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O papel do Capital Humano na Inovação Aberta e o efeito mediador nos Ecossistemas de Inovação

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The role of human capital in open innovation strategies and the mediating effect of innovation ecosystems

Dissertação apresentada na Universidade de Aveiro para cumprimento dos requisitos necessários para a obtenção do grau de Mestre em Gestão, realizada sob a orientação científica da Professora Doutora Joana Maria Costa Martins das Dores, Professora Auxiliar do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro e co-orientação científica do Professor Doutor João Carlos Gonçalves dos Reis, Professor Auxiliar da Faculdade de Engenharia da Universidade Lusófona de Humanidades e Tecnologias.

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palavras-chave Inovação aberta, capital humano, ecossistemas de inovação

resumo A inovação aberta ganhou relevância a nível mundial, uma vez que é considerada uma fonte de vantagem competitiva nas organizações e em várias áreas do conhecimento, reunindo universidades, empresas e capital humano que resultam na utilização de sistemas de informação e comunicação. Desta forma, o principal objetivo desta investigação é estabelecer a relação entre capital humano (HC) e inovação aberta (OI). Este artigo inclui uma análise sobre a forma de promover as influências da inovação e os ecossistemas da inovação. Assim, foi feita uma revisão sistemática da literatura, na qual uma análise quantitativa de 27 artigos foi inicialmente realizada através da utilização de ferramentas biométricas e uma análise qualitativa para identificar os conceitos abordados nos artigos. Os principais resultados são que a literatura evidencia a relação entre o capital humano, o capital intelectual e o desempenho financeiro das empresas. Dados os avanços tecnológicos e a competitividade do mercado, estima-se que a inovação aberta será uma vantagem para as empresas e a forma mais conseguida de o conseguir será a partir do capital humano.

keywords open innovation, human capital, innovative ecosystems

abstract Open innovation has gained relevance worldwide, as it is considered a source of competitive advantage in organizations and various areas of knowledge, bringing together universities, companies, and human capital that result in the use of information and communication systems. Therefore, the main goal of this research is to establish the relationship between human capital (HC) and open innovation (OI). This article includes an analysis of how to promote innovation influences and innovation ecosystems. Therefore, a systematic review of the literature was made, in which a quantitative analysis of 27 articles was at first performed through the use of biometric tools and qualitative analysis to identify the concepts addressed in the articles. The main results are that literature evidences the relationship between human capital, intellectual capital, and the financial performance of companies. Given the technological advances and market competitiveness, it is estimated that open innovation will be an advantage for companies and the most accomplished way to achieve that will be from human capital.

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1. Introduction

The starting point to approach Open Innovation (OI) appeared in 2003. Chesbrough [1] considered that open innovation was an exceptional way to explain how innovation management leads companies to perform better. Subsequently, open innovation was defined by Chabbouh and Boujelbene [2] as the use of knowledge movements to accelerate internal innovation and expand markets for the external use of innovation. The fact that companies interact with other organizations allows them to promote their knowledge in research, development and also acquire new forms of knowledge [3]. Although open innovation is initially studied in large and high-tech companies, this overview has been changing due to the growing importance of Small and Medium-sized Enterprises in the economy. Human capital (HC) arises from the knowledge, skills, and experiences of the employees of a company [1,3,4]. It can be stated that human capital has a direct positive effect on a company's capacity for innovation. Individuals' qualities are crucial for companies to achieve desirable goals [5]. Several factors can influence these skills, Jang [5] remarks are related to education, professional experience, and hobbies. This intangible asset improves the performance of Open Innovation since it is considered a way of accelerating the absorption of external knowledge [3]. Good management of Human Capital allows managers to have a greater competitive advantage. A company that invests in internal and external research along with the development of activities, but doesn't invest in internal knowledge stock, may have higher costs [1]. Thus, the involvement of human capital in Open Innovation allows companies to become more available for development and in this regard the share capital of their employees to reach external actors [6]. It becomes important to refer to the research question "How does human capital influence open innovation?". Human capital, being the result of the set of skills and experience of people, provides companies with an internal knowledge that provides the ability to recognize opportunities and thus integrate them into the external factors that Open Innovation makes available. The characteristics of human capital influence the combination of internal knowledge with external knowledge. The fact that companies are rich in Human Capital promotes the incorporation of external knowledge and promotes the development of innovation due to the advantage they may have vis-à-vis the existing market. This organizational complement enables the creation of alliances with other companies and the obtaining of knowledge and exchange of information. Thereby, it is intended to understand the role of human capital in open innovation strategies, since this is a topic that Madrid-Guijarro et al. [7] assumes has gained great relevance in management studies and that according to additional research done by us can be illustrated through the following articles: in the field of business performance "Effect of board

size and duality on corporate social responsibility: what has improved in corporate governance in Asia?" (Ahmed et al, 2019), under corporate reputation "Intellectual capital based reputation for market internationalization: The case of engineering consultancy firms" (Ulubeyli and Yorulmaz, 2019), under higher education "Scale development and modeling of intellectual property creation capability in higher education" (Kashyap and Agrawal, 2019) and entrepreneurship "Promoting corporate entrepreneurship through human resource management practices: A review of empirical research" (Hayton, 2005) and OECD market studies such as "OECD 2012 Report: Education, Employment and Entrepreneurship". According to Spithoven [8], innovation studies have focused on innovative behavior, innovative performance, and technological innovation. Thus, it is intended to provide researchers with new perspectives through a systematic literature review. The literature review is structured as followed: firstly, a brief presentation of the methodological process that exposes the database used and the main criteria selected to obtain the most relevant articles related to "Open Innovation" and "Human Capital"; secondly, a qualitative analysis is made about the results found. So, it's intended to determine the effect of human capital on open innovation and what the advantages of endorsing open innovation in companies are.

2. Methodology

This article is based on a systematic literature review, through data collection in the Scopus database, as it is the appropriate strategy to condense relevant studies into the existing literature. It was decided to use the Scopus database, as it is recognized as one of the largest databases of citations in the peer-reviewed literature and therefore multidisciplinary and comprehensive. Innovation has been considered a factor of competitive advantage in companies and for this reason, several types of research have been generated both in organizations and in the academic area. Therefore, the systematic review of the literature seeks to provide a rigorous evaluation of theoretical progress along with empirical studies [9]. In addition, the systematic review of literature is the key tool to addressing the diversity of knowledge in a specific academic area [10]. Since the systematic review of the literature is a way of gathering knowledge on a theme [11] and requires a high effort when classifying the way to make it simpler, the analysis was divided into two approaches: a qualitative approach based on bibliometric analysis and a quantitative approach based on content analysis. Although these techniques have advantages and disadvantages, they are complementary. To illustrate the approaches mentioned (Table 1):

Table 1. Research methodology.

Phase	Typology	Description

Phase 1	Quantitative Approach	Identify, select, analyze and characterize the main articles for bibliometric analysis.
Phase 2	Qualitative Approach	Discussion of relevant results with added value to the role of human capital in open innovation strategies and the mediating effect of innovation ecosystems.

To select the database, it was considered the need for peer blinded-reviewed articles related to open innovation and human capital. The search was conducted on March 6th, 2021, with the keywords "open innovation" and "human capital" (title, abstract, and keywords), and 44 documents were found. To improve the review process, search filters were applied to exclude irrelevant articles, save time and ensure viable results (Table 2). The filtering process was to be selected articles in English because this is the universal language and decreases the possibility of linguistic interpretation errors. The selected documents were restricted to journal articles.

Table 2. Methodology approach.

Search for articles in the Scopus databases		
Criteria	Filters	Documents
Keyword	"Open Innovation" and "Human Capital"	55
Restriction	Title, abstract, keywords	
Selection of articles		
Language	English and Spanish	54
Source type	Journals	38
Document type	Article	36
Review of abstracts		
Selection by theme	Relevant information	27

After this selection, a general evaluation was made of the abstracts and data processed in each article and discarded the articles that did not bring relevant information to the subject. Thus, through the indicated process, the number of articles selected from the Scopus database was 27. In summary, out of the 36 articles, 9 were discarded, leaving 27 articles that can provide valid research perspectives on the relationship between Open Innovation and Human Capital, which makes it possible to carry out a bibliographic review to complete the objective of the study.

To complete the search there was the need to add 6 supplementary articles that are outside the scope of the Scopus search and their analysis to obtain conclusions about the theme of this systematic literature review, they are used merely to support the technical information of the adopted methodology and econometric analysis.

The content analysis was performed as follows: we identified the codes, i.e. we took small excerpts from reading the articles, and grouped these codes into categories, as shown in the following table.

The next section presents the results explaining the quantitative analysis and the qualitative analysis. The quantitative analysis is bibliometric and the qualitative analysis is the summary of the content analysis.

Qualitative Analysis

3. Results

3.1. Quantitative Results

Over time we have found that articles on Open Innovation and Human Capital have increased (Figure 1). A large number of articles, special issues, books, and conferences have been dedicated to this field, according to Chabbouh & Boujelbene [2] (p.2), thus confirming the importance of a paradigm shift in the management of the innovation process. It can be seen that the first publication appears in 2010, and in 2013 there is the first peak of publications about the themes, and in this period there were 5 publications. Between 2014 and 2015 there was a decrease in the number of publications compared to the previous year, with a total of 3 publications. The second peak occurs a few years after the first, in 2016, and from that year on the number of publications reaches two more peaks until 2023, interspersed by one year, with a total of 22 publications during that period. It can be considered that these peaks are due to the valorization of human capital in open innovation, as an indispensable factor to overcome economic adverse factors, and also by the increase of companies that have implemented these relationships since 2016.

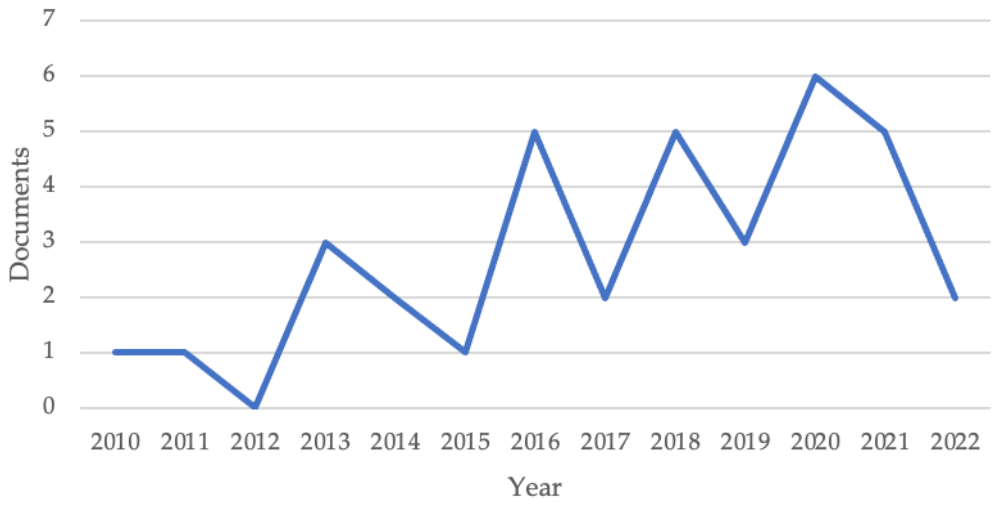

Figure 1. Number of published documents per year.

It is confirmed that the countries that contributed the most to scientific publications in this area were Spain, Italy, the United Kingdom, and the United States with 7, 5, and 4 publications, respectively (Figure 2). Germany, Belgium, China, Finland, South Korea, and Tunisia have 2 publications. According to Madrid-Guijarro et al. [7], the study of Spanish industries is especially interesting due to the innovation of industrial activities linked to Spanish SMEs that is lower than the European average, the fact that the Spanish government has recently launched innovative programs to promote knowledge creation and technological innovation, the fact that the Spanish industrial sector is receptive to radical changes to adapt its business models to gain greater competitiveness through innovation, and the efforts that are being made to boost human capital in Spanish companies as it is considered a crucial factor for knowledge and innovation. Also, García Martínez et al. [26] adds that the Spanish industrial sector is ill-equipped to withstand the crisis, with public R&D budgets shrinking in times of recession. Regarding the United Kingdom, the authors also add that there are studies that report the fact that the financial crisis forced many companies to postpone R&D projects and that the lack of internal financial resources hampered innovation during the crisis. In the United States, companies founded by entrepreneurs with a higher education level grow faster than companies founded by people less educated than entrepreneurs [5]. It is found that in the first open innovation survey in 2011, conducted among high and low-tech companies in the United States and Europe, 80% of companies practice open innovation [21]. Thus, the countries of

the European Union, Spain, Italy, and, at the time, the United Kingdom and also the United States present a greater number of publications due to the repercussions of the economic crisis and the need to find alternatives to technological developments and the financial difficulties faced by countries. There is a duality between the two large emerging economies of the world, the United States and China, with 5 and 2 publications respectively. This is due to the devaluation of human capital and the cost of labor offset by the use of technology.

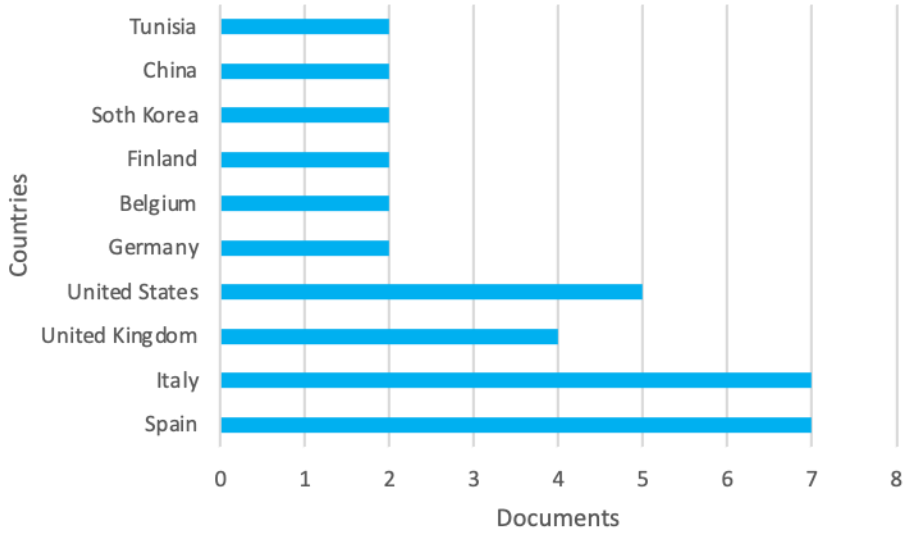

Figure 2. Number of published documents by country.

Open innovation has been explored in several areas and has even been introduced in medicine, chemical engineering, and agricultural and biological sciences, as we can see (Figure 3). As can be seen, 33% of the published articles are classified under "Business, Management, and Accounting" because it is considered the dominant area of this subject. This is followed by "Social Sciences" and "Engineering" with 17% and 12%, respectively. This result is related to the development and formulation of public policies and also to the constant development of technology and the search for constant technical problem-solving. Economics, Econometrics, and Finance represent 9% of the publications. These publications derive from the economic advantage of companies investing in human capital and open innovation through the reuse of intellectual resources and the sharing of knowledge. Computer Science and Decision Science represent 7% and 6% of publications, Environmental Science and Psychology represent 4 and 3%, and Agricultural and Biological Sciences, and Chemical Engineering represent 3% and 2% of publications. The remaining 4 % represent other areas such as medicine, mathematics, and energy. These areas represent a smaller number of publications because they are cognitively more science-oriented areas.

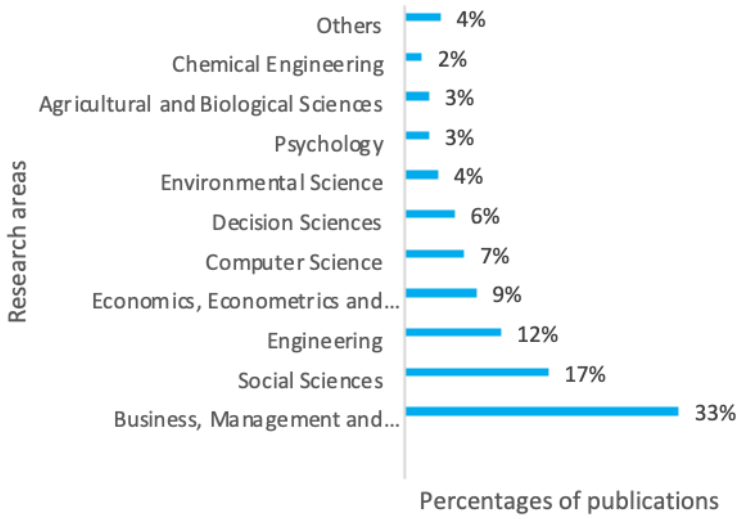

Figure 3. Research areas.

We also explored the distribution list of research articles by journals (Table 3) and the quality of their publications. To this end, a survey was conducted on the SCImago Journal & Country Rank (SJR, https://www.scimagojr.com), which assesses the impact, influence, and notoriety of journals. It turns out that there are not many publications per journal. The journal Technological Forecasting and Social Change and the Journal of Open Innovation: Technology, Market, and Complexity stand out by having 2 and 3, respectively, publications in the studied subject. Technological Forecasting and Social Change is a peer-reviewed forum that publishes articles with future studies and evaluates and forecasts technology. Open Innovation Journal: Technology, Market and Complexity is an international journal on entrepreneurship, open innovation, and open business models. Only articles from journals that belong to Q1 (Table 3) were considered because this index guarantees that they have more impact. The SCImago results also present data regarding other journals with different impact indexes.

Table 3. SJR.

Source Title	Quartile/ H-index	Number of published articles
Research Policy	Q1/224	1
Journal of Business Research	Q1/179	1
Technovation	Q1/121	1
Environment and Planning A	Q1/121	1

Industrial and Corporate Change	Q1/104	1
Technological Forecasting and Social Change	Q1/103	2
R and D Management	Q1/99	1
Journal of Intellectual Capital	Q1/80	1
Journal of Engineering and Technology Management - JET-M	Q1/62	1
Creativity and Innovation Management	Q1/55	1
International Journal of Technology Management	Q1/54	1
Strategic Entrepreneurship Journal	Q1/38	1
BMC International Health and Human Rights	Q1/37	1
Journal of Open Innovation: Technology, Market, and Complexity	Q1/20	3
Review of Managerial Science	Q1/20	1

The Journals titles presented are between 2010 and 2021. They are mostly empirical and have as their main focus open innovation, human capital, and innovative capacity. Since there is still a spacing between the first publication (2010) and the last (2022), we can conclude that the theme has had a gradual evolution. There is a diversity of journals and the areas by which they are distributed as well. This means that there are not many publications per newspaper. Overall, each journal has

one publication except for "*Technological Forecasting and Social Change*" and "*Journal of Open Innovation: Technology, Market, and Complexity*" which have two publications.

The journals with the highest ranking in publications are also the ones with the highest H-index because they are cited the most.

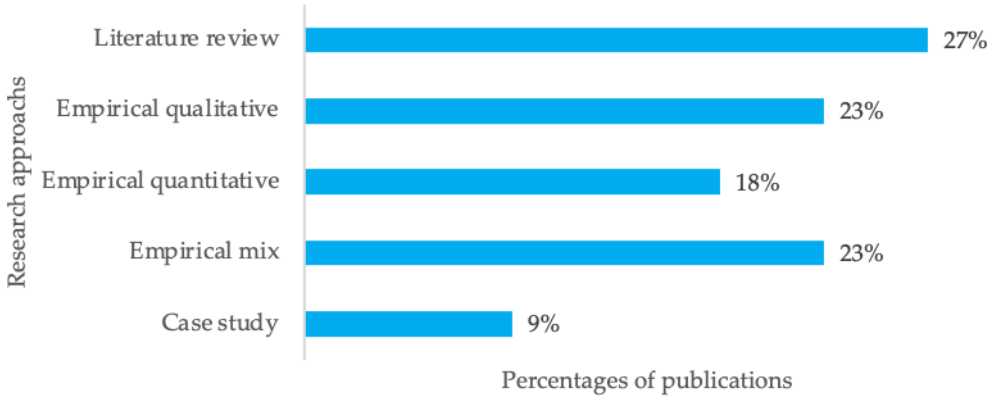

Figure 4. Research approaches used to study “OI” and “HC”.

In order to reduce the error in the classification of the types of research approach, it was decided to classify the documents with the type of approach identified by the author. Thus, out of the 27 articles considered for this research, 23 were studied. Figure 4 represents the research approaches used to study "Open Innovation" and "Human Capital". Through the analysis of the data in Figure 4, it is clear that the type of approach the most used in the period under analysis is the empirical research, which corresponds to 64% of the articles (empirical qualitative, empirical quantitative, and empirical mix), while 27% are theoretical and 9% are cases of study.

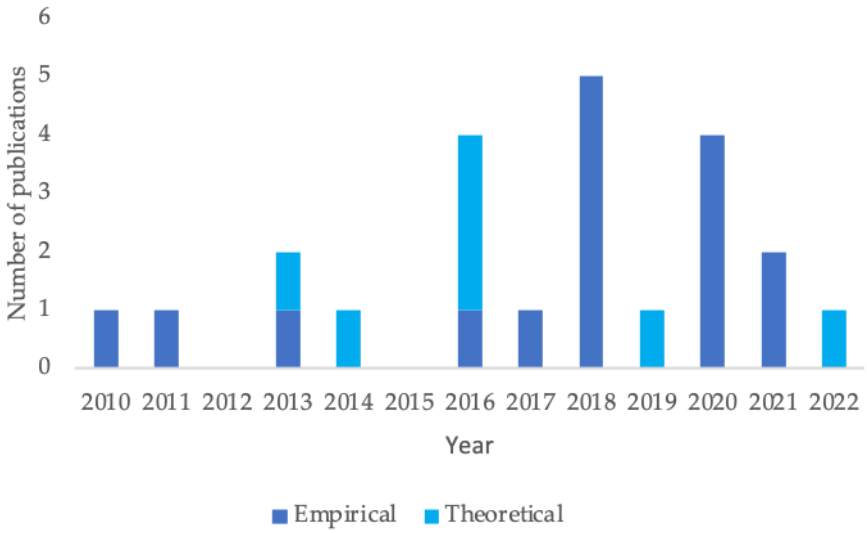

Figure 5. Distribution of research approaches.

Empirical studies are predominant (Figure 5), and 67% are empirical and 33% are theoretical studies. The year that presented the most empirical studies was 2018 and the year that presented the most theoretical studies was 2016. It can be seen that there is great importance given to empirical studies because almost every year there is a publication with a study of this character because they bring the results that theoretical studies describe and apply the theory to practice. However, theoretical studies on human capital and open innovation should be strengthened to create a constant information segment. In the span of 12 years (2010-2022), there were theoretical studies only in 5 scattered years. This rupture provides dissipation of information and thus also conditions the empirical studies.

3.2. Qualitative Results

To synthesize the existing literature, we decided to summarize the theoretical framework through a table of contents (Table 4). The different perspectives were analyzed and the authors who focused more on the theme studied were selected. This is intended to select authors to explore the role of Human Capital in Open Innovation and how they can influence innovation ecosystems.

Table 4. Qualitative analysis

Authors	Article	Journal	Objective
Carmona-Lavado et al. [1]	Does open innovation always work? The role	Technological Forecasting	Identify OI settings, and analyze which settings are

	of complementary assets	and Social Change	associated with high and low OI performance.
Chabbouh & Boujelbene [2]	Open innovation in SMEs: The mediating role between human capital and firm performance	Journal of High Technology Management Research	Understanding the performance of SMEs combined two approaches: resources and open innovation.
Kim & Choi [10]	The intensity of organizational change and the perception of organizational innovativeness; with discussion on open innovation	Journal of Open Innovation: Technology, Market, and Complexity	Verify how the investment in individual HRD relates to employees' perceptions of organizational innovation and employee perceptions about organizational innovation through multilevel analysis using hierarchical linear models.
Barrena-Martínez et al. [3]	Joint forces: Towards integration of intellectual capital theory and the open innovation paradigm	Journal of Business Research	Provide a theoretical model that presents synoptically how intellectual capital overlaps the OI and test the theoretical model by analyzing how the CI of companies performance and relates to OI.
Matricano, Candelo, Sorrentino, & Cappiello [12]	Investigating the link between intellectual capital and open innovation processes: a longitudinal case study	Journal of Intellectual Capital	Investigate the relationship between Intellectual Capital and OI.
Zouaghi et al. [4]	Did the global financial crisis impact firms' innovation performance? The role of internal and external knowledge capabilities in high- and low-tech industries	Technological Forecasting and Social Change	Assess the role played by internal innovation and the effect of active external knowledge resources such as dynamic capabilities to overcome adverse economic conditions.
Zhang, Yang, Qiu, Bao, & Li [14]	Open innovation and firm performance: Evidence from the Chinese mechanical manufacturing industry	Journal of Engineering and Technology Management - JET-M	Understand how human capital affects the relationship between open innovation and the financial performance of companies.
Bogers, Foss, & Lyngsie [15]	The “human side” of open innovation: The role of employee	Research Policy	Understand what are the characteristics of innovation associated with employees

	diversity in firm-level openness		that add greater openness to the company.
Alexy et al. [6]	Toward an aspiration-level theory of open innovation	Industrial and Corporate Change	Behavioral theory about open innovation.
Lenart-Gansiniec [16]	Relational capital and open innovation - In search of interdependencies	Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis	Discover the interdependencies between relational capital and open innovation.
Podmetina, Volchek, Dąbrowska, & Fiegenbaum [17]	Human resource practices and open innovation	International Journal of Innovation Management	Understanding the role of HR in open innovation, analyzing HR practices in companies operating under the open innovation approach.
Sartori, Favretto, & Ceschi [18]	The relationships between innovation and human and psychological capital in organizations: A review	Innovation Journal	Overview of the concept of innovation and the relationship with human and psychological capital.
Ostrovska, Tsikh, Strutynska, Kinash, Pietukhova, Golovnya & Shehynska [19]	Building an Effective Model of Intelligent Entrepreneurship Development in the Digital Economy	Eastern-European Journal of Enterprise Technologies	Building a model for the development of smart entrepreneurship in the digital economy to achieve the economic, social, managerial, capitalization, and image efficiency of entrepreneurship and the predominance of the role of the human being in the modern economy as an intelligent factor of economic growth.
Zhang, Wang & Chun [20]	The Effect of Knowledge Sharing on Ambidextrous Innovation: Triadic Intellectual Capital as a Mediator	Journal of Open Innovation: Technology, Market, and Complexity	Explores the relationship between knowledge sharing and the open innovation paradigm.

As can be seen in Table 4, some themes related to the study we intend to carry out, such as the financial development of companies and the impact on intellectual capital. In addition, it is

considered that OI is related to a variety of practices and processes that affect the performance of innovation [1].

The risks associated with the loss of technological competitiveness require companies to make investments in activities that generate knowledge [4]. In this way, opting for open innovation can bring new knowledge to the company and allow it to remain competitive.

The articles selected for research suggest useful information for innovation management in companies. It helps to realize whether companies are available to share information in their value chain; whether companies have human capital that fulfills the innovative process and whether companies connect with the innovative community. Finally, it helps to perceive whether human capital influences open innovation and whether there is a competitive advantage in opting for open innovation.

4. Theoretical Basis and Literature Review

4.1. Human Capital

Human capital brings more benefits to the open innovation process. According to Chabbouh & Boujelbene [2] (p. 6) "a company's performance in the context of innovation is greater if it has a rich asset of competencies represented in its Human Capital". Thus, human capital is defined by tacit knowledge, skills, and cumulative competencies [1,3,4,19]. Without the need for a qualified team, the company does not have the prior knowledge to successfully use external knowledge [7]. These capabilities include different skills and skills necessary for internal management of activities, mainly in planning, organization, resource mobility, and control capacity [2]. Most studies focus on how company executives influence business innovation and forget about the role of employees. Innovation strategy relies heavily on intelligent employees who are not only providers of ideas but also executors and implementers of ideas [20]. These skills are obtained through education or previous experiences and are positively related to company performance [5]. Professional experience and education explain the ability to obtain external information and thus allow a general opening to companies [14]. Diversified experience allows employees furthermore explore external sources of knowledge and diversified education develops good behavior and makes it more exploratory in designing and solving problems [14, 20].

Companies that hire Research and Development (R&D) activities but do not invest in Human Capital may have higher costs. A company cannot acquire external knowledge without ensuring that it has a good internal base. However, if Human Capital is low due to a lack of

knowledge and skills, the ability to identify benefits is low, which does not allow a rapid selection of partners [1]. The internal capacity of R&D is considered an essential element for innovation because it stimulates the process of creating new knowledge and the possible transformation into new products [2]. In the process of assimilating and transforming knowledge, a compatible cognitive structure is needed [13]. In this way, companies that have a high level of Human Capital can use it to get better internal results by crossing with external knowledge [2]. The developments of these capabilities result in positive changes in the knowledge, skills, and development of the organization's members [11, 12]. Madrid-Guijarro et al. [7] highlight that the broader the HC base of a company, the better it will be able to acquire and explore new knowledge. Jang [5] also adds that the higher the HC, the more likely it is to recognize new opportunities and successful exploration.

The processes of integration and sharing of knowledge allow companies to implement different strategic options [7]. Throughout the literature, human capital plays a fundamental role in Open Innovation because it allows the opening of the process of knowledge creation [2]. When referring to Human Capital, researchers define it as all the intangible resources that companies can take advantage of to achieve and provide their competitive advantage in the market [12]. The flow and exchange of knowledge in a company not only increases the depth of intellectual capital but also the active sharing of knowledge between individuals and deepens the understanding of their knowledge and skills by enabling increased understanding of others [20]. Thus, it is believed that this has a direct and positive effect on a company's ability to innovate. However, the organizational and social antecedents of absorption capacity act as strong mediators in the relationship between openness and performance [3].

Some research shows that in times of crisis in companies, HC is a valuable resource because it promotes innovation and creativity. In a time of crisis, innovation needs efficient capacities through investment in HC in order to increase production and reduce costs [4]. The author adds that companies looking for "talented" employees have greater long-term survivability and if there is such a link between R&D and HC accumulation there may be a livelihood of economic growth in uncertain conditions. In this way, and once again, companies with high levels of HC are better positioned to survive adverse macroeconomic conditions. Zhang et al. [14] suggest that the accumulation of HC and the improvement of its management are sources of sustainable competitiveness. This feature is directly related to the problem-solving ability, leadership, and creativity that employees have [13, 21]. Several authors suggest that HC accumulation affects corporate performance and improving its management is a source of sustainable competitiveness [12, 14, 16, 22, 23].

The HC structure can be classified into two categories: production-oriented and technology-oriented. When production-oriented there is a focus on cost reduction and market share through mass production [14]. About technology orientation, competitive advantages are related to process innovation and incremental improvement that make production costs lower and more efficient.

In the context of open innovation, companies with a high level of HC also have a greater capacity to combine internal and external knowledge [16]. The quality of HC is associated with cognitive skills and information processing skills. Companies with higher HC quality are more successful in finding, evaluating, assimilating, and integrating external technology well as in transforming and commercializing markets [13]. Thus, Human Capital for Open Innovation is considered important because it requires that there are more skills than those that are traditionally located in the internal departments of companies. The effects are positive for performance thus improving the results for successful innovation.

Hypothesis 1: Human Capital has a positive impact on Open Innovation.

4.2. Open Innovation

Open innovation is defined by the distributed innovation process based on knowledge flows [15]. This is widely known as the strongest weapon for companies to create competitive and sustainable advantage [26]. It involves the recombination of knowledge and can result in the creation and adaptation of economic value and competitive advantage [14]. It is considered an activity that is seen as a measure of business performance that creates tasks and solves problems with new ideas and methods, becoming an important factor in enhancing competitiveness both at a technological level and in various forms of cooperation and innovation in the design and management innovation [12]. The open innovation model considers external ideas as important as internal ideas, it is the systematic exploration of internal and external resources to find opportunities for innovation [17]. Over time companies have chosen to use more external knowledge to improve their internal processes, as well as in the search for commercial opportunities. This knowledge is associated with external sources such as suppliers, customers, and universities through different mechanisms such as sourcing and collaboration [14]. In this way, companies use not only their internal innovation capabilities but also a range of external actors and resources that increase the innovation process and allow access to new markets [2]. The introduction of innovative knowledge and innovation models requires the creation of knowledge platforms, the innovative markets. These markets require a market structure which is crowdsourcing. This structure consists of using the intelligent potential of society to obtain new knowledge or open innovation allowing to accelerate the innovative development and adapt the product [19].

The importance of OI arises because Chesbrough has provided an "umbrella that covers, connects, and integrates a series of existing activities" [1]. The author highlights that this proposal coincided with a growing interest in strategies and activities that required an open vision of the company (outsourcing, networking, core competencies, and the internet). Other factors are related to the growth of OI, not only at the level of concept, but also in the field of research, and knowledge for innovation is widely distributed in the economy and is favored by the mobility of workers, the improvement of the qualification of universities and by the emergence of the Internet, social networks and information and communication technologies [3]. Ostrovska et al. [19] affirms that "The global spread of knowledge, technology, information, smart resources, the growing significance of open interactions and qualitatively new effects (the "butterfly effect") lead to changes in the very nature of competition and the forms of smart business." (p.3). Thus, it is perceived that it is difficult for a company to innovate in isolation and must maintain interactions with different types of organizations to acquire knowledge and external resources.

This type of innovation does not happen for no reason. Companies are in a certain place, as well as their markets, their sources of information, and their partners who collaborate with information sharing. According to Spithoven [8] (p. 5) "the first implication for open innovation is that location is important. In some industries and technological environments, establishing bonds and establishing a physical presence in a region where important knowledge resides is fundamental." Most companies, even market leaders, cannot research and develop new technology on their own because there are technological challenges and financial constraints that force independent and sometimes competing companies to collaborate [13].

The first factor that attracts researchers in this field is the way OI strategies influence performance [1]. It's believed that OI is beneficial because the more the company interacts with other organizations, the greater the access to new ideas, knowledge, skills, and other intangible assets that increase the likelihood of successfully innovating. Moving from closed to open innovation allows for faster implementation and development of processes to gain high-level competitive advantages [19]. The constant introduction of new technologies that satisfy the growing form of customers are the reason for the high performance of companies [13,17]. Although the openness between companies is associated with interactions with other organizations, the OI strategy can be based on diversification of activities, such as the interaction between partners, which may be diverse or with external knowledge [1].

The level of openness is determined by the number of partners and the different types of partners with which the company collaborates, as well as by the outsourcing of research and

development services (R&D) [25,26]. As the OI model admits that a company cannot innovate in isolation and needs external resources from other partners, collaborative innovation agreements have been considered a central practice of OI [15,27]. The fact that companies have this type of agreement allows the reduction of spillovers, provides access to complementary knowledge, tacit knowledge, and know-how that come from innovation partners and that are not easily obtained through market transactions and reduction of innovation costs and there is a development of economies of scale and scope in research and development [1]. The diversity of partners and the number of alliances influence the level of openness. Companies with greater openness have access to different ways to troubleshoot and achieve better levels of performance. The main reason companies use alliances is to acquire know-how, skills, and capabilities from other partners. Thus, alliances are an effective method of knowledge transfer [3]. However, IO related practices involve a willingness to take risks [18]. Thus, there is a need to create a tolerant culture so that it is possible to assume the risks associated, for example, with sharing information.

Thus, in addition to open innovation being an extremely important strategy for the development of companies, because it allows the diversity of information, human capital adds the possibility of exchanging it and responding to new challenges.

Hypothesis 2: Open innovation creates a competitive advantage for companies.

Hypothesis 3: Companies that do Open Innovation are those that use Human Capital.

4.3. Innovative Ecosystems

While conducting this research, a conceptual model of innovation ecosystems was identified. This term seems to be more used when talking about open innovation and human capital in different disciplines. According to Rostoka et al. [30], it is a topic that began to be analyzed at the beginning of the 21st century and was considered essential in the development of companies, highlighting financial and human resources.

Although there is still no single and clear definition, innovation ecosystems are characterized by representing the business environment where there is a connection between different actors, which distinguishes innovation from the starting point for social and economic development. Companies remove cooperative borders through outsourcing and cooperate more with other companies to engage in activities and obtain resources outside their borders [6]. Zouaghi [4] believes that cooperation with suppliers makes it possible to improve efficiency and enhance the technological base. Simultaneous engagement in R&D cooperation with different partners (competitors, customers, suppliers, etc.), under certain circumstances, has a positive impact on

performance. Some authors also emphasize that cooperation between universities and companies resulted in a different perspective as they took into account global trends and European Union initiatives that characterize development [30].

One aspect that is important for this conceptual framework is the importance of knowledge flows for the sustainability of an innovation ecosystem. Flexibility, cooperation, and exchange of knowledge contribute to the creation of a favorable atmosphere for inbound and outbound activity. Flexibility, cooperation, and exchange of knowledge contribute to the creation of a favorable atmosphere for inbound and outbound activity [7]. Knowledge sharing allows companies to adapt to an evolving and increasingly complex market environment or even for companies to become stronger and stronger based on their current market position in this way they absorb, transform and apply knowledge [20]. Zhang, Wang & Chun [20] add that " Knowledge sharing can help enterprises become learning organizations with an efficient resource flow, promote the diffusion of knowledge throughout the enterprise, and generate intellectual capital through the integrated operation of business and value processes, thereby providing the impetus for enterprises to innovate at different levels." (p.1).

Despite the variation in literature around this term, it is composed of different elements that can have more or less importance depending on the ecosystem and are integrated into a geographical, industrial, economic, or business area that interacts with each other. These elements are universities, companies, associations, and the government. In open innovation models, the issues of managing inter-industry clusters, local innovation networks the system of trilateral cooperation between science, state, and business are quite important [19]. All these components have interrelationships, have some degree of dependence on each other, and play different roles in innovation processes. Innovation ecosystems allow the different parts that make it up to cooperate with each other and in this way grow and acquire competitive advantages that alone did not have this possibility. The acquisition of external technology only leads to the performance of companies at higher levels of R&D and internal effects. All these actors, which relate to each other, present goals that aim at the development of innovation and technology mainly with the use of the intangible resource associated with Human Capital.

These ecosystems present an added value and wealth to an economy because it determines strategies that aim at economic development and its recovery in periods of crisis. On the other hand, in the process of creating a new company, the sources of internal knowledge are narrow for the creation and development of new products and sometimes lack the knowledge to identify relevant opportunities. Sharing knowledge internally, among employees is a form of open innovation that

creates value for the company thus reducing the uncertainty and complexity caused by external resources [20]. In this manner, IO provides strategies for establishing inter-organizational linkages through formal and informal networks to achieve market success in the new firm [11], [22].

Thus the contents studied previously can be modified taking into account ecosystems.

Hypothesis 4: Companies that do Open Innovation and use Human Capital connect to the system.

5. Conclusions

5.1. Theoretical contributions

Systematic literature review, analysis, and understanding of the two major themes under study, open innovation, and human capital. Both OI and HC were essential to outline the structure of this article, especially in terms of its methodology. In this way, the withdrawals will be chosen throughout the study.

The purpose of this article was to define the concept of OI and HC and understand how they were related. It was found that these themes have gained over the years both at the level of companies and at the academic level due to the dynamic economy that exists throughout the world, influenced by social changes and technological developments [34]. There are several definitions associated with open innovation, but in general, the authors define it as the exchange of knowledge and ideas between the company and abroad. Additionally, some authors have Dimensions such as the strategy in the case of Bogers et al. [15] and collaboration in the case of Barrena-Martínez et al. [3].

In the OI model, there is a relationship between the organization and the environment [31]. In this way, it was important to understand, in addition to the definition of innovation, which other factors influenced the performance of companies, such as the capacity to absorb information, the level of education and training, and the level of R&D. Thus, in the knowledge base evaluated HC.

Concerning human capital, it is clear that this brings about OI processes. It was identified that individuals with high levels of education and educational background become more relevant to the innovative performance of companies [14,15,16,33]. Previous experiences are also relevant in terms of openness to sharing knowledge and accessing it.

During the analysis of the two concepts, the existence of the conceptual model of innovation ecosystems that represent the surrounding environment of companies and the connection between the different actors was verified.

Thus, and as already mentioned, the main objective of this article is to synthesize the results obtained and the existing literature through a systematic review of the literature on OI and HC. Thus,

the relationship between HC and OI was analyzed and the existing knowledge was synthesized. It became important to understand the nature of knowledge flows across organizational boundaries and the benefits and disadvantages of the relationship between HC and IO. Although there are already some beneficial facts about the use of OI, there are still no very consistent data. This article intends to go deeper into IO and relate it to HC, identifying the benefits for companies both economically and in terms of performance.

Through this theoretical study, it was possible to understand that there is a positive relationship between open innovation and human capital and this favorable interconnection to innovation ecosystems.

5.2. Managerial contributions

The completion of this article allowed us to deepen the relevant points of the two main themes under study. In this way, it was analyzed how the themes are related.

It is considered that this study may have great relevance for companies from various sectors, as it helps to understand that it is possible to diversify information through knowledge sharing. Thus, this study allows boosting the sharing of information to obtain a competitive advantage in the market.

The contribution of this analysis is related to the valuation of HC and the relationship between companies in sharing knowledge without the risk of harming the business. The relationship between open innovation, human capital, and innovation ecosystems is also left as a future proposal.

5.3. Limitations and future research

This research presents some limitations, mainly due to the keywords and database choices. The keywords were the ones that provided the most specificities to the research, thus allowing it to become more appropriate, and then the articles were substantially reduced after the application of several filters making the research suitable for a better analysis. Regarding the database used, although for a systematic review several articles choose to use several databases, the priority of this article was transparency and easy reproduction of results.

It is suggested that future studies assess motivation within human capital, especially in larger companies, as they have a larger number of employees and thus need effective channels and good strategies to motivate the greatest number of employees.

Empirical Analysis

6. Methodology

6.1. Introduction

After the careful data collection, its analysis, and the selection of the most relevant information through the literature review, it is necessary to turn to an empirical analysis through data collection to answer the central question of the dissertation: the role of human capital in open innovation strategies and the mediating effect of innovation ecosystems.

Initially, descriptive statistics will be done with the variables under study and later with the correlations and estimates. The quantitative methodology consists of conducting and analyzing data that play a key role in exploring, presenting, relating, and interpreting data [35]. The SPSS program was used to analyze the variables and the data was analyzed using cross-tables and correlation tables.

The research question for this study is "How does human capital influence open innovation?" and for this, we will answer some underlying questions such as: which firms do product, process, service, and organizational innovation which firms use knowledge acquisition, which firms do open innovation, and with which partners they cooperate.

This chapter will present the methodologies used in data collection, such as a description of data analysis, method of data collection, and data processing and analysis.

6.2. Definition of objectives

This study intends to respond to the initially defined objective, which is to understand how human capital influences open innovation and the mediating effect of ecosystems. Thus, it intends to analyze the relationship between the different variables under study and also the characteristics of companies belonging to the database of the Community Innovation Survey (CIS). The dependent variables under study are innovation and open innovation ecosystems and the independent variable is human capital. The aim is to study how human capital affects open innovation and the mediating effect on innovation ecosystems.

To answer these questions, some specific objectives have been formulated. Table X allows us to verify the specific objectives of the empirical study.

Table 5. Specific objectives.

Characterization of	• Size of companies

Empirical study	database	• Acquisition of knowledge • Cooperation partners

	Exploratory analysis	• Cross data tables
		  • Human Capital
		  • Open Innovation
		  • Innovation Ecosystems
		•

	Descriptive statistics	• Correlation table of variables and descriptive statistics
	Econometric analysis	• Determinants of propensity

6.3. Description of the data analysis

The empirical analysis is based on data collection through the Community Innovation Survey (CIS) 2018 in Portugal, a Statistical System rating instrument that measures and characterizes innovation activities in firms between 2016 and 2018. This survey aims to produce and update statistical indicators on business innovation at the European level. The database is composed of 13701 Portuguese companies with heterogeneous structural characteristics and innovative profiles.

6.4. Characterization of data under study

The companies studied are about the CIS Survey for the period 2016-2018. The sample consists of 13701 firms.

Of all companies, 11.4% have carried out in-house innovation and 6.3% have carried out extramural innovation. Only 615 companies, which corresponds to 4.49% of the companies, carried out open innovation, that is, the simultaneous use of intramural and extramural innovation.

In figure 6, we can see that 69% of the companies are small, 26% are medium-sized and 5% are large.

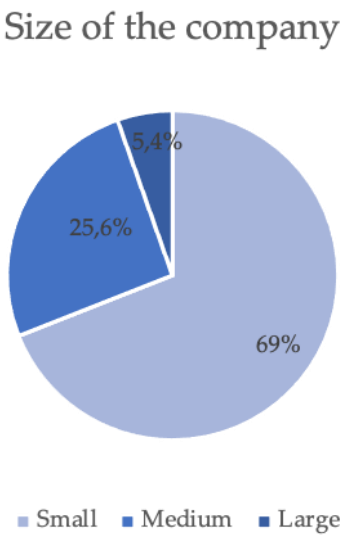

Figure 6. Size of the company.

According to figure 7, 55.7% of companies seek knowledge through "Conferences, fairs or exhibitions", 50.5% of companies through "Information from professional or industrial associations" and 42.2% of companies through "Scientific/technical journals or trade publications". These are the 3 ways of obtaining knowledge that stand out for being the most sought after by the companies.

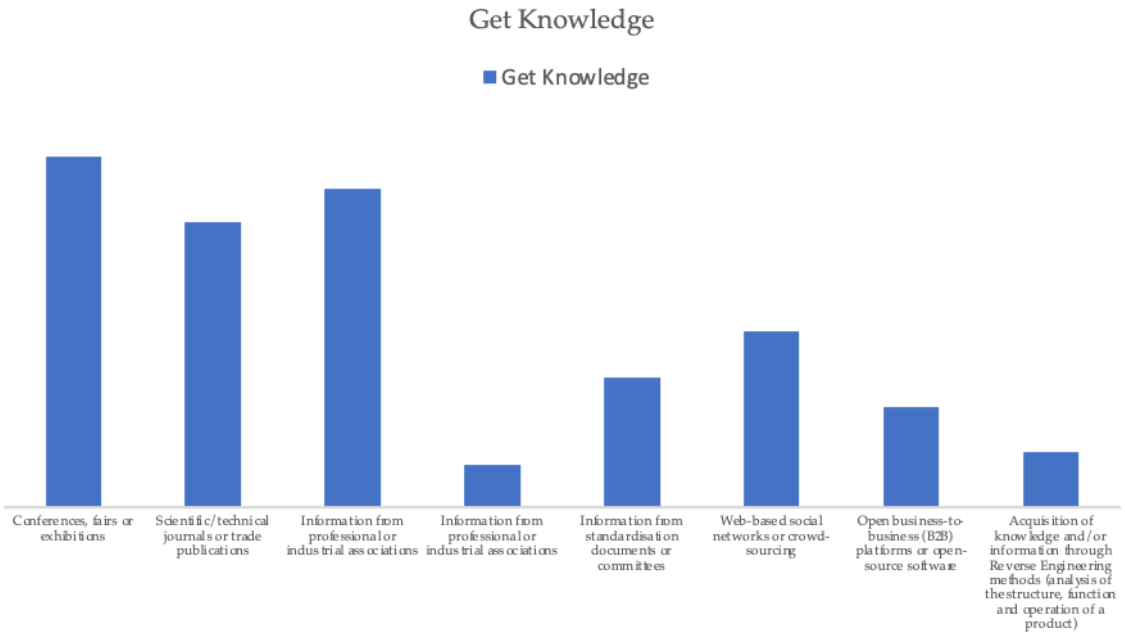

Figure 7. Get knowledge.

Regard to innovation partners are divided into 6 partners: companies outside the group to which it belongs, companies within the group to which it belongs, universities and other higher

education institutions, public intervention institutes, public sector clients, and non-profit organizations.

The companies outside the group to which the enterprise belongs are subdivided into 5 categories, as shown in figure 8. In Portugal 5.15% of enterprises cooperate with "Suppliers of equipment, materials, computers or software", 4.55% cooperate with "Consultants, commercial laboratories or private intervention institutes" and 3.17% with "Client enterprises". In the European Free Trade Association (EFTA) and the European Union (EU), 2.11% of the enterprises cooperate with "Suppliers of equipment, materials, computers or software", 1.55% cooperate with "Client enterprises" and 1.40% with "Consultants, commercial laboratories or private intervention institutes". As for the cooperation with other countries, 0.62% cooperate with "Client enterprises", 0.58% cooperate with "Suppliers of equipment, materials, computers or software" and 0.42% cooperate with "Consultants, commercial laboratories or private intervention institutes".

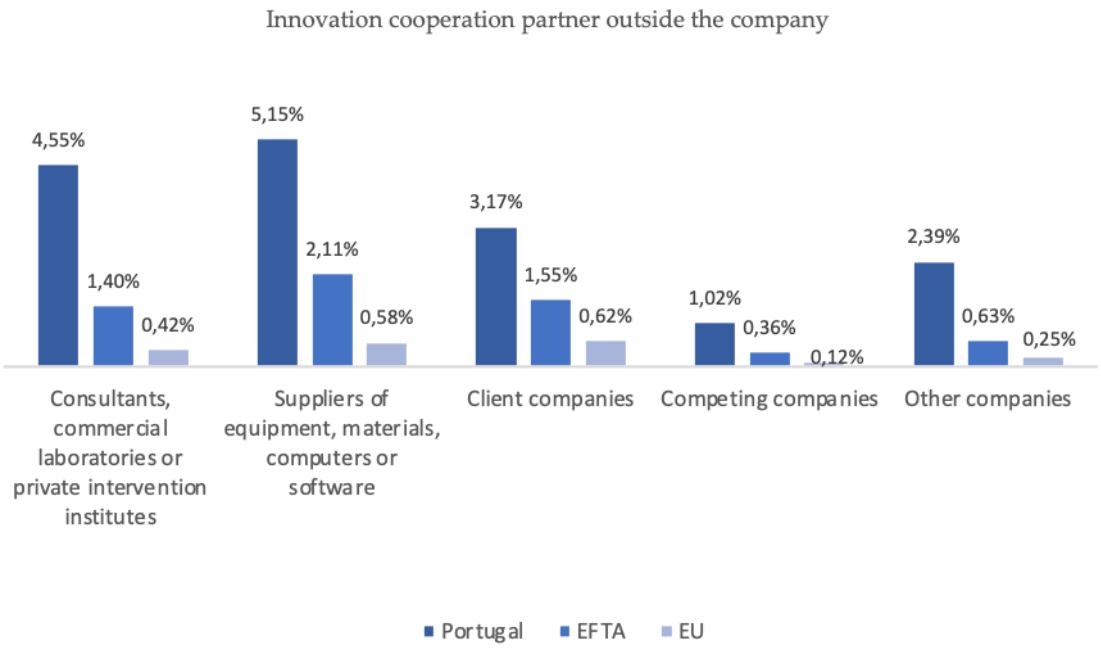

Figure 8. Cooperation partner outside the company.

In respect of cooperation with the other partners, in Portugal, "Universities or other higher education institutions" stands out with 4.39%, followed by "Enterprises within their group of enterprises" with 3.29%, and finally "Public intervention institutes" with 2.05%. For EFTA and the EU, "Enterprises within their group of enterprises" stands out with 1.26%, followed by "Universities or other higher education institutions" with 1.02%. Regarding other countries, "Companies from your group of companies" with 0.58% stand out.

As mentioned in the literature review, it is found that cooperation with universities and

industries is important and frequent, due to the constant evolution of technology and the need for new capabilities to deal with challenges.

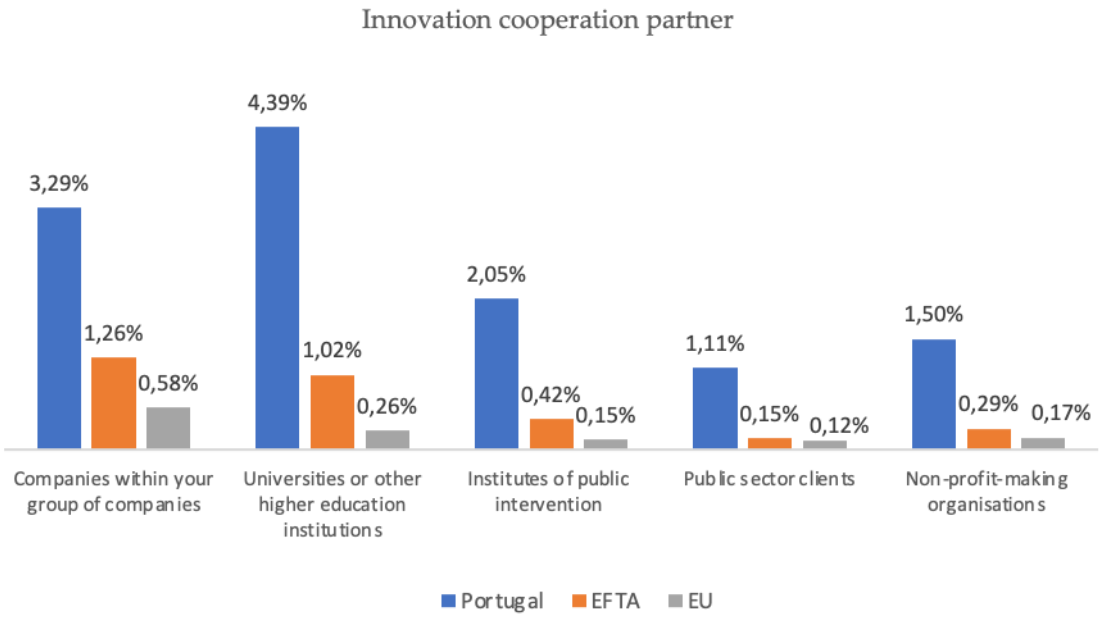

Figure 9. Innovation cooperation partner.

6.5. Variables in use

According to the CIS questionnaire, table 5 describes the measurement scale of each variable that will be used in this study. In order to improve the analysis, the variables correspond to the basic mathematical conversions and the original CIS scale.

Table 6. Variable description.

Abbreviation	Variable name	Description	Measurement
REG_TECH (1)	Technological regime	The technological regime of the company (Bogliaccino and Pianta)	1- Suppliers dominated 2- Scale intensive 3- Specialist suppliers 4- Science-based
SIZE (2)	Company size	Size of the company	1-3 degree
EMPUD (3)	Human capital	Human capital intensity	1-6 degree
OPEN_INNOV (4)	Open innovation	Internal and external innovation	2
GEN_INNOV (4)	Innovation	Performed innovation	Binary

PROD_INNOV (5)	Product innovation	Achieves product innovation	Binary
SERV_INNOV (6)	Service innovation	Achieves service innovation	Binary
PROC_INNOV (7)	Process innovation	Achieves process innovation	Binary
ORG_INNOV (8)	Organization innovation	Achieves organization innovation	Binary
CHANNELS (9)	Knowledge creation	Seeks out the community to obtain knowledge	0-8 degree
COOP_INNOV (10)	Innovation cooperation partners	Seeks to cooperate with the community	Binary
OUT_COOP (11)	Cooperation outside	Cooperation with partners outside the company	Binary
IN_COOP (12)	Cooperation inside	Cooperation with partners inside the company	Binary
UNI_COOP (13)	Cooperation university	Cooperation with university	Binary
INST_COOP (14)	Cooperation research institutes	Cooperation with research institutes	Binary
PUB_COOP (15)	Cooperation public sector institutes	Cooperation with public sector institutes	Binary
ORG_COOP (16)	Cooperation organizations	Cooperation with organizations	Binary

Regarding technological regimes, companies were divided into four categories according to technological intensities, according to Boliciano and Planta [36] (p.157). Firm size is categorized as small, medium, and large, according to the methodology of the European Commission and the European Innovation Scoreboard [37]. Human Capital is measured by the percentage of people with higher education which is identified through intensities. Regarding innovation, it was divided into six categories: product innovation, service innovation, process innovation, organizational innovation, general innovation, and open innovation. General innovation results from the realization of at least one of the innovations at the product, service, process, and organizational level. Just as open innovation results in the combination of intramural innovation and extramural innovation. All these dimensions are evaluated as binary variables. In this way, we can identify the types of innovation that the company practices and whether openness and knowledge is sharing with the outside world. Obtaining knowledge was also evaluated as a binary variable and characterizes whether the company seeks to obtain knowledge or not. The cooperation and innovation partners are characterized by the different agents that, through knowledge sharing, cooperate with the firms and are evaluated as binary variables.

6.6. Exploratory Analysis

To provide a better explanation, the following table shows the combination of variables. The variables highlighted in this analysis are open innovation, human capital, and innovation ecosystems.

The behavior of the three variables should be studied together since they are dependent. Open innovation is considered to consist of the simultaneous conduct of research and development activities, inside and outside the company. The combinations of open innovation strategies with human capital increase the capacity to share knowledge. Innovation results from human capital and commitment to individual capabilities that create and strengthen the firm's innovative culture and improve its organizational performance. Thus, this results in the intensity of human capital and ways of obtaining knowledge. The innovation ecosystem is the sharing of information between different actors.

The aim of table 7 is to understand initially how firms with higher human capital intensity perform innovation (intramural or extramural), whether they perform open innovation (intramural simultaneously with extramural), whether they perform product, process, service, and organizational innovation and whether they consume from the community and obtain knowledge. In this way, human capital can be assessed. Next, the aim is to understand, taking into account the size of the company, how many of them perform innovation, open innovation, process, and product innovation, and whether they consume from the community. Thus, it is intended to identify whether the size of the company influences open innovation. Finally, we intend to evaluate the ecosystems of innovation, and which are the partners that cooperate with companies in innovation. To this end, initially, we seek to understand whether companies that perform open innovation and extramural innovation obtain knowledge and then, of these companies how many cooperate with companies outside and within their group of companies, whether they cooperate with universities or other higher education institutions, institutes of public intervention, public sector customers and non-profit organizations.

Table 7. Summary of the exploratory analysis.

EMPUD		Firms performing open innovation		Firms performing innovation		Firms performing product innovation		Firms performing service innovation		Firms performing process innovation		Firms performing organizational innovation		Knowledge gathering	
	N	N	%	N	%	N	%	N	%	N	%	N	%	N	%
0%	2013	8	0,4	295	14,7	173	8,6	145	7,2	183	9,1	216	10,7	793	39,4
>=1% a <5%	3923	61	1,6	1143	29,1	700	17,8	580	14,8	787	20,1	903	23,0	2552	65,1
>=5% a <10%	1757	78	4,4	687	39,1	430	24,5	362	20,6	498	28,3	565	32,2	1354	77,1
>=10% a <25%	2207	163	7,4	1011	45,8	677	30,7	527	23,9	714	32,4	816	37,0	1826	82,7
>=25% a <50%	1463	111	7,6	648	44,3	385	26,3	383	26,2	447	30,6	555	37,9	1200	82,0
>=50% a <75%	1141	79	6,9	511	44,8	261	22,9	367	32,2	337	29,5	434	38,0	948	83,1
>=75% a 100%	1197	115	9,6	595	49,7	285	23,8	447	37,3	377	31,5	507	42,4	1032	86,2
Total	13701	615	-	4890	-	2911	-	2811	-	3343	-	3996	-	9705	-

Size of company		Firms performing open innovation		Firms performing innovation		Firms performing product innovation		Firms performing service innovation		Firms performing process innovation		Firms performing organizational innovation		Knowledge gathering	
	N	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Small	9451	202	2,1	2889	30,6	1683	17,8	1671	17,7	1922	20,3	2343	24,8	6286	66,5
Medium	3509	286	8,2	1591	45,3	950	27,0	892	25,4	1117	31,8	1300	37,0	2792	79,6
Large	741	127	17,1	410	55,3	278	37,5	248	33,5	304	41,0	353	47,6	627	84,6
Total	13701	615	-	4890	-	2911	-	2811	-	3343	-	3996	-	9705	-

Innovation ecosystems		Knowledge gathering		Companies outside its group of companies		Companies inside its group of companies		Universities or higher education institutions		Public intervention offices		Public sector clients		Non-profit organizations	
	N	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Open Innovation	615	600	97,6	350	56,9	196	31,9	255	41,5	133	21,6	51	8,3	84	13,7

External Innovation	863	821	95,1	856	99,2	444	51,4	500	57,9	237	27,5	139	16,1	188	21,8
Total	1478	1421	-	1206	-	640	-	755	-	370	-	190	-	272	-

Technological regime		Firms performing open innovation		Firms performing innovation		Firms performing product innovation		Firms performing service innovation		Firms performing process innovation		Firms performing organizational innovation		Knowledge gathering	
	N	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Suppliers dominated	7993	239	3,0	2683	33,6	1680	21,0	1478	18,5	1837	23,0	2179	27,3	5492	68,7
Scale intensive	2699	161	6,0	940	34,8	594	22,0	499	18,5	637	23,6	736	27,3	1874	69,4
Specialist supplier	2307	139	6,0	869	37,7	417	18,1	540	23,4	594	25,7	740	32,1	1731	75,0
Science-based	762	76	10,0	398	52,2	220	28,9	294	38,6	275	36,1	341	44,8	608	79,8
Total	13761	615	-	4890	-	2911	-	2811	-	3343	-	3996	-	9705	-

Based on the exploratory analysis, 9.6% of the companies that carry out open innovation have higher human capital intensity. Relative to the realization of innovation overall there is a greater number of companies in the maximum intensity of human capital. Human capital allows companies to seek more ways to innovate. The companies that have a greater intensity of human capital also present more innovation in services and at the organizational level, but at the level of product and process innovation, the intensity of human capital that stands out is >=10% to <25%. Regarding the size of companies, it can be seen that larger companies show a higher percentage in all levels of innovation and are also the companies that most seek to obtain knowledge.

In terms of innovation ecosystems, the partners that companies most seek to cooperate with are companies outside their corporate group and universities, both in open innovation and in companies that only practice extramural innovation.

In terms of technological regime, science-based companies are those that most practice innovation and the obtaining of knowledge.

Thus, it is verified that these results are in accordance with the literature review.

6.7. Descriptive Statistics

Table 8 provides descriptive statistics and correlations between the variables used in this study. This table aims to explain the link between the variables through the Pearson correlation.

When analyzing the table, it appears that there is a significant relationship between human capital and open innovation as there is a positive correlation, this means that human capital creates value to open innovation. The correlation between human capital and channels for obtaining knowledge is also significant, therefore human capital positively influences obtaining knowledge. On the other hand, human capital positively influences innovation ecosystems and has significant value with respect to cooperation partners.

Finally, it appears that human capital becomes beneficial in open innovation as well as in obtaining knowledge, which allows the better functioning of innovation ecosystems.

Table 8. Descriptive statistics and correlation.

	MIN	MAX	MEAN	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
REG_TECH (1)	1	4	1,7	0,938	1																		
SIZE (2)	1	3	1,36	0,583	,016*	1																	
EMPUD (3)	0	6	2,39	1,859	,372**	,156**	1																
OPEN_INNOV (4)	0	1	0,04	0,207	,089**	,191**	,145**	1															
IN_INNOV (5)	0	1	0,32	0,467	,075**	,164**	,199**	,262**	1														
OUT_INNOV (6)	0	1	0,30	0,459	,068**	,160**	,212**	,274**	,790**	1													
GEN_INNOV (7)	0	1	0,36	0,479	,072**	,165**	,210**	,265**	,923**	,884**	1												
PROD_INNOV (8)	0	1	0,21	0,409	0,01	,136**	,113**	,265**	,609**	,789**	,697**	1											
SERV_INNOV (9)	0	1	0,21	0,404	,095**	,113**	,214**	,228**	,622**	,772**	,682**	,633**	1										
PROC_INNOV (10)	0	1	0,24	0,430	,056**	,148**	,152**	,244**	,826**	,715**	,763**	,584**	,582**	1									
ORG_INNOV (11)	0	1	0,29	0,455	,075**	,152**	,203**	,246**	,933**	,737**	,861**	,559**	,594**	,735**	1								
CHANNELS (12)	0	6	2,31	2,098	,114**	,227**	,360**	,252**	,383**	,393**	,385**	,323**	,337**	,354**	,376**	1							
COOP_INNOV (13)	0	1	0,14	0,585	,120**	,198**	,213**	,414**	,334**	,340**	,330**	,291**	,288**	,322**	,313**	,319**	1						
OUT_COOP (14)	0	1	0,08	0,265	,106**	,178**	,192**	,403**	,318**	,324**	,311**	,280**	,285**	,309**	,302**	,301**	,895**	1					
IN_COOP (15)	0	1	0,04	0,197	,104**	,183**	,160**	,307**	,226**	,224**	,217**	,179**	,200**	,215**	,225**	,223**	,639**	,556**	1				
UNI_COOP (16)	0	1	0,05	0,208	,105**	,176**	,175**	,385**	,243**	,239**	,239**	,209**	,203**	,235**	,228**	,269**	,680**	,607**	,457**	1			
INST_COOP (17)	0	1	0,02	0,144	,095**	,134**	,131**	,294**	,169**	,165**	,166**	,144**	,154**	,163**	,161**	,205**	,459**	,447**	,367**	,599**	1		
PUB_COOP (18)	0	1	0,01	0,108	,074**	,069**	,099**	,143**	,133**	,132**	,126**	,102**	,150**	,127**	,136**	,148**	,341**	,351**	,335**	,375**	,453**	1	
ORG_COOP (19)	0	1	0,02	0,127	,067**	,102**	,122**	,204**	,147**	,149**	,143**	,109**	,147**	,144**	,143**	,156**	,404**	,382**	,326**	,465**	,499**	,495**	1

*. The correlation is clear at the 0.05 level (one-sided). **. The correlation is clear at the 0.01 (one-sided) level.

7. Econometric Analysis

7.1. Econometric analysis description

Regression models are an important tool in statistical data analysis when you want to model relationships between variables. Thus the main objective of the following table is to explore the explanatory variables (independent) and a response variable (dependent).

To answer the hypotheses created 6 Logit models were developed. Models 1, 2, 3, and 4 analyze the impact of the independent variables on the four types of innovation that can happen at the core of the company (product innovation, service innovation, process innovation, and organizational innovation). Model 5 analyzes the impact of the variables on internal innovation and Model 6 the impact of external innovation. To evaluate the impact on innovation in general we have Model 7. Model 8 analyzes the impact of the variables on open innovation and finally, Model 9 analyzes the impact on cooperation for innovation.

Table 9. Econometric Estimations.

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9
	PROD_INNOV	SERV_INNOV	PROC_INNOV	ORG_INNOV	IN_INNOV	OUT_INNOV	GEN_INNOV	OPEN_INNOV	COOP_INNOV
EMPUD	-0,009	0,132	0,010	0,078	0,060	0,087	0,077	0,102	0,023
SIZE	0,177	0,051	0,182	0,168	0,213	0,186	0,212	0,665	0,033
TECH_REG	-0,123	0,029	-0,012	-0,009	-0,001	-0,04	-0,019	0,103	0,055
CHANNELS	0,316	0,305	0,327	0,327	0,329	0,344	0,323	0,306	0,051
OUT_COOP	1,321	1,199	1,357	1,287	1,557	1,630	1,658	1,749	39,727
IN_COOP	0,071	0,222	0,346	0,656	0,602	0,473	0,592	0,317	39,316
UNI_COOP	0,273	-0,147	0,305	0,203	0,478	0,271	0,616	0,895	38,714
INST_COOP	-0,114	-0,289	-0,269	-0,305	-0,217	-0,399	-0,119	0,226	41,654
PUB_COOP	-0,121	0,725	-0,025	0,479	0,219	0,139	0,015	-0,835	48,946
ORG_COOP	-0,241	0,253	0,176	0,093	0,121	0,275	0,183	-0,045	38,679
CONSTANT	-2,340	-2,815	-2,431	-2,305	-2,190	-2,298	-1,995	-6,239	-21,162

7.2. Results and discussion

Model 1 shows that human capital, technological regime, cooperation with institutions, cooperation with the public sector, and cooperation with organizations negatively affect product innovation. The positive relationship between cooperation with firms outside the business environment and product innovation stands out. This relationship results from sharing information with non-direct competitors that brings benefits in negotiations, reducing marketing costs, conquering new markets, and exchanging services and information. The fact that they are not direct competitors brings more confidence to the company in the exchange of information and does not cause constraints in the fight for a place in the market.

In model 2 cooperation with companies outside the business environment also positively affects service innovation, however, unlike product innovation, human capital is also found to positively affect service innovation. This fact is due to the know-how and knowledge of individuals in previous experiences, the same happens with models 3 and 4 in process innovation and organizational innovation that end up being related to experiences previously experienced by individuals.

In model 3, channels, cooperation with companies outside the business environment, cooperation with universities, and cooperation with organizations positively affect process innovation. It becomes important to highlight, that contrary to what is observed in product and service innovation, cooperation with universities positively affects this variable. This positive relationship is because universities contribute significantly to the lack of technological and scientific knowledge presented by companies. Through the long-term research produced by universities and knowledge transfer, there are closer relations between science and industrial innovation.

In model 4, it is found that the technological regime and cooperation with research institutes negatively affect organizational innovation. The intensity of knowledge in companies or the lack of it determines the investment that the company can make and the development of human capital. Although cooperation between research institutes and universities is extremely important, in R&D activities, it is verified that there is little support from the state in funding them, thus there is a negative impact of this variable. The same is true for models 5, 6, and 7. The technological regime and cooperation with research institutes also negatively affect internal innovation, external innovation, and general innovation.

According to model 8, open innovation is negatively affected by cooperation with public sector institutes and organizations. However, firm size is relevant, cooperation with partners outside

the business context, and cooperation with universities.

About model 9, human capital, firm size, technological regime, and channels for obtaining knowledge positively affect cooperation for innovation, however, what stands out are firm size and channels for obtaining knowledge.

In summary, it can be seen that cooperation with partners outside the business context positively affects all variables, and cooperation with research institutes negatively affects all forms of innovation except open innovation. Human capital is only negatively affected in product innovation and is more relevant in service innovation, open innovation, and cooperation for innovation.

Through this analysis it can be stated that human capital has a positive impact on open innovation, thus confirming hypothesis 1. In the same way, it is verified that open innovation creates a competitive advantage for the company through cooperation channels, thus confirming hypothesis 2.

7.3. Moderation e Mediation

The moderation effect consists of a variable that affects the direction or intensity of the relationship between an independent and a dependent variable. In this way, moderation corresponds to individual differences or situational conditions that alter the initial relationship between the variables. The moderating effect has a positive relationship between the variables [31]. Mediation analysis is a statistical method used to answer questions about how the independent variable affects the dependent variable. The mechanism that influences the different variables is considered. This mechanism could be an emotional, cognitive or other phenomenon [32].

In the present study, a diagram with three variables can be drawn: open innovation, human capital, and innovation ecosystems. According to the research and application to the present study, open innovation is a predictor, human capital is a moderator, and innovation ecosystems are the result. These variables are causally related because changing one of these variables does not imply changing the other.

Thus, it appears that there is a simple mediation model that is related to open innovation, human capital (the mediator), and innovation ecosystems. Figure 6 shows how the framework works.

This model is proven when variations in independent variables are significant. In this case, human capital is significant for open innovation.

Figure 10. Moderator Structure.

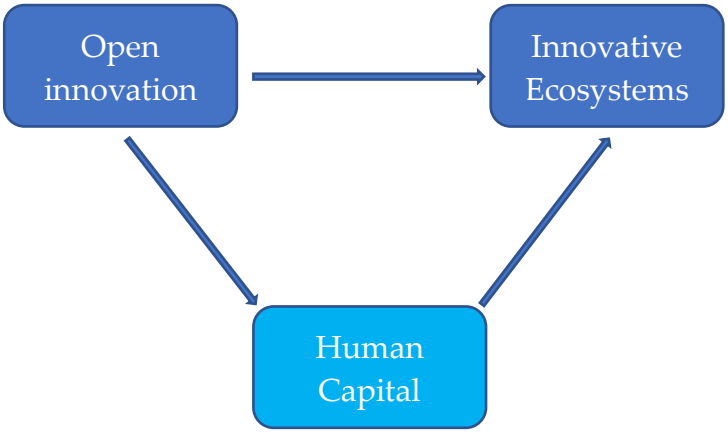

Figure 11. Mediator Structure.

Knowledge is a valuable asset and must serve to create wealth. It can be seen that an employee's preparation is directly related to the ability to improve their productivity and action in the company [33]. For a company to be competitive in the market and to innovate openly, using HC is an asset for this evolution. The fact that employees have knowledge drives OI and thus the sharing of knowledge in innovation ecosystems.

There is a positive relationship between a company's diversity of knowledge and its ability to innovate, with the diversity of employees having a positive effect on innovation. The diversity of a company's HC creates room for a broader search and capacity for the company to become creative and open to new ideas.

The practice of innovation implies more knowledge and training. In this way, the diversity of HC allows companies to have a greater capacity to respond to new challenges.

Table 10. Mediator Model Effects.

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5	MODEL 6	MODEL 7	MODEL 8	MODEL 9
	PROD_INNOV	SERV_INNOV	PROC_INNOV	ORG_INNOV	IN_INNOV	OUT_INNOV	GEN_INNOV	OPEN_INNOV	COOP_INNOV
SIZE*EMPUD	0,062	0,133	0,083	0,110	0,104	0,114	0,109	0,167	0,182
TECH_REG*EMPUD	0,121	0,200	0,138	0,176	0,168	0,186	0,177	0,236	0,257
CHANNELS*EMPUD	0,000	0,052	0,014	0,000	0,030	0,036	0,034	0,064	0,079
OUT_COOP*EMPUD	0,116	0,313	0,174	0,257	0,241	0,266	0,256	0,301	0,236
IN_COOP*EMPUD	0,175	0,381	0,233	0,316	0,301	0,330	0,317	0,424	0,424
UNI_COOP*EMPUD	0,167	0,390	0,231	0,321	0,302	0,333	0,318	0,389	0,478
INST_COOP*EMPUD	0,213	0,442	0,281	0,373	0,355	0,388	0,371	0,503	0,576
PUB_COOP*EMPUD	0,230	0,454	0,298	0,387	0,372	0,403	0,388	0,565	0,611
ORG_COOP*EMPUD	0,234	0,468	0,302	0,398	0,380	0,412	0,396	0,560	0,613
CONSTANT	-1,811	-2,238	-1,758	-1,644	-1,487	-1,618	-1,326	-4,515	-3,464

7.3.1. Mediator model effects

The number of samples was 13701 and the confidence interval used was 95%. The results of the test are presented in table 10.

It can be seen that human capital is an excellent mediator/influencer concerning different innovations in all types of cooperation. One can highlight the impact created by open innovation and innovation cooperation. As Ostrovska et al. [19] state *"In accordance with the rules for the formation of an open innovation system, the management of innovative development is based on such principles as (...) susceptibility to innovations of society, science, state, and business;*" (p.4). the authors also reinforce that the use of the open innovation interaction model allows for creating and maintaining sustainable channels of innovation inclusion which will contribute to the use of windows of technological opportunities to accelerate innovation.

According to table 10, we can verify that human capital is a good mediator for open innovation thus verifying hypothesis 3. Nevertheless, companies that practice open innovation and use human capital connect to the system thus confirming hypothesis 4.

8. Concluding Remarks

Knowledge sharing has a positive effect on human capital because the greater the knowledge sharing, the more likely it is to accumulate intellectual capital and human capital has a positive effect on knowledge sharing. After all, it is a quick process that brings benefits to firms. In addition, companies that have employees who are rich in skills and experience are more likely to share knowledge. Knowledge-based services change the economy [19]. According to the rules of formation of an open innovation system, the management of innovative development is based on principles such as a trilateral cooperation system between science companies and the state [20]. Despite presenting some risks, companies show to use knowledge sharing and cooperation between different means of cooperation. Open innovation provides faster development and implementation of innovations to create more competitive advantages.

The objective of this research was to understand the role of human capital in open innovation and the mediating effect in innovation ecosystems. In this way, we proceeded to understand them and cross-reference them.

For this development, econometric models from the CIS database were implemented. Initially, it was found that cooperation with firms outside the business environment was relevant for the different types of innovation, most notably open innovation. Another data that became relevant was the cooperation with universities, where open innovation can be highlighted. The cooperation

of the public sector and organizations in open innovation stands out negatively. This result is because public sector aids are extremely specific and sometimes it is such a bureaucratic system that does not facilitate the movement of information. The fact that the state does not have a clear policy and also lacks the political will to implement what is already prepared is one of the main problems regarding open innovation [29]. Authors Zouaghi et al. [4] add that the public sector is ill-equipped to weather the crisis due to cuts in public R&D budgets.

When we confronted human capital as a mediator in the different models we found that the effect of the variables became positive. Thus the empirical results prove that human capital is essential in open innovation, aligning with the literature that tells us that human capital influences the ability to combine internal and external knowledge for innovation [2]. When knowledge sharing through human capital was coupled with cooperation between different agents it was found that cooperation with different partners in these circumstances has a positive impact on the performance of firms because it is found that there is a positive value in the different types of innovation. According to the literature studied cooperation and knowledge exchange contributes to the creation of a favorable atmosphere in the input and output activities [7] thus promoting innovation ecosystems.

Finally, the overall conclusions of this paper argue that human capital influences open innovation by playing crucial roles in the development of firms and also becomes essential in the development of innovation ecosystems.

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Appendix

Appendix A

Authors	Article	Journal	Objective

Carmona-Lavado et al. [1]	Does open innovation always work? The role of complementary assets	Technological Forecasting and Social Change	Identify OI settings, and analyze which settings are associated with high and low OI performance.
Chabbouh & Boujelbene, [2]	Open innovation in SMEs: The mediating role between human capital and firm performance	Journal of High Technology Management Research	Understanding the performance of SMEs combined two approaches: resources and open innovation.
Kim & Choi [12]	The intensity of organizational change and the perception of organizational innovativeness; with discussion on open innovation	Journal of Open Innovation: Technology, Market, and Complexity	Verify how investment in individual DHR relates to employees' perceptions of organizational innovation and employees' perceptions of organizational innovation through multi-level analysis using linear hierarchical models.
Barrena-Martínez et al. [3]	Joint forces: Towards an integration of intellectual capital theory and the open innovation paradigm	Journal of Business Research	Provide a theoretical model that synoptically presents how intellectual capital overlaps with IO and test the theoretical model by analyzing how companies' CI affects performance related to IO.
Madrid-Guijarro et al. [7]	Capacity of open innovation activities in fostering product and process innovation in manufacturing SMEs	Review of Managerial Science	Study whether open innovation practices in SMEs favor technological innovations and their drivers.
Matricano et al. [13]	Investigating the link between intellectual capital and open innovation processes: a longitudinal case study	Journal of Intellectual Capital	Research on the relationship between Intellectual Capital and OI.
Jang [5]	Entreprenurial Human Capital and Inward Technology Licensing in the Context of New Technology-Based Firms	International Journal of Innovation and Technology Management	Investigation on the utilization rate of ITL (Internal Technology Licensing), mainly in the use of HC.
Rostoka, Locovs, & Gaile-Sarkane [29]	Open innovation of new emerging small economies based on university-construction industry cooperation	Journal of Open Innovation: Technology, Market, and Complexity	Analyze the existing cooperation between universities and the construction industry and investigate what is the most effective model of long-term cooperation between the

			university and the private construction sector.
Marullo, Casprini, Di Minin, & Piccaluga [23]	'Ready for Take-off': How Open Innovation influences startup success	Creativity and Innovation Management	Identify the success of a new company based on identifying different factors in the pre-startup phase.
Greul, West, & Bock [27]	Open at birth? Why new firms do (or not) use open innovation	Polymer Engeneering and Science	Research on the nature and antecedents of knowledge flows in the creation of new companies and the interdependence of incoming and outgoing knowledge flows.
Zouaghi et al. [4]	Did the global financial crisis impact firms' innovation performance? The role of internal and external knowledge capabilities in high- and low-tech industries	Technological Forecasting and Social Change	Assess the role played by internal innovation and the effect of active external knowledge resources as dynamic capabilities to overcome adverse economic conditions.
Zhang et al. [14]	Open innovation and firm performance: Evidence from the Chinese mechanical manufacturing industry	Journal of Engineering and Technology Management - JET-M	Understand how human capital affects the relationship between open innovation and companies' financial performance.
Bogers et al. [15]	The "human side" of open innovation: The role of employee diversity in firm-level openness	Research Policy	Understand what the characteristics of innovation are associated with employees that add greater openness to the company.
Garcia Martinez, Zouaghi, & Sanchez Garcia [26]	Capturing value from alliance portfolio diversity: The mediating role of R&D human capital in high and low tech industries	Technovation	It examines the value of alliance portfolio diversity and whether R&D human capital is the way in which alliance portfolio diversity influences newness of innovation.
Koprivsek [22]	Regional policy in the eastern Slovenia cohesion region-innovative open technologies (smart specialization)	Podravina	Develop an innovative ecosystem that will create a symbiosis between the university, the economy and local communities through innovations and open technologies and the creation of knowledge for new professions.
Ettlinger [21]	The governance of crowdsourcing: Rationalities of the new exploitation	Environment and Planning A	Contextualization of corporate crowdsourcing in a specific work regime and examines

			rationales that govern this exploration.
Bianchi & Lejarraga [35]	Learning to license technology: the role of experience and workforce's skills in Spanish manufacturing firms	R and D Management	Explore the role of task-specific experience and workforce skills as determinants of higher education volume.
Alexy et al. [6]	Toward an aspiration-level theory of open innovation	Industrial and Corporate Change	Behavioral theory on open innovation.
Lenart-Gansiniec [15]	Relational capital and open innovation - In search of interdepencies	Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis	Discover the interdependencies between relational capital and open innovation.
Madina & Mansurova [34]	Influence of the international academic and labor mobility on the activity of open innovations	International Journal of Environmental and Science Education	Provide a scientific analysis of the reasons and assumptions for the increased activity of migratory flows of human resources and the influence of these processes on the superiority of innovation in countries that initiate open innovations.
Michelino et al. [25]	Measurement of open innovation through intellectual capital flows: Framework and application	International Journal of Intelligent Enterprise	Suggest a methodology to measure the degree of openness of companies through accounting data and provide a relationship between open innovation activities and components of intellectual capital.
Kondev, Tenchev, & Vasileva [28]	An open innovation model in the context of improving the competitiveness of the chemical and metallurgical industries	Journal of Chemical Technology and Metallurgy	Test an innovative model of open innovation in the metallurgical industry.
Podmetina et al. [16]	Human resource practices and open innovation	International Journal of Innovation Management	Understanding the role of HR in open innovation, analyzing HR practices in companies operating under the open innovation approach.
Sartori et al. [17]	The relationships between innovation and human and psychological	Innovation Journal	Overview of the concept of innovation and its relationship

	capital in organizations: A review		with human and psychological capital.
Spithoven [8]	Open innovation practices and innovative performances: An international comparative perspective	International Journal of Technology Management	Analysis of differences between R&D intensity and product innovation sales.
González-Sánchez & García-Muiña [24]	Open innovation: a preliminary model from knowledge management	Revista Venezolana de Gerencia	Construction of the integrated model in key success factors in innovation processes.
Simiyu, Masum, Chakma, & Singer [33]	Turning science into health solutions: KEMRIs challenges as Kenyas health product pathfinder	BMC International Health and Human Rights	Understand which institutional and external factors promote the development of new products in a public research institute.
Ostrovska, Tsikh, Strutynska, Kinash, Pietukhova, Golovnya & Shehynska [19]	Building an Effective Model of Intelligent Entrepreneurship Development in Digital Economy	Eastern-European Journal of Enterprise Technologies	Building a model for the development of smart entrepreneurship in the digital economy to achieve the economic, social, managerial, capitalization, and image efficiency of entrepreneurship and the predominance of the role of the human being in the modern economy as an intelligent factor of economic growth.
Zhang, Wang & Chun [20]	The Effect of Knowledge Sharing on Ambidextrous Innovation: Triadic Intellectual Capital as a Mediator	Journal of Open Innovation: Technology, Market, and Complexity	Explores the relationship between knowledge sharing and the open innovation paradigma.

Appendix B

Source Title	Quartile/ H-index	Number of published articles
Technological Forecasting and Social Change	Q1/103	2
Journal of Open Innovation: Technology, Market, and Complexity	Q1/20	2
Journal of High Technology Management Research	Q2/43	1
Journal of Business Research	Q1/179	1
Review of Managerial Science	Q1/20	1
Journal of Intellectual Capital	Q1/80	1

International Journal of Innovation and Technology Management	Q3/17	1
International Journal of Innovative Technology and Exploring Engineering	Q4/40	1
Creativity and Innovation Management	Q1/55	1
Strategic Entrepreneurship Journal	Q1/38	1
Journal of Engineering and Technology Management - JET-M	Q1/62	1
Research Policy	Q1/224	1
Technovation	Q1/121	1
Podravina	Q4/5	1
Environment and Planning A	Q1/121	1
R and D Management	Q1/99	1
Industrial and Corporate Change	Q1/104	1
Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis	Q3/15	1
International Journal of Environmental and Science Education	Q2/22	1
International Journal of Intelligent Enterprise	Q3/6	1
Journal of Chemical Technology and Metallurgy	Q3/17	1
International Journal of Innovation Management	Q2/39	1
Innovation Journal	Q3/15	1
International Journal of Technology Management	Q1/54	1
Revista Venezolana de Gerencia	Q3/8	1
BMC International Health and Human Rights	Q1/37	1