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Strategic Knowledge Transfer Model Based on Intellectual Property Market Analysis to Strengthen Business Innovation Portfolios

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Abstract

The effective transfer of knowledge has become a critical necessity for emerging economies. In Colombia, despite advances in research, many companies lack clear strategies for leveraging intellectual property (IP) as a strategic asset. This article presents a proposed knowledge transfer model based on an analysis of the intellectual property market, with an emphasis on Artificial Intelligence (AI), aimed at strengthening corporate innovation portfolios. Using a mixed-methods approach with document analysis, semi-structured interviews, data mining, and technology monitoring, 288 patents registered between 2015 and 2025 by leading Colombian companies were evaluated. The results reveal a concentration in sectors such as energy and manufacturing, limited academia-industry collaboration, and gaps in intangible asset management. The proposed model allows for the identification of strategic transfer pathways, the creation of university-industry links, and the development of institutional policies to revitalize the regional innovation ecosystem.

Introduction

Intellectual property (IP) has become a strategic mechanism for knowledge transfer and value creation in productive environments (Barney, 1991; Guzmán, 2019). However, in Colombia, a significant gap persists between academic output and its appropriation by the business sector. In this context, the Universidad Autónoma del Caribe positions itself as a strategic actor in the valorization of IP, not only as an educational institution but also as an agent for bridging the gap between knowledge and the market. In emerging economies, innovation and the strategic use of intellectual property are key factors for competitive development (WIPO, 2021; OECD, 2020). In this regard, this article proposes a strategic knowledge transfer model based on the analysis of patents from leading Colombian companies and their relationship to institutional research capabilities. The model seeks to identify technological opportunities, align academic capabilities with the demands of the productive environment, and define efficient transfer pathways. Several studies have shown that patenting dynamics and the management of intellectual property directly influence the levels of business innovation in Colombia (Campi et al., 2020). This proposal is particularly relevant in emerging sectors such as Artificial Intelligence, where the lack of structured strategies limits the consolidation of sustainable innovation ecosystems.

Methods

Study design

This research was developed using a mixed-methods, descriptive-analytical approach, which allowed for addressing both technical aspects (such as technology monitoring and patent analysis) and strategic aspects (university-industry collaboration and model design). The methodology was structured in five phases (Figure 1).

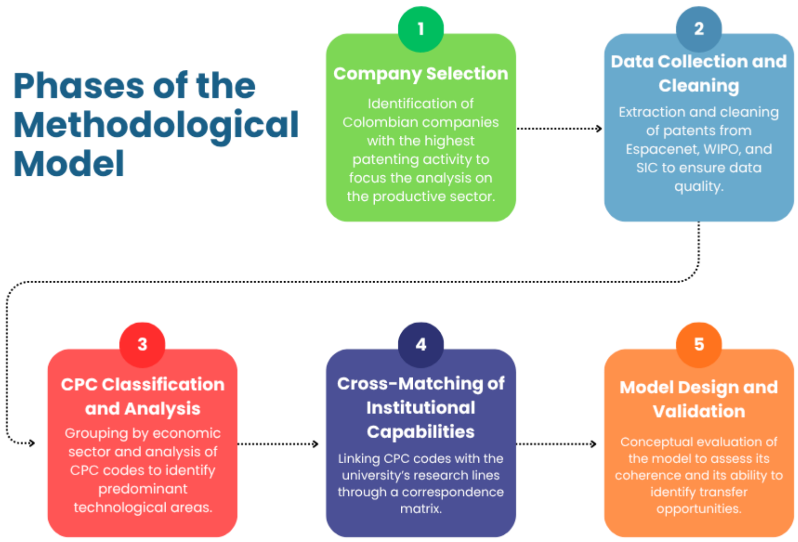

Figure 1. Phases of the Proposed Methodological Model.

1. Identification of leading IP companies: The 20 Colombian companies with the highest number of patents registered between 2015 and 2025 were selected, excluding individuals and universities, to focus the analysis on the productive sector. This exclusion reflects the need to analyze innovation dynamics at the organizational level, where intellectual property management is linked to business strategies. In this sense, universities are considered primarily knowledge generators, while individuals do not always reflect structured technology transfer processes.

2. Data collection and cleaning: 288 active patents were extracted from Espacenet, WIPO, and SIC. The records were filtered to eliminate duplicates or inconsistencies, ensuring a reliable dataset.

3. Sectoral Classification and CPC Analysis: Patents were grouped by economic sector (energy, manufacturing, biotechnology, among others), and CPC codes were analyzed to identify predominant technological areas.

4. Cross-referencing with Institutional Capabilities: A matrix was developed linking CPC codes with the research lines of the academic groups at the Universidad Autónoma del Caribe to identify transfer opportunities. The Cooperative Patent Classification (CPC) enables the identification of technological trends, market niches, and innovation opportunities through the systematic analysis of patents (WIPO, 2021).

5. Model Design and Validation: Model validation was approached from a conceptual perspective, applying the model to the results obtained from the patent analysis and the identification of technology transfer opportunities. This exercise allowed for the evaluation of the model's internal consistency and its capacity to integrate information from different sources, such as CPC codes and institutional capabilities. In this sense, the evaluation focused on analyzing the viability of the model for identifying opportunities to connect academic knowledge with the needs of the productive sector, rather than on measuring quantitative results. However, the lack of empirical validation in real-world settings is recognized as a limitation, which opens the possibility of future studies aimed at piloting the model and measuring its impact in specific contexts.

Instruments and Sources

Several specialized databases were used for data collection, including Espacenet, WIPO, SIC Colombia, and Scopus. These platforms provide access to national and international patent records, as well as scientific publications related to intellectual property.

To ensure the quality of the analysis, exclusion criteria were applied, consisting of eliminating duplicates, patents registered in the name of individuals, and records without recent activity, thus focusing the study on current and relevant information.

In addition, semi-structured interviews were conducted with researchers, entrepreneurs, innovation officials, and intellectual property managers, providing a qualitative perspective that complements the data analysis. Eight semi-structured interviews were conducted with key actors in the innovation ecosystem in Colombia, including university researchers (3), entrepreneurs in the technology sector (2), intellectual property managers (2), and one official involved in technology transfer processes. Participants were selected using purposive sampling, prioritizing profiles with experience in innovation management and the strategic use of intellectual property. The interview protocol was structured around three thematic axes: (i) barriers to knowledge transfer, (ii) perception and use of intellectual property in the productive sector, and (iii) opportunities for university-industry collaboration.

The interviews were analyzed using a thematic analysis approach, identifying recurring patterns and emerging categories. The results were subsequently triangulated with quantitative patent analysis, which strengthened the interpretation of the identified gaps and provided input for the design of the proposed strategic model.

Tools such as Excel and Python were used for processing and analysis, facilitating the cleaning, organization, and visualization of the data. A matrix was also developed that cross-references CPC codes with university areas of specialization, allowing for the identification of technology transfer opportunities.

Results

Sectoral Distribution of Patenting Activity

Identifying strategic sectors with innovation potential in Colombia requires a thorough study of intellectual property activity. For this purpose, the period 2015-2025 was chosen, considering that patents typically have a validity period of 15 to 20 years, depending on current legislation.

This timeframe ensures that the identified technologies not only represent current trends but also maintain their relevance for medium- and long-term use. The temporal approach also aligns with the need to manage current information, in accordance with market trends and innovation strategies implemented in the past decade. This analysis provided a precise view of the innovation ecosystem in Colombia, based on the performance of leading companies and their technological sectors (Figure 2).

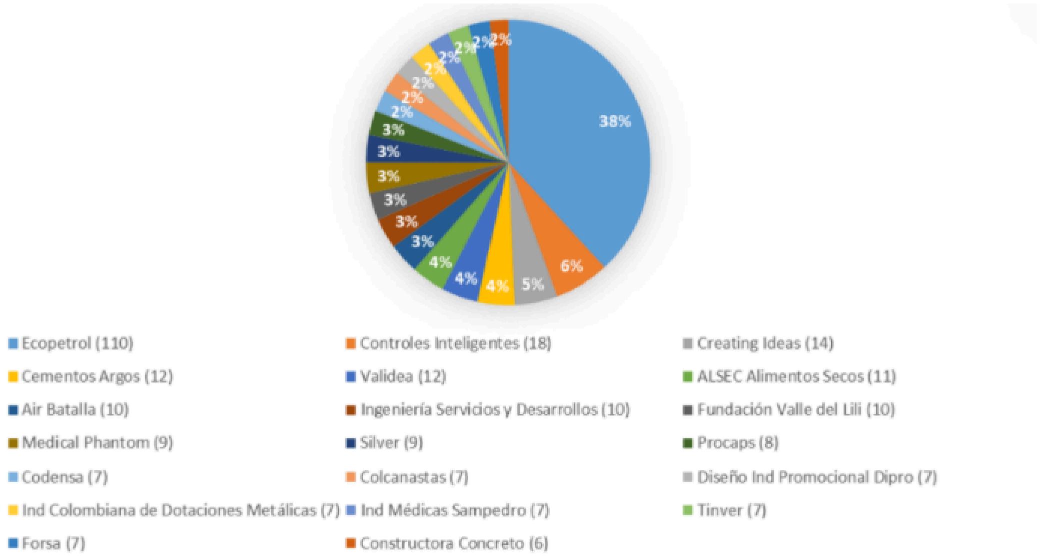

Figure 2. Diagram of the Top 20 Colombian Companies with the Highest Patent Registrations.

The analysis of the 288 patents showed a clear concentration in the energy sector (41%), led by Ecopetrol. Other significant sectors were advanced manufacturing (17%) and biotechnology (12%). Most of the innovative companies operate in Bogotá and Medellín, while the Caribbean region participates only marginally, despite its potential (Figure 3).

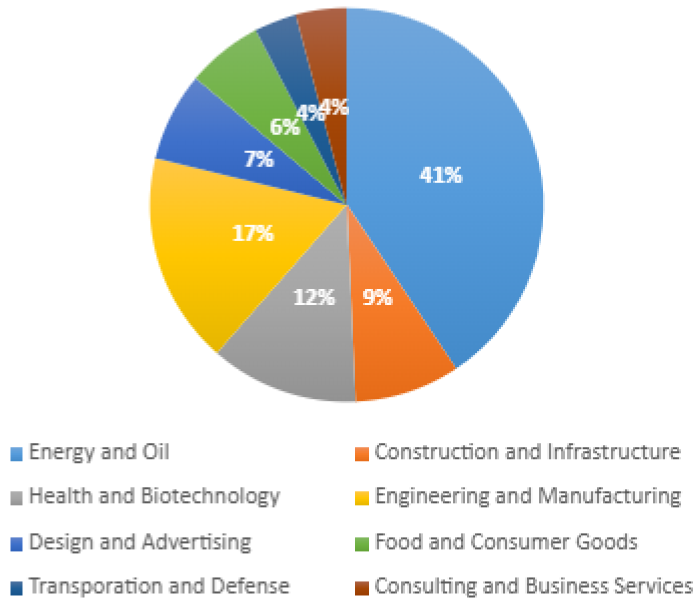

Figure 3. Distribution of patents by industrial sector in Colombia (2015–2025)

In order to analyze the territorial distribution of innovative activity, the geographical location of the companies included in the study was examined (Figure 4). This perspective allows for the identification of concentration patterns and potential regional imbalances in patent generation.

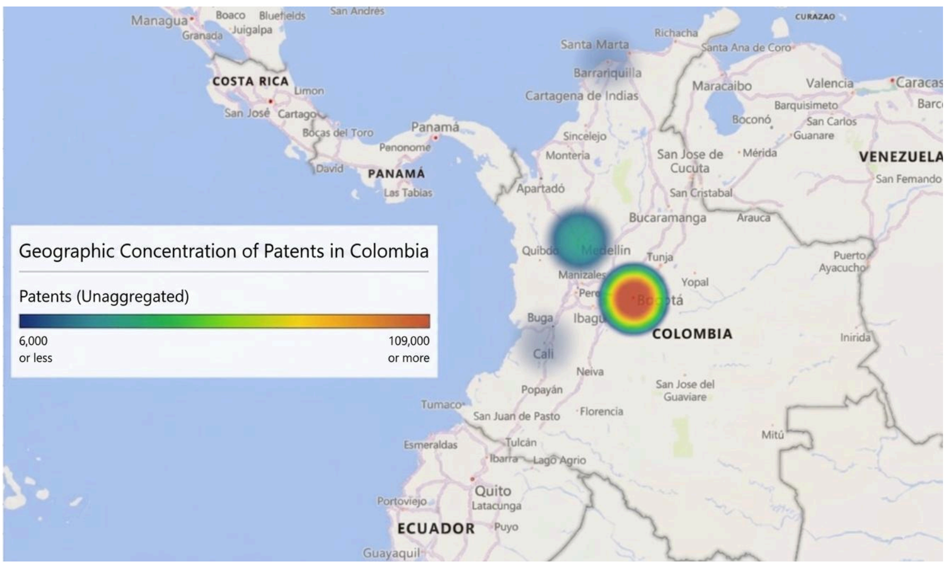

Figure 4. Geographic Heat Map of Patents in Colombia.

The map of geographic patent concentration in Colombia illustrates the distribution of innovation activities nationwide, clearly highlighting a high concentration in Bogotá. The high concentration of patents in Bogotá is due to the presence of numerous leading companies, such as Ecopetrol, in the region. Bogotá is consolidating its position as the nation's economic and technological hub, with infrastructure and access to resources that foster innovation. Medellín, historically recognized as the epicenter of innovation in Latin America, also exhibits a significant concentration, with companies like Controles Inteligentes and Cementos Argos standing out. Although Cali and Barranquilla have a lower density, they demonstrate their regional relevance in specific areas, such as engineering (Cali) and pharmaceuticals (Barranquilla, with Procaps) which is consistent with the patterns reported in national science, technology, and innovation indicators (Observatorio Colombiano de Ciencia y Tecnología, 2023) (Table 1).

In order to identify opportunities for technology transfer, a matrix was constructed cross-referencing the identified CPC codes with the university's research areas. This matrix allows for establishing relationships between emerging technological areas and institutional capabilities (Table 1).

Table 1. Linking Engineering Research Groups with Companies and Associated CPC Codes.

Linking Engineering Research Groups with Companies and Associated CPC Codes			
Group	**Related Companies**	**CPC**	**Description**
CEBI - UAC	Fundación Valle del Lili, Medical Phantom, Ind. Médicas Sampedro	A61B5/00, A61B5/02, A61B5/11	Medical diagnostic devices.
	Procaps, ALSEC Alimentos Secos	A61K9/00, A61K9/50, A61K9/51	Controlled drug delivery systems.
	Fundación Valle del Lili, Medical Phantom	A61M16/00, A61M16/20	Medical fluid administration devices.
	ALSEC Alimentos Secos, Procaps	C12P13/00, C12P7/64	Biotechnological processes (production of amino acids, lipids).
GIIM	Tinver, Ind. Colombiana de Dotaciones Metálicas	B25J13/00	Robotic tools.
	Controles Inteligentes, Air Batalla	G05B19/00	Automated control systems.
	Air Batalla, Ingeniería Servicios y Desarrollos	F16K31/508	Electric actuators for valves.
	Controles Inteligentes, Creating Ideas	G06K9/00	Data processing for computer vision.
GIIMA	Ecopetrol, Codensa, Constructora Concreto	Y02E50/10, Y02P20/584	Technologies for renewable energy and emission reduction.
	Ecopetrol, Constructora Concreto	C02F1/00, C02F1/40	Water treatment and purification.
	Ecopetrol	C10G1/00, C10G47/00	Sustainable hydrocarbon refining.
IET	Creating Ideas, Silver, Codensa	H04L12/00, H04Q1/00	Communication networks.
	Creating Ideas, Diseño Ind. Promocional Dipro	G02B6/00, G02B6/44	Optical fiber and connectors.
	Validea, Silver	G06F3/00, G06Q20/32	Electronic transaction systems.
IMTEF	Forsa, Ind. Médicas Sampedro	B22F3/00, B29B9/00	Manufacturing processes of polymers and metals.
	Cementos Argos, Constructora Concreto	C04B7/00, C04B28/08	Sustainable cements and additives.
	Forsa, Ind. Colombiana de Dotaciones Metálicas		Composite materials.
OPTIMA	Validea, Colcanastas, Ecopetrol	G06Q10/06, G06Q10/10	Operations management and planning.
	Validea, Silver	G06Q20/34, G06Q30/018	E-commerce and transactions.
	Ecopetrol, Constructora Concreto	Y02P30/20	Emission reduction in industrial processes.
SINT	Controles Inteligentes, Creating Ideas	G06N3/00, G06K9/62	Neural networks and pattern recognition.
	Silver, Tinver	G08G1/01, G08G1/123	Intelligent traffic systems.
	Silver, Diseño Ind. Promocional Dipro	H04M1/675	Biometric authentication.

To illustrate the structure of the cross matrix between the CPC codes of the patents and the research groups of the University, a representative case is presented corresponding to the Interdisciplinary Research Group of Basic Sciences (GIICB), characterized by its focus on fundamental research with applications in physical, chemical and biotechnological sciences.

Table 2. Cross-referencing between CPC codes, companies and the GIICB Research Group.

GIICB	Procaps, ALSEC Alimentos Secos	G01N27/00, G01N33/18	Chemical and electrochemical analysis.
	Ecopetrol, Procaps	B01J2/00, B01J23/00	Catalysts and chemical processes.
	Procaps, ALSEC Alimentos Secos	C07C67/56	Synthesis of organic compounds.

In the overall framework, the GIICB is linked to various companies and CPCs associated with developments in analytical chemistry, industrial processes, and biotechnology, particularly with companies such as Procaps, ALSEC Alimentos Secos, and Ecopetrol. Below are some representative examples of these relationships:

• G01N27/00 – G01N33/18
Partner Companies: Procaps, ALSEC Dry Foods
Application Area: Chemical and electrochemical analysis related to material characterization and quality control in industrial processes.

• B01J2/00 – B01J23/00
Partner Companies: Ecopetrol, Procaps
Application Area: Catalysts and chemical processes related to the optimization of industrial reactions and the development of refining and synthesis processes.

• C07C67/56
Partner Companies: Procaps, ALSEC Dry Foods
Application Area: Synthesis of organic compounds with applications in the formulation of chemical and pharmaceutical products.

Additionally, the GIICB is linked to higher-level CPC areas such as G21, C10 and C12, which reinforce its interdisciplinary character:

• G21 (Physics and Nuclear Engineering): potential applications in energy and advanced processes.
• C10 (Petroleum and Fuels Industry): development of refining and fuel transformation technologies.
• C12 (Biochemistry and Biotechnology): applications in industrial microbiology and biotechnological processes.

This example demonstrates how a single research group can be involved with multiple technological domains, reflecting the cross-cutting nature of research capabilities and their alignment with different industrial sectors.

Identified gaps

1. Technical Capabilities: Limited specialization in intellectual property (IP) is evident in the companies analyzed, reflected in the low diversification of cost-effectiveness criteria (CPCs) associated with their management. This is related to the concentration of 65% of patents in the energy and health sectors, suggesting a concentrated technological focus but with limited maturity in IP strategies.

2. Institutional Culture: A low valuation of intangible assets is identified, associated with barriers such as a lack of clear policies, corporate resistance to sharing data, and budgetary limitations, which weakens the strategic appropriation of intellectual property.

3. Weak University-Industry Links: The matrix reveals unsystematic relationships between CPCs and research groups. However, there is potential for collaboration, given that groups such as CEBI (health) and GIIMA (energy) have capabilities aligned with business demands, contrasting with the current low level of collaboration.

Additionally, the geographical inequality, where Bogotá and Medellín concentrate nearly 80% of patents, reinforces the need to strengthen coordination in regions such as the Caribbean.

Technological Opportunities in AI

The analysis of patents identified in the study revealed multiple opportunities for university-industry collaboration around artificial intelligence-based technologies. Among the main areas with potential for transfer and collaboration are the use of smart sensors, the automation of industrial and logistics processes, computer vision systems applied to sectors such as healthcare, manufacturing, and surveillance, and predictive analytics using machine learning and big data models.

These technological areas not only reflect current trends in business innovation but also significantly align with the capabilities declared by active research groups within the university. In particular, institutional research lines focused on the development of AI algorithms, signal processing, embedded systems, robotics, data analysis, and intelligent simulation were identified. This convergence represents a strategic opportunity to strengthen knowledge transfer, accelerate open innovation processes, and foster the creation of high-impact collaborative projects.

Limitations of the Study

The study has some methodological limitations. The selection of companies may introduce bias by focusing on organizations with higher patenting activity. Furthermore, the coverage of the Espacenet database may not be entirely exhaustive. The definition of active patents depends on the availability of public information, which may lead to variations in their classification. Finally, the mapping between CPCs and research groups involves a degree of interpretation, introducing some subjectivity into the analysis.

Proposed Strategic Model

The designed model seeks to facilitate the effective transfer of knowledge generated in the academic environment to the productive sector, with a focus on the valorization of intellectual property (IP). Its structure is based on four fundamental components that interact dynamically to identify, articulate, transfer, and evaluate technologies with high impact potential.

Sectoral Technology Monitoring

This component is based on the systematic use of the Cooperative Patent Classification (CPC) as a tool to track emerging technologies in key sectors of the Colombian economy. Through the analysis of patents and technical literature, priority areas are identified, such as Artificial Intelligence (AI), advanced manufacturing, and biotechnology, which have high technological potential and limited local adoption. Technology monitoring allows for anticipating trends, detecting untapped opportunities, and establishing research priorities with the greatest market impact.

Institutional Capacity Mapping

In this phase, the internal strengths of the Universidad Autónoma del Caribe are analyzed by characterizing its research groups in terms of scientific output, developed technologies, areas of expertise, and technology readiness level (TRL). This mapping facilitates strategic alignment between academic offerings and business demand, and serves as a basis for identifying technologies with the potential to be transferred or co-developed with companies.

Technology Transfer Pathways

With the identified technologies and capabilities, specific mechanisms are established for their transfer, such as:

- Technology licensing, which allows companies to exploit university inventions through regulated contracts.
- Creation of spin-offs and start-ups, based on research results with commercial applications.
- Technology collaboration agreements, which link joint R&D projects between the university and companies.
- Joint university-company ownership, applicable when both parties actively participate in the development of an invention.

These pathways are defined according to the nature of the knowledge, the level of technological maturity, and the strategic interests of the parties involved.

Evaluation and Impact

The model includes the definition of evaluation indicators to measure its effectiveness in terms of tangible results. Some of the suggested indicators are:

- Number of technologies transferred or licensed.
- Estimated economic value of the transfer.
- Percentage of projects co-financed by companies.
- Level of technological adoption achieved in the productive sector.

These can be measured using institutional records of technology transfer, licensing agreements, and financial reports of university-industry projects.

Discussion

The proposed strategic model is framed within the triple helix approach, where university, business, and government interact to energize the innovation ecosystem (Etzkowitz & Leydesdorff, 2000). From the perspective of the resource-based view, knowledge and intellectual property constitute strategic assets that can generate sustained competitive advantages (Barney, 1991). In the Caribbean region, this collaboration is limited by factors such as a weak intellectual property culture, a lack of technology transfer policies, and institutional weaknesses in knowledge management. The use of the CPC (Continuous Patent Cooperation) as an analytical tool allowed us to identify not only high-value technologies but also gaps in the alignment between research output and real market needs.

One of the most relevant findings was the identification of small companies, such as Creating Ideas, which, despite having limited human resources, register high productivity in terms of patents, with a total of 14 in the analyzed period (2015–2025). This result is particularly significant when compared to larger companies that exhibit similar or even lower levels of technological output.

This behavior suggests that innovative capacity does not depend exclusively on organizational scale, but rather on the implementation of strategies geared toward the active management of intellectual property. In this sense, these types of organizations represent a strategic niche for collaboration with universities, since their operational agility and innovative approach can complement the technical and scientific capabilities of the academic environment.

Likewise, this case demonstrates the potential of applying the proposed model in business contexts with flexible structures, facilitating transfer processes through mechanisms such as co-creation, licensing, or the joint development of technologies.

On the other hand, it was evident that many universities still operate under a paradigm of isolated knowledge, without clear transfer mechanisms or formal structures to market their developments. The designed model proposes to reverse this trend through a systematic strategy that begins with recognizing the value of university knowledge and its potential for productive application. Furthermore, this model is replicable in other academic institutions in the country, provided that a prior capacity assessment is conducted and the transfer pathways are adapted to the predominant economic sectors in each region.

Conclusions

The study shows that the strategic management of intellectual property remains a challenge for Colombian companies, especially in regions with less integration between innovation and the market. The use of the CPC classification, in conjunction with technology monitoring tools, allows for the identification of evidence-based transfer opportunities and guides decision-making in business contexts. The proposed model offers an applicable framework for aligning academic capabilities with the needs of the productive sector, facilitating effective knowledge transfer processes. In this context, its integration into institutional technology transfer policies and regional development strategies is recommended to strengthen the innovation ecosystem. This study provides a replicable methodological basis for strengthening university-industry collaboration in emerging economies. At a global level, although investment in innovation has shown slowdowns in some contexts, technological progress continues to advance, driven by the dynamics of knowledge and intellectual property (WIPO, 2024).

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