice (2015), geographic proximity is capable of promoting an increase in research due to the sharing of work environments, laboratories, incubators, and coworkers. For graduate students, EA1 argued that "of the 40 master's students, 30 were scholarship holders from the center"; their projects were the Polo projects. "So, we were managing to keep these students and they were able to defend [their dissertation] within the deadline." This perception is reinforced by EA3 when it mentioned that "of the four projects we have here at the hub, three have master's students involved." A situation similar to that described by EA4 – "of the students involved in the projects, around 80% are master's students."

The second facilitator's factor corresponds to the support received from other members of the innovation ecosystem. For companies, the technical support received at the hubs stands out: "I think that the hub's technical support was fundamental for our business" [EE3]. The support of investors from the innovation networks, as explained by the businessman from the south of Minas, "an investor appeared in the incubator (...). Then he got interested in the idea, we evaluated the proposal, we needed to take a bigger step, he contributed the capital, became a partner and we started to invest this capital" [EE2].

The third factor is the credibility resulting from the social recognition achieved by the Federal Institutes in the regions where they operate. This credibility figures as a relevant factor for the collaboration process between the actors in the innovation ecosystem. In the narrative of the manager of the Florianópolis hub, the size and capillarity of the Institutes make the difference: "on this campus alone, there are almost 6,000 students and there are more than 20 units in the state. That is why we have a good representation" [EA3].

The longevity of the institution is also mentioned by EA1: "Our institute is over 100 years old. So, we have a lot of alumni in the companies, so when you close a partnership in the industry and find alumni, you already realize that the treatment is different, they value all the work developed by the institution."

Skilled labor corresponds to the fourth factor facilitator's collaboration and knowledge transfer. For the representative of society, this benefit generates a chain reaction: "the government will increase the collection in a way that it will no longer be retroactive; there will be better jobs and more sustainable companies" [ES1]. For EA1 and EA2, more qualified students favor a closer relationship with the industry.

From the interviews, aspects considered as barriers as they trigger resistance to collaboration and knowledge transfer in the innovation process also emerged. The first complicating factor is associated with the typical public service bureaucracy, which somehow conflicts with the agility of the process of releasing resources from Embrapii. This situation is confirmed by the exposition of EA2; for him, "the bureaucracy is already at our core, the guy is already taking a back seat to talk to me because of the amount of paperwork he needs to fill out." On the same path, EA3 completes by assuring that "The main obstacles are really internal, we are from the public service and the bureaucracy is still too big! We need to win this one!"

The second complicating aspect refers to ideological questions with regard to the role of the public university in Brazil. It is worth remembering that the organizing principle of the triple helix resides in the expectation that the university assumes entrepreneurial responsibility in society. This is equivalent to stating that, by assuming the responsibilities derived from activities involving teaching, research, and extension, the university must collaborate to promote economic and social development through knowledge transfer, a trait that fits the US university tradition, for example, but conflicts with the values that sustain the public university in Brazil.

Still on the ideological issue, EA3 and EA4 converge in terms of perception by stating that, "there is a very strong ideological issue, there are people who think that applied research is the privatization of the public university" [EA3], "there are people who think that because we do applied research, we are privatizing the university" [EA4]. This reading of Polo's managers disregards the constraint of privatizing the results achieved by public universities; however, the Federal Institutes can assume this responsibility since they were created for this.

The third obstacle, particularly pointed out by the interviewed entrepreneurs EE1 and EE3, is the financial barrier. From the perspective of EE3, the risks involved in the innovation process, especially for micro and small entrepreneurs, make the difference in the continuity of the industry: "you are going to join a project, you are small, (...) you want to join, if reinvent to create a new place in the market and you often have to take money to put into the project, it will end up decapitalizing you." Even with Embrapii's support, the financial contribution of 1/3 of the project's value is still a challenge: "if I were going to continue with the project, I would not be able to because I did not have enough resources" [EE3]. For Etzkowitz (2008), the government is responsible not only for establishing the rules of the game but also for making risk capital available to help start new ventures.

Miscommunication is the fourth challenge mentioned by the respondents. Attention is drawn to the alignment of expectations in the relationship between academia and companies. For EE4, the main objective of the project should be the arrival of the product on the market: "the great interest should be commercial, in my opinion, then for science. We did this and this, it went wrong, and we learned this. Okay, but I financed this, and it was nothing for the market. So the feeling of the industry is: my money went to waste!"

Finally, the fifth subcategory of obstacles highlighted were obstacles related to business management. The emblematic report of EE3 revealed the anguish of many entrepreneurs when faced with good ideas, but with a lack of administrative knowledge, "for me and for the other team members, it was [innovation] a fantastic tool (...), but there in the market who would like to have it? Who would pay for this? I had no idea how to sell this!" [EE3]. The same challenge is shared by EE2 when he/she stated that, "like any industry that is being born, the worst phase is the beginning, when the entrepreneur still has no idea how to structure a business."

The data gathered in Table 3 were made available by the managers of the selected innovation poles and comprise the absolute numbers of knowledge transfer accumulated since the creation of the poles until May 2020. The result corroborates the allocation proposal made in the comparative matrix of the cases – it is noticed that the poles that transferred the most knowledge (Fortaleza and Florianópolis) are exactly those that presented the highest level of collaboration between the actors. On the other hand, the poles with fewer actors operating in the innovation ecosystem (Campos dos Goytacazes and Sul de Minas) had a reduced transfer of knowledge.

Table 3

Types of knowledge transfer by pole

	Type	Fortaleza	Sul de Minas	Florianópolis	Campos dos Goytacazes
1	Internships/employment for graduates	12	2	15	3
2	Joint conferences	12	5	8	1
3	*Spin-outs*	2	0	3	4
4	Professional journal publications	0	2	4	0
5	Networks	0	0	5	0
6	Joint supervision	0	1	0	1
7	Professional training and development	2	1	3	4
8	Standing out	0	0	3	0
9	Collaborative research	62	4	3	1
10	Contracted research and consultancy	0	2	2	1
11	Shared facilities	0	4	2	2
12	Patents and Licenses	32	5	2	14
13	Joint ventures	0	0	0	0

Source: Adapted from Alexander and Martin (2013).

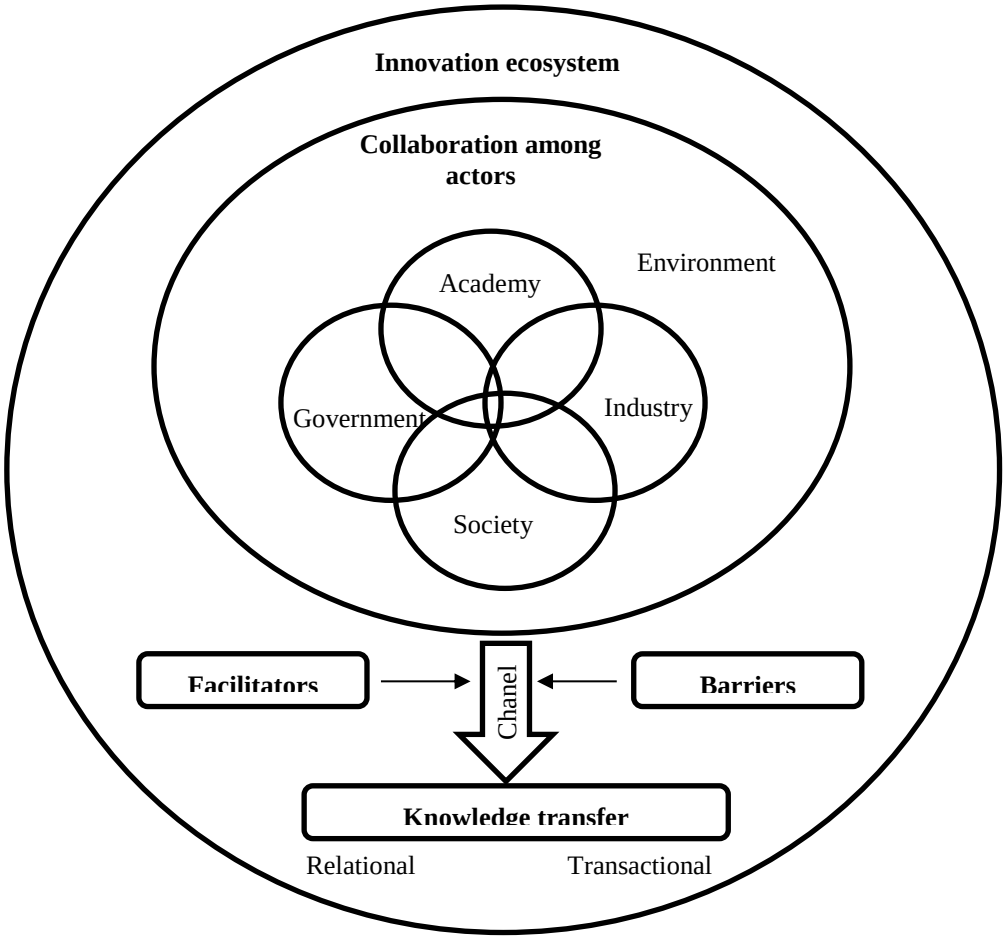
It is important to clarify that other factors, such as the time of accreditation of the pole as an Embrapii unit, also impacted the amount of knowledge transferred. According to the conducted interviews, in the first months after the implementation of the unit, a great part of the efforts is in prospecting for partnerships. “In fact, in the first year (...), we made contacts, participated in events and as I also give lectures; it is an opportunity to promote the pole” (EA3).

Based on the construction of theoretical lenses and the gathering of empirical evidence found, an analytical model capable of revealing how collaboration between actors in the innovation ecosystem is related to knowledge transfer was developed. This model benefits from other models found in the literature but differs by considering the existing collaboration between the actors of the innovation ecosystem, here represented by the quintuple helix, encompassing and analyzing the level of collaboration between them and the effective knowledge transfer. Considering the channel used, the influencing factors (facilitators or barriers) and the type of governance.

Figure 1 presents the interaction between the actors of the innovation ecosystem evidenced by the quintuple helix, in which its members are represented by the four indicative circles of university, business, government, and society, plus the environment that involves all relationships. Knowledge transfer channels are influenced by aspects that facilitate or hinder the relationship between collaboration and knowledge transfer. After suffering from these interferences, knowledge is finally transferred in a transactional or relational way.

Figure 1

Analytical Model – Collaboration relationships and knowledge transfers between actors in the Innovation Ecosystem



Source: Elaborated by the authors (2021).

In summary, the relationship between the actors in the innovation ecosystem and the knowledge transfer occurs according to the level of collaboration between institutions, represented in this article by the complexity of the relationships established. In addition, knowledge transfer also involves the management of the facilitators and barriers factors evidenced in empirical research. Therefore, in the investigated units of study, it is observed that the greater the level of collaboration, the greater the knowledge transfer.

Given the above, knowledge management among the actors in the innovation ecosystem can be planned, considering the specificities of organizations and the particularities of the context in which they are inserted. This is because these specific characteristics will give rise to the facilitators and obstacles to the relationship of collaboration and knowledge transfer. Therefore, knowledge management plays a

preponderant role in the search for mechanisms that can enhance the facilitators factors and minimize the obstacles in the search for innovation to generate the desired economic and social impact.

5 Final considerations

The research that resulted in the article was guided by the identification of a gap in the discussion on the relationship that involves collaboration and knowledge transfer between actors in the innovation ecosystem.

Based on the proposed objective, the research advances toward the type of transactional or relational governance that most favors the transfer of knowledge. However, within the limits of empirical research, the results were not conclusive as the type of governance did not prove to be a determining factor in the amount of knowledge transfer. This finding is illustrated in Table 3 – the innovation poles that stood out the most in the amount of knowledge transferred to Fortaleza, with, for example, 62 collaborative researches with partners from the innovation ecosystem and Florianópolis, with 15 graduate students involved in innovation projects, whereas the first gathers more formal characteristics of governance, in the second pole more informational characteristics prevail in the relationships between actors in the local ecosystem. In addition, both relational characteristics were identified, such as the prior establishment of trust relationships between the parties involved in the contracts and the transactional ones, an example of the activation of contractual clauses for a resolution of conflicts.

The results of the research enable us to state that the level of collaboration existing in the researched ecosystems is the factor that is most related to the transfer of knowledge. Through the research conducted, it was possible to ensure that a greater number of propellers working in an integrated manner favor the transfer of knowledge.

By expanding the discussion centered on the triple helix concept and focusing on aspects that involve the quadruple helix in the researched environments, it is possible to observe that there are still restrictions both in the cooperation between competitors and in the more participative relationship of society in the innovative process.

In the improvement actions suggested for the government, the need to expand non-refundable credit lines for startups with innovative projects, or even exemption from paying taxes for micro and small businesses during the incubation period, stands out. In the researched units of study, even with the costs of the projects being divided between Embrapii and the pole, the entrepreneurs reported financial difficulties at some point during the project execution, which could even make the product's arrival on the market unfeasible.

For the level of collaboration of the innovation ecosystem to be expanded, the academy, represented here by the Federal Institutes of Education, Science and Technology, needs to overcome

ideological and cultural issues and to strengthen the relationship with companies, aiming to direct research toward the priority demands of society.

Even in projects that are openly applied research, partially financed by Embrapii, a purely academic tendency was observed in some procedures adopted by the pole. The protocols and deadlines practiced at the hubs are still very bureaucratic, generating a mismatch with the team practiced in the industry, for example, in the process of purchasing inputs, in defining the macro deliveries of projects, and in the deadline for construction and validation of prototypes. A fact that caught our attention during the field research was that among the entrepreneurs interviewed, half of them were also students of the Federal Institute's graduate programs, and their respective projects at the center were linked to the scientific research they developed during their graduate studies. Given this finding, it was possible to see that several projects worked on at the centers were more focused on academic demands than on the maturation of a product with a view to its launch on the market. Even with factors such as the proximity of *sensu stricto* programs and the qualified workforce recognized as facilitators for collaboration and knowledge transfer, it is important to distinguish the commercial expectations of an entrepreneur from the academic goals of a student.

This study also demonstrated that companies still need to overcome internal challenges in their processes and routines. Through the field work carried out, it was evident that the organizational aspect represented a major barrier in those environments. Even before investing in innovation projects, companies needed to seek not only technical support but also management support (team building, finance, marketing, etc.). Despite the aforementioned support, it does not exist in the innovation poles but in ecosystem partners, such as Brazilian Micro and Small Business Support Service – Sebrae and incubators. This analysis reinforces the need to expand the interaction between the pole and other actors in the innovation ecosystem when the interest in overcoming barriers to knowledge management and transfer prevails.

The main theoretical contribution of the work is the proposition of the analytical model that integrates the aspects of knowledge management theory and the innovation ecosystem, considering the quintuple helix and knowledge transfer. Through the elaboration of this model, it was possible to affirm, based on the research, that the greater the level of collaboration between the actors of the interaction ecosystem, the greater the knowledge transfer in the researched environments.

The managerial implications of the work emerge from empirical evidence that reveal fundamental aspects (facilitators and barriers) in the relationship of collaboration and knowledge transfer between the actors in the innovation ecosystem. The disclosure of these factors can contribute to the success of other institutions that may adopt similar models in their areas of action.

It is expected that this work will impact society, contributing to the expansion of collaboration and, as a consequence, the knowledge transfer, by enhancing the facilitators factors and minimizing the

obstacles identified in the researched innovation ecosystems. With these actions, it would be possible to create a virtuous circle between the actors in the innovation ecosystem.

There is an awareness that research does not exhaust the possibilities of deepening and expanding the investigated theme; therefore, developments are always possible. It would be opportune, for example, to study ecosystems consecrated by the maturity of university–industry collaboration in the world and adopt them as a benchmark to seek to adapt the main characteristics for the creation of a model or guideline for the Brazilian context, considering the results of this article.

Authors' contributions

Contribution	Nascimento, Sandro F.	Lima, Manolita C.	Gondim, Igor J. C.
Contextualization	X	x	----
Methodology	X	---	----
Software	--	--	----
Validation	X	---	----
Formal analysis	X	---	x
Investigation	X	X	----
Resources	---	------	----
Data curation	X	X	X
Original	X	X	X
Revision and editing	X	X	X
Viewing	X	X	X
Supervision	X	x	----
Project management	X	-------	----
Obtaining funding	---	---	x

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