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Research Article

Factors Influencing the Knowledge and Technology Transfer in Higher Education Institutions in Developing Countries

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ABSTRACT

The advancement of knowledge and globalization is transforming the world. Higher education institutions (HEIs) have thus assumed a more active role through knowledge transfer (KT) and technology transfer (TT), not only in developed countries but also in emerging economies. This research analyzed the internal situation of Colombian HEIs, focusing on the management, administration, teaching and research subsystems, and how these interact with their environment to improve the effectiveness of KT and TT. The non-probabilistic sample included 258 participants from 59 public and private HEIs, who answered a 53-item questionnaire. A partial least squares structural equation modeling (PLS-SEM) is presented to analyze the relationships between six constructs: (i) leadership and governance (LG), (ii) organizational capacity, people and incentives (OCPI), (iii) institution and external relations (IER), (iv) knowledge and technology transfer impact (KTTI), (v) KT and (vi) TT. The findings reveal a limited development of KT and TT in the Republic of Colombia. This study empirically validated four hypotheses that relate constructs one to another: KT and LG (0.048), KT and OCPI (0.045), KT and IER (0.032) and TT and KTTI (0.035). Environmental pressures on HEIs may explain the direction of the causal relationships found in the study. This research contributes to the discussion on the role of HEIs in emerging economies and the importance of adapting the KT and TT models to the specific conditions of each territory, facilitating the economic and social development of developing countries.

Keywords: Universities, knowledge transfer; innovation; technology transfer; research results; PLS-SEM.

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1. INTRODUCTION

Globalization, the knowledge economy and global crises have generated strong competitive pressure on companies and society. This situation has led higher education institutions (HEIs) to strengthen their contribution to companies, public entities and civil society organizations. Their impact therefore goes beyond the training of professionals and the generation of new knowledge. They become an external source of scientific knowledge and technologies, positioning themselves as a key player for socioeconomic development and assuming an active role in the open innovation processes of companies and organizations in general (Bai et al., 2020; Marrocu et al., 2022).

The knowledge society pressures HEIs to ensure their research and knowledge transfer align with societal and business needs (Matthews, 2022). Leveraging university research results for social and economic development is a topic of discussion among academics and public decision-makers in highly developed countries. The situation differs in developing countries, where this issue is not a national priority nor a focus for most HEIs (Ramzi et al., 2022). Likewise, in scientific literature, the knowledge and technology transfer from HEIs has been widely analyzed in developed countries, but little studied in the context of emerging countries (Huian et al., 2023).

In line with the above, bibliometrics was used to obtain an overview of scientific production in KT and TT in HEIs (Bastos et al., 2021). The Scopus indexed reference database was used, reviewing data from abstracts and citations of peer-reviewed multidisciplinary scientific literature. A search equation was then built with thesauri that included KT and TT. It was delimited by areas of knowledge: “Business, Management and Accounting”, “Social Sciences”, “Economics, Econometrics and Finance” and “Multidisciplinary”; Document type: “Article”, “Conference paper” and “Review”. The main findings of the bibliometrics are: (i) the first publication on the object of study was in 1971: an increasing trend was evident from 2000 to date, with a small variation in 2020 explained by the Covid-19 pandemic; and (ii) within the countries with the highest scientific production, the following are identified: United States (889), United Kingdom (617), Germany and Italy (308 each), Spain (303) and China (240).

At the Latin American level, the following were found: Brazil (137), Mexico (68), Colombia (64), Peru (21), Chile (16) and Argentina (13). From the perspective of scientific production, few developments were observed at the Latin American level (emerging countries) in relation to KT and TT from HEIs.

In light of this, a research gap was identified that was addressed by answering the following questions: Does LG in HEIs impact the KT and TT activities? Does OCPI in HEIs affect KT and TT activities? Does IER have an impact on KT and TT associated with research results? And does KTTI assessment in HEIs affect KT and TT associated with research outcomes?

This research aims to investigate the internal management, administration, teaching, and research practices of Colombian HEIs, and to propose a theoretical model that can contribute to the improvement of KT and TT activities related to research outcomes in emerging countries.

The article presents the study's theoretical framework, hypotheses, methodology, and findings. Subsequently, it addresses the discussion, the conclusions, and finally, the limitations along with the possible future lines of research.

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1.1. The third mission in HEIs

The “third mission” of HEIs emphasizes their social and economic role through links with external organizations, complementing their traditional roles of teaching and research (Liu & van der Sijde, 2021; Pereira & Franco, 2022).

According to Meetei et al. (2024), the third mission emerged in response to increasing expectations for HEIs to contribute to innovation and regional development. The concepts of entrepreneurial HEI, civic HEI and engaged HEI, as well as the triple helix model have been used to describe this mission of HEIs.

The vision of HEIs' role in society and the market continues to be a subject of academic discussion, with the specific role of each institution influenced by its unique configuration of activities, human resources, financial resources, territorial context, and local, regional, national, and international institutional frameworks (Leon-Roa et al., 2024; Ramzi et al., 2022).

As such, it is stressed that missions do not exist in isolation, but that the activities that implement them are built and adapted with a systemic vision, in response to the changing environment surrounding the HEIs. It is therefore stated that the missions are dynamic and fluid (Etzkowitz, 2011; Sánchez-Barrioluengo, 2014).

1.2. Subsystems in HEIs related to KT and TT

From an organizational perspective, in the context of the study in the HEIs of Colombia, four subsystems were identified that interact in the development of KT and TT activities carried out by research and technological development (R&D) groups and centers: i) management subsystem, ii) administration subsystem, iii) teaching subsystem and iv) research/environmental interaction subsystem (Figure 1).

In these subsystems, the mechanical bureaucratic organization of the “management subsystem” and the “administration subsystem” coexist with the professional bureaucracy that characterizes the work carried out in the “teaching subsystem” and in the “research/environmental interaction” in traditional HEIs (Clark, 1995; Muñoz, 2019; Siegel et al., 2003).

These different types of organization within HEIs generate strong tensions that affect the performance of the "teaching" and "research/environmental interaction" subsystems, since normally the "management" and "administration" subsystems prevail over the others by being "supported" by national laws, the internal regulations generated in the development of institutional autonomy, and the dependence of the academy (“teaching” and “research/environmental interaction”) on the management of human talent and material and financial resources carried out by the management and administration of the HEI (Muñoz, 2019).

The “teaching” and “research/environment interaction” subsystems are based on the work carried out by disciplinary departments and R&D groups and centers, which have their own dynamics, cultures and varied experiences of interaction with the local, regional, national and international environment. One of the explanations for these tensions is related to the different perspectives on the development of the third mission and the imbalance of power that favours the “management” and “administration” subsystems - which fully develop bureaucracy and a hierarchical system with high administrative inefficiency and low flexibility in their processes (Agasisti et al., 2019; Clark, 1996; Muñoz, 2019).

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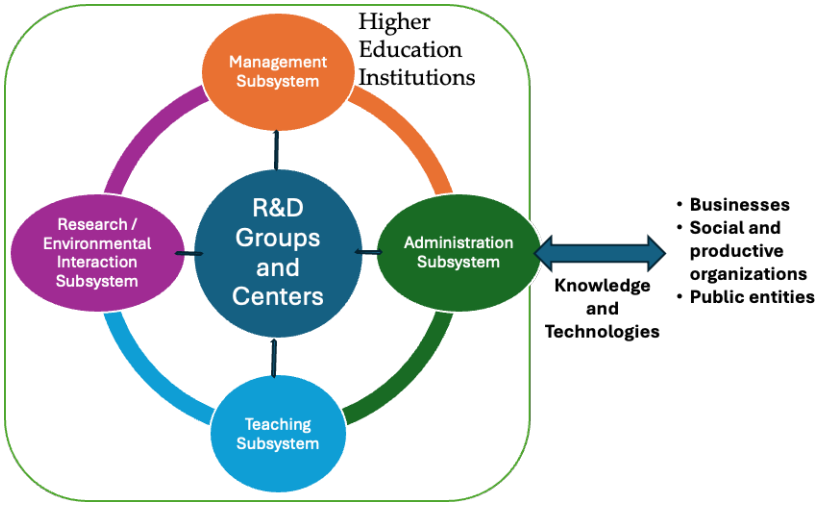
1.3. Knowledge and technologies of HEIs as external sources in open innovation processes

The open innovation model establishes a framework for collaboration between HEIs and different stakeholders in the regional innovation ecosystem. This approach emphasizes the importance of knowledge sharing, both within and between organizations, to drive innovation in the public and private sectors (Chesbrough, 2003). For a successful implementation, a favorable predisposition on the part of those involved is required, as well as changes in cultural aspects and organizational processes of knowledge and technology producers (HEIs and other entities) and of the organizations that seek to innovate (Bašić, 2023; Parveen et al., 2023). To drive innovation in developing countries, HEIs should embrace open innovation and collaborate with external organizations to address complex social and economic challenges (Leon-Roa et al., 2024; Padilla Bejarano et al., 2023).

Figure 1. University subsystems and research and technological development groups and centers



In this way, open innovation can increase the impact of HEIs and the importance of higher education for business and society (Leon-Roa et al., 2024).

1.4. KT and TT activities in the HEIs

KT and TT from HEIs aims to share research results, knowledge and technologies with various external actors, public and private, interested in carrying out open innovation processes, to generate a tangible impact on society, promote socioeconomic development and contribute to the solution of relevant problems (De Silva et al., 2023; Knudsen et al., 2021).

KT and TT from HEIs is important to the extent that it has the potential to generate positive impact in terms of: i) economic development, as it drives the creation of new businesses and jobs and increased competitiveness of organizations; ii) business innovation, through the adoption of new knowledge and technologies to develop new and improved products, services, and processes; and iii) social well-being, as it contributes to solving social and environmental problems and improving quality of life (Nugent & Chan, 2023; Sarabia-Altamirano et al., 2022; Schnurbus & Edvardsson, 2020).

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It is important to highlight that KT and TT from HEIs to organizations in society and the market does not correspond to a unidirectional process that begins with HEI researchers and ends with the appropriation and use of knowledge and technologies by external actors in their open innovation processes. Rather, it requires joint work and permanent, bidirectional interaction, depending on each context, between the actors of the HEIs and external organizations to achieve the success of the process and the attaining of the objectives of each organization, which are varied and different for each organization and for each of the actors involved (Kanning & Meyer, 2022; Padilla Bejarano et al., 2023).

Aspects that justify this bidirectional process are the differences in the contexts in which KT and TT activities are developed and according to the knowledge and technology absorption capacities, market knowledge, personal and organizational objectives of the parties involved, and the advancement of the third mission in the HEIs, etc. However, in this research, the unidirectional relationship between KT and TT activities and the internal subsystems of the HEIs was prioritized, given the low level of development of the HEIs of Colombia as regards KT and TT (Arboleda Muñoz & Plazas Tenorio, 2024; Leon-Roa et al., 2024). In the following, the KT and TT activities in the HEIs are explored in depth.

1.4.1. KT Activities in the HEIs

Knowledge, both explicit and tacit, is the information and skills used to solve problems and make decisions. It is a capacity that is internalized, accumulated, and shared within an organization to achieve a competitive advantage (Fioravanti et al., 2023; Hamilton & Philbin, 2020).

Explicit knowledge, which is formally documented and can be shared through various mediums such as books, articles, and databases, is readily transferable. Tacit knowledge, on the other hand, is personal and context-specific, requiring direct interaction between the knowledge holder and the recipient for effective transfer (Fioravanti et al., 2023; Laptev & Shaytan, 2022; Pereira & Franco, 2022).

Some of the mechanisms identified in the scientific literature for the transfer of knowledge, both tacit and explicit, are (Alexander et al., 2020; De Silva et al., 2023; Gopalakrishnan & Santoro, 2004; Naranjo Africano & Mejía Reatiga, 2018): i) Science, technology and innovation projects (STI), ii) Mobility (internships, hiring) of students and professors to surrounding organizations, iii) Use of equipment and physical infrastructure of HEIs by external actors, iv) Linking graduates to external organizations, v) Specialized continuing education actions aimed at companies and other public and private organizations, vi) Consulting and/or specialized technical assistance to external organizations, among others.

Depending on the moment in which the KT is carried out on the environment, two strategies are identified (Acevedo et al., 2005; De Silva et al., 2023): The first is during the execution of projects that involve external actors and occurs through different activities (workshops, meetings, consultancies, among others) and partial products (reports, booklets, etc.). The second is associated with the products resulting from the CTeI project that seek the dissemination and appropriation of the results among external actors who can benefit from them and is carried out through theoretical-practical training, technical assistance, dissemination products (booklets, books, audiovisuals, etc.), sale, donation or licensing of the patrimonial exploitation rights of the research results, among others.

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In the context of Colombia, the Ministry of Science, Technology and Innovation (Minciencias) published in 2021 the conceptual document of the "National call for the recognition and measurement of research, technological development or innovation groups and for the recognition of researchers of the National System of Science, Technology and Innovation – 2021" which was reviewed and analyzed in detail in this research. This allowed identifying the following products resulting from activities of the research groups as associated with KT activities (Minciencias, 2021): Scientific-technical consulting; Consulting in arts, architecture and design; Spaces for citizen participation; Knowledge communication strategy; Scientific event; Artistic events; New genetic sequence; Citizen participation in STI projects; Specialized knowledge network; Creation workshops; Scientific collection; New scientific registry; StartUp; Creative and cultural companies; Regulation and norm; and Concepts and technical reports.

In the conceptual document of the call (Minciencias, 2021), each of these CTeI products included in the measurement of the activity of the research groups has specified: definition, existence requirements, category and quality requirements. The information on these products in the research groups that participated in said Minciencias call in 2021 made it possible to measure the *knowledge transfer* construct, KT.

1.4.2. TT activities in the HEIs

Technology, which is the application of knowledge in products, is designed to benefit society and organizations. Technology transfer involves the delivery of products and the underlying knowledge related to their production and application (Kalmykova & Ivushkina, 2017). While technology transfer and knowledge transfer are distinct concepts, both are necessary for organizations to add value by leveraging research results and engaging in open innovation processes.

Some of the mechanisms identified in the literature for TT in HEIs are: i) S&T projects, ii) spin-off companies, iii) licensing, sale or donation of commercial exploitation rights of products with intellectual property such as patents and industrial secrets, iv) research contracted by companies to solve specific problems, in which the contracting company has preferential or exclusive access to the results of the research, after negotiating the intellectual property rights (Naranjo Africano & Mejía Reatiga, 2018; Vázquez González, 2017).

In the context of Colombia, similarly to what was done for KT activities, taking Minciencias (2021) as a reference, the following products resulting from research group activities were identified as associated with TT activities: industrial design with contract; pilot plant; industrial prototype; business secret; spin-off; business management innovation; innovations in procedure and service; and records of licensing agreements for the exploitation of research works.

Each of these CTeI products included in the measurement of the activity of the research groups has definition, existence requirements, category and quality requirements. The information on these products in the research groups that participated in this Minciencias call for proposals held in 2021 made it possible to measure the *technology transfer* construct, TT.

1.5. Influential factors of KT and TT in the HEIs

Within the HEIs that are beginning to appropriate the third mission, which are the majority in developing countries (Abu-Rumman & Ahliyya, 2019; Compagnucci & Spigarelli, 2020), KT and TT activities are normally led by teaching staff (professors) interested in ensuring that the results they have

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obtained in carrying out science and technology projects do not remain within the HEIs and scientific databases, without generating a real social and economic impact; rather than reaching society and the market directly through innovative products and services implemented by companies in the market, or spinoffs created with the support of the HEI, interested in strengthening themselves and contributing to regional and national development through innovation (Arboleda Muñoz & Plazas Tenorio, 2024; Liefner & Schiller, 2008).

The KT and TT processes at HEIs involve a large number of stakeholders, both internal and external. At the internal level, there are the professors and researchers who have generated the knowledge and technology to be transferred, who must interact with the directors, lawyers and general administrative staff of the HEI, as well as with other professors at the HEI involved in the process for administrative reasons. At an external level, the leading researchers and support staff of the HEIs must interact with the managers and professionals of the company or external organization interested in taking advantage of the research results and, in most cases, the interaction is also extended to officials of public entities with resources to finance innovation processes and/or related to the regulations to be met, in addition to other social actors involved in the supply of raw materials or as potential users of the innovation (Arboleda Muñoz & Plazas Tenorio, 2024; Chen et al., 2024; Godonoga & Sporn, 2023; Moscardini et al., 2022; Smolentseva, 2023).

The following are the four constructs that were identified as influential in KT and TT from HEIs in developing countries, as a result of the review of the literature and the study of the guiding framework for entrepreneurial universities developed by the European Organisation for Economic Co-operation and Development (OECD, 2012): (i) *leadership and governance* (LG), (ii) *organizational capacity, people and incentives* (OCPI), (iii) *institution and external relations* (IER), (iv) *knowledge and technology transfer impact* (KTTI).

1.5.1 Leadership and Governance (LG) in the HEIs in relation to KT and TT

This construct explores factors related to the leadership and governance of HEIs in the aspects associated with KT and TT. Many HEIs include KT and TT in their mission, vision and strategic objectives statements, but this should be more than a reference and should have associated strategies with operational plan, resources and performance indicators, etc. (Abu-Rumman & Ahliyya, 2019; OECD, 2012, 2022). Strategies for KT and TT should be known throughout the institution and considered as a priority by managers, teachers, administrators and students. The commitment should be shared and supported by internal communication efforts. Maximizing the autonomy of the respective HEI units or areas and overcoming bureaucratic barriers is key for KT and TT (Atta-Owusu & Fitjar, 2022; Audretsch & Belitski, 2021; Baglieri et al., 2018; OECD, 2022; Stolze & Sailer, 2021; Veltri et al., 2022).

For HEI–company–state–society collaboration in KT and TT activities, HEIs face important challenges. These relate to the leadership of their managers, the governance and organizational model, update of the university strategic plan in which the interest in KT and TT appears explicit, and explicit guidelines to the academic unit, since researchers have identified the need to provide strategic flexibility and administrative and financial autonomy to the areas in charge of interaction with companies and other entities in the environment, which would support the solution of the aforementioned barriers, among which the long times that HEIs take in the procedures associated with the development of KT and TT activities stand out (Cunningham et al., 2021; Hamilton & Philbin, 2020; Koekkoek et al., 2021; Matthews, 2022).

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Based on the above, the following hypotheses are proposed:

H1A. *KT activities have a direct and positive relationship with LG in HEIs.*

H1B. *TT activities have a direct and positive relationship with LG in HEIs.*

1.5.2 Organizational Capacity, People and Incentives (OCPI) in the HEIs in relation to KT and TT

HEIs can be limited by their own organizational structures and approaches, which makes it difficult to implement KT and TT strategies (Abu-Rumman & Ahliyya, 2019; OECD, 2012, 2022). Some of the barriers that researchers have identified in relation to KT and TT in HEIs are: high disconnection between the respective subcultures of professors and researchers, and that of management and administrative staff; university bureaucracy; lack of university policies, regulations and structures that promote university-business interaction and intellectual property management in KT and TT; excessive teaching workload (first mission) for professors; lack of monetary and non-monetary incentives for professors and researchers to support the development of the third mission; high centralization in university decision-making; high turnover of management and administration staff; low internal and external funding for science and technology activities; low interaction with external public and private organizations (Farrell et al., 2022; Liboreiro et al., 2022; López-Mendoza & Mauricio, 2018).

This construct includes factors that relate to the need for HEIs to recruit and retain knowledgeable professionals for the development of KT and TT by the university community, since, as it corresponds to a new university mission, the staff has cultivated skills for the development of teaching and research, but very little for articulation with the social and economic environment. Regarding incentives, traditionally professors are incentivized for publishing in prestigious journals. However, in most HEIs in developing countries, incentives for carrying out KT and TT activities are not formally defined (Alarcón & Brunner, 2024; Atta-Owusu & Fitjar, 2022; Chen et al., 2024; Godonoga & Sporn, 2023).

Based on the above, the following hypotheses are proposed:

H2A. *KT activities have a direct and positive relationship with OCPI in HEIs.*

H2B. *TT activities have a direct and positive relationship with OCPI in HEIs.*

1.5.3 Institution and External Relations (IER) in the HEIs in relation to KT and TT

The involvement of diverse stakeholders, internal and external, is crucial for successful KT and TT in HEIs and to the creation of value for the institution and society. Building and maintaining relationships with internal collaborators and external entities (public sector, companies, unions, productive and social associations, alumni and NGOs, among others) is essential to achieve the maximum potential of HEIs in the KT and TT strategy and thus achieve a better positioning as a proactive actor in the knowledge society, economic income, strengthening of laboratories and pilot plants, and the creation of new spaces for academic and consulting activities. (Abu-Rumman & Ahliyya, 2019; Baglieri et al., 2018; OECD, 2012, 2022; Vázquez González, 2017).

The HEIs interested in carrying out KT and TT processes must strengthen their relationships with public organizations, civil society organizations, and companies. To do this, it is necessary to strengthen the organizational culture in relation to the third mission and review and update internal regulations,

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policies, processes, and procedures in order to promote administrative flexibility and institutional agility in fulfilling the commitments made with external actors (Bürger & Fiates, 2024; Etzkowitz, 2004; Godonoga & Sporn, 2023; Kirihata, 2024; Leon-Roa et al., 2024).

The characteristics of the regional environment of the HEIs is a factor to be taken into account in the KT and TT strategy since it is of high impact to have proximity with external companies and organizations from regional and national strategic sectors, with experience in innovation processes (Belitski et al., 2019; Galan-Muros & Davey, 2017; Godonoga & Sporn, 2023; Horner et al., 2019; Klein & Pereira, 2021)).

Based on the above, the following hypotheses are proposed:

***H3A*. KT activities have a direct and positive relationship with the IER of HEIs.**

***H3B*. TT activities have a direct and positive relationship with the IER of HEIs.**

1.5.4 Knowledge and Technology Transfer Impact (KTTI) in the HEIs

The impacts of KT and TT activities affect the university community as well as external actors. HEIs should assess the level of commitment to KT and TT strategies in all areas or units involved, as well as compare the findings and ensure that the results are communicated internally and externally and are fed back into the renewal of the strategy (Abu-Rumman & Ahliyya, 2019; Naranjo Africano & Mejía Reatiga, 2018; OECD, 2012, 2022).

To strengthen KT and TT in HEIs, it is necessary to strengthen institutional capacities that seek social cohesion and network with strategic actors in the region and the country to address their problems, needs and opportunities in science, technology and innovation projects. It is necessary to measure and communicate the actions and results of high social, economic and environmental impact that are achieved in KT and TT activities together with the social and economic actors involved (Baglieri et al., 2018; della Volpe & Esposito, 2020)).

To assess the impact of university KT and TT, it is necessary to go beyond economic indicators and take into account the benefits for teaching and research, as well as the level of satisfaction that these processes generate in external actors in relation to the solution of their needs, problems and opportunities (Baglieri et al., 2018; Boh et al., 2016).

Based on the above, the following hypotheses are proposed:

***H4A. KT** activities have a direct and positive relationship with KTTI within HEIs.*

***H4B. TT** activities have a direct and positive relationship with KTTI within HEIs.*

2. METHODOLOGY

The research methodology employed a quantitative approach, divided into three phases: (i) a systematic review of the literature was carried out in order to establish the proposal for the theoretical model, (ii) a questionnaire-type instrument was constructed with a Likert scale for measurement, consisting of 53 items for six constructs: LG, OCPI, IER, KTTI, KT and TT; (iii) The partial least squares

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structural equation modeling (PLS-SEM) technique was used, which from the perspective of the formation of a model of compounds, unobservable variables and constructs, (Henseler & Schuberth, 2020), allowed the estimation of causal relationships between latent classes through the use of the SmartPLS 4 software, (Henseler et al., 2015).

As a result of the literature review already described for each of the constructs used in this study, the constructs LG, OCPI, IER, KTTI correspond to a reflective measurement model, in which the indicators have a direction of causality from the construct, representing effects or influence towards other constructs (Hair et al., 2022).

In the case of the KT and TT constructs, as already specified in the conceptual description, these correspond to a formative measurement model to the extent that the indicators form the construct and therefore the direction of causality goes from the indicators to the construct. Unlike the reflective model, in the formative measurement model the indicators are not interchangeable, as each indicator captures a distinct aspect of the construct (Hair et al., 2022). The decision criteria defined by Hair et al. (2022) to justify the design of the KT and TT constructs as formative are i) respectively, the indicators KT1 (scientific technical consulting), KT2 (consulting in arts, architecture and design), KT3 (spaces for citizen participation), KT4 (artistic events), KT5 (new genetic sequence), KT6 (citizen participation in science, technology and innovation (STI) projects), KT7 (creative workshops) and KT8 (concepts and technical reports) for the KT construct. The indicators TT1 (spin-off) and TT2 (business management innovation) for the TT construct define different independent aspects of each construct, therefore the directions of causality are from the indicators to the construct; ii) each construct, KT and TT, does not explain the respective indicators, but on the contrary the combination of the indicators of each construct defines it; iii) indicators KT1 to KT8 and TT1, TT2 are causes of the construct, meaning that a change in the indicators generates changes in the respective construct; iv) a change in each of the constructs, KT or TT, will not generate simultaneous changes in all the indicators of each construct, since they are independent causes of each construct and are not consequences; and v) each of the indicators of the KT and TT constructs refers to different aspects of each construct, so they are not interchangeable and the elimination of any indicator changes the concept of the respective construct.

2.1 Data collection and sample formation

A non-probabilistic sample was carried out consisting of 258 records linked to 59 public and private HEIs in Colombia (Figure 2 and Table 1). Research group directors (RGD), researchers, professors, administrative professors (AP), research professors (RP) and research-administrative professors (R-AP) were surveyed. Data were collected through a Google form, sent by email between September and November 2022. Two reminders were sent requesting completion of the questionnaire. Previously, in August 2022, a pretest was conducted with 30 people, who represented various profiles or roles. This pretest provided recommendations that allowed the instrument to be adjusted.

The questionnaire also included questions related to the profile of the respondents and the latent variables of the model, using 5-point Likert scales, where 1 corresponded to “totally disagree” and 5 to “totally agree”.

Since the structural equation model was used for the data analysis, Figure 3 illustrates the representation of the theoretical model.

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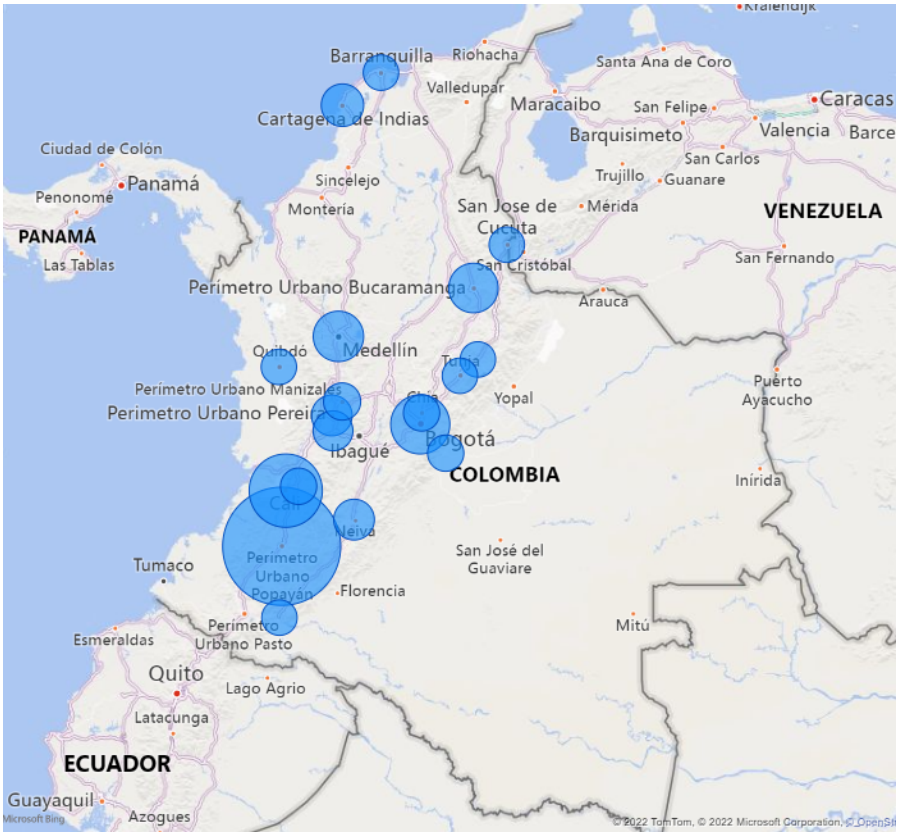
Figure 2. Map with the geographic location of the HEIs and the respondents.



Note: own compilation

Table 1. Description of the sample of HEIs

		Character of HEI		
Type of HEI	**Role**	**Public quantity (%)**	**Private quantity (%)**	**Total quantity (%)**
Professional Technical Institution	RP	1 (0.38%)	0 (0%)	1 (0.38%)
	Total	1 (0.38%)	0 (0%)	1 (0.38%)
Technological Institution	RP	4 (1.55%)	0 (0%)	4 (1.55%)
	R-A P	3 (1.16%)	0 (0%)	3 (1.16%)
	Total	7 (2.71%)	0 (0%)	7 (2.71%)

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		Character of HEI		
Type of HEI	**Role**	**Public quantity (%)**	**Private quantity (%)**	**Total quantity (%)**
University Institution	RGD	1 (0.38%)	6 (2.32%)	7 (2.71%)
	Researcher	0 (0%)	1 (0.38%)	1 (0.38%)
	Professor	5 (1.94%)	1 (0.38%)	6 (2.32%)
	AP	4 (1.55%)	9 (3.49%)	13 (5.04%)
	RP	5 (1.94%)	10 (3.87%)	15 (5.81%)
	R-A P	6 (2.32%)	6 (2.32%)	12 (4.65%)
	Total	21 (8.14%)	33 (12.79%)	54 (20.93%)
University	RGD	12 (4.65%)	3 (1.16%)	15 (5.81%)
	Researcher	7 (2.71%)	0 (0%)	7 (2.71%)
	Professor	14 (5.43%)	12 (4.65%)	26 (10.08%)
	AP	5 (1.94%)	11 (4.26%)	16 (6.20%)
	RP	61 (23.64%)	16 (6.20%)	77 (29.84%)
	R-A P	32 (12.40%)	23 (8.91%)	55 (21.32%)
	Total	131 (50.78%)	65 (25.19%)	196 (75.97%)
Total	RGD	13 (5.04%)	9 (3.49%)	22 (8.53%)
	Researcher	7 (2.71%)	1 (0.38%)	8 (3.10%)
	Professor	19 (7.36%)	13 (5.04%)	32 (12.40%)
	AP	9 (3.49%)	20 (7.75%)	29 (11.24%)
	RP	71 (27.52%)	26 (10.08%)	97 (37.60%)
	R-A P	41 (15.89%)	29 (11.24%)	70 (27.13%)
	Total	160 (62%)	98 (38%)	258 (100%)

Note: own compilation

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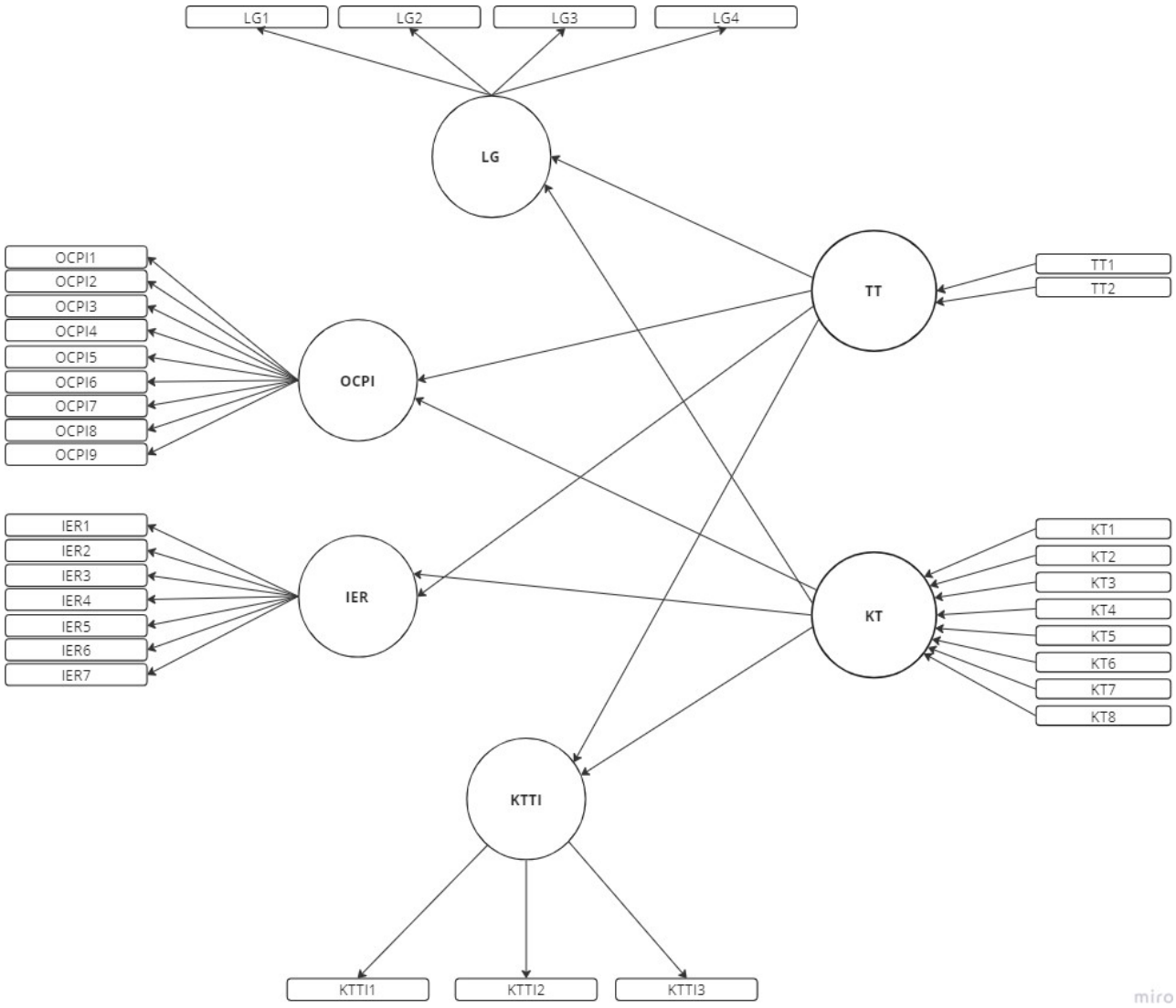
Figure 3. Theoretical conceptual model.



3. RESULTS

The relationship between the items and the latent variables was analyzed following a composite process (Richter et al., 2016), which estimates the relationship between LG, OCPI, IER and KTTI, as a reflective estimate, that is, from the construct to the items, while due to the nature of the phenomenon studied, the TT and KT activities are left as a formative estimate, from the items to the constructs.

Considering what was recommended by Cepeda-Carrion et al. (2019), the research will result in an analysis that is divided into two stages: reliability and validity of the measurement model, external model, and validation of the structural model, internal model, with which hypotheses are finally corroborated through the significance of the path coefficients.

In order to verify the validity and reliability of the measurement model for the problem under analysis, Cronbach's alpha, composite reliability index, CR, and average variance extracted (AVE) indicators were used as criteria, with which the 53 items for the measurement of the six constructs

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involved were tested. Initially, the analysis for the reliability of the external model did not adequately satisfy the fit and Cronbach's alpha dropped below 0.7. So, according to that proposed by Saxe & Weitz (1982), it was necessary to purge some items and thus gain power of explanation in the variability of the object of study, raising the coefficient of determination R2 of the model.

After carrying out various tests and purging the instrument of measurement, 20 items that did not meet the minimum reliability statistics were excluded (Saxe & Weitz, 1982), which allowed refining the scale, integrating the six dimensions in analysis again and leaving a total of 33 items in the available database. Once the adjustment was made, the following indicators were obtained: x2= 1311.3, p≤0.0000, NFI= 0.79, SRMR= 0.07. This indicates a good fit of the model (Cepeda-Carrion et al., 2019).

Table 2 shows the results of the reliability and validity tests of the scales of the proposed external model. The results of the correlations, factor loadings, of the items are consistent and significant, statistically speaking, presenting levels >0.707; the Cronbach's Alpha indicators, composite reliability (CR), internal consistency reliability of the rhoA measurement model (Henseler et al., 2016), are greater than 0.7 in all cases; for convergent validity, the average extracted variance index (AVE) is shown, with an average >0.5. The discriminant validity is confirmed with the criterion of Fornell & Larcker (1981) and the heterotrait-monotrait (HTMT) ratio of Henseler et al. (2015) which are presented in in Table 3 and Table 4.

In addition, following Hair et al. (2019), due to the formative nature of the KT and TT constructs, the variance inflation factor (VIF) is shown, which allows to evaluate the possible collinearity between the formative indicators, which in effect for the present measurement model reach levels lower than 3.0, (Table 2), which evaluates the stability and reliability of the measures for the KY and TT constructs and justifies their inclusion as predictors.

Likewise, it is important to clarify that for the KT and TT constructs, Cronbach's alpha (α), composite reliability (CR) index and average variance extracted (AVE) index measures do not apply (Hair et al., 2019), because they are designed to evaluate the reliability and validity of reflective measures, where the indicators are expected to be highly correlated. Due to the characteristics of the KT and TT formative constructs, the items are not expected to be correlated with each other, nor to share a common amount of variance, so following Hair et al. (2017), it is more convenient to evaluate based on the collinearity of the indicators and the significance of the indicator weights.

As can be seen, Cronbach's alpha values for each factor are greater than 0.7, which allows verifying that the reliability of the scales is acceptable as presented by Nunnally & Bernstein (1994). The composite reliability index, CR, indicates that for the six factors of the model, measures greater than0.7 are obtained, which following the recommendations of Fornell & Larcker (1981) confirms the internal consistency of the indicators of each factor. Finally, for the average variance extracted index, AVE, the analysis carried out shows levels greater than 0.5, (Fornell & Larcker, 1981). As such, the validity of the measurement model is confirmed.

To validate the structural model, the significance of the path coefficients that measure the relationship between the constructs was examined: 10,000 random subsamples were calculated through a random resampling process with replacement, bootstrapping, achieving confidence intervals with significance levels of 95% as evidence for the validation of the working hypotheses and therefore their corroboration (Hayes & Scharkow, 2013) (Table 5). Table 5 shows that four hypotheses were supported - H1A, H2A, H3A and H4B – while discarding four others proposed in the present study - H1B, H2B, H3B and H4A - because they yielded a *p*-value greater than .005. Finally, Figure 4 presents the structural model with the results.

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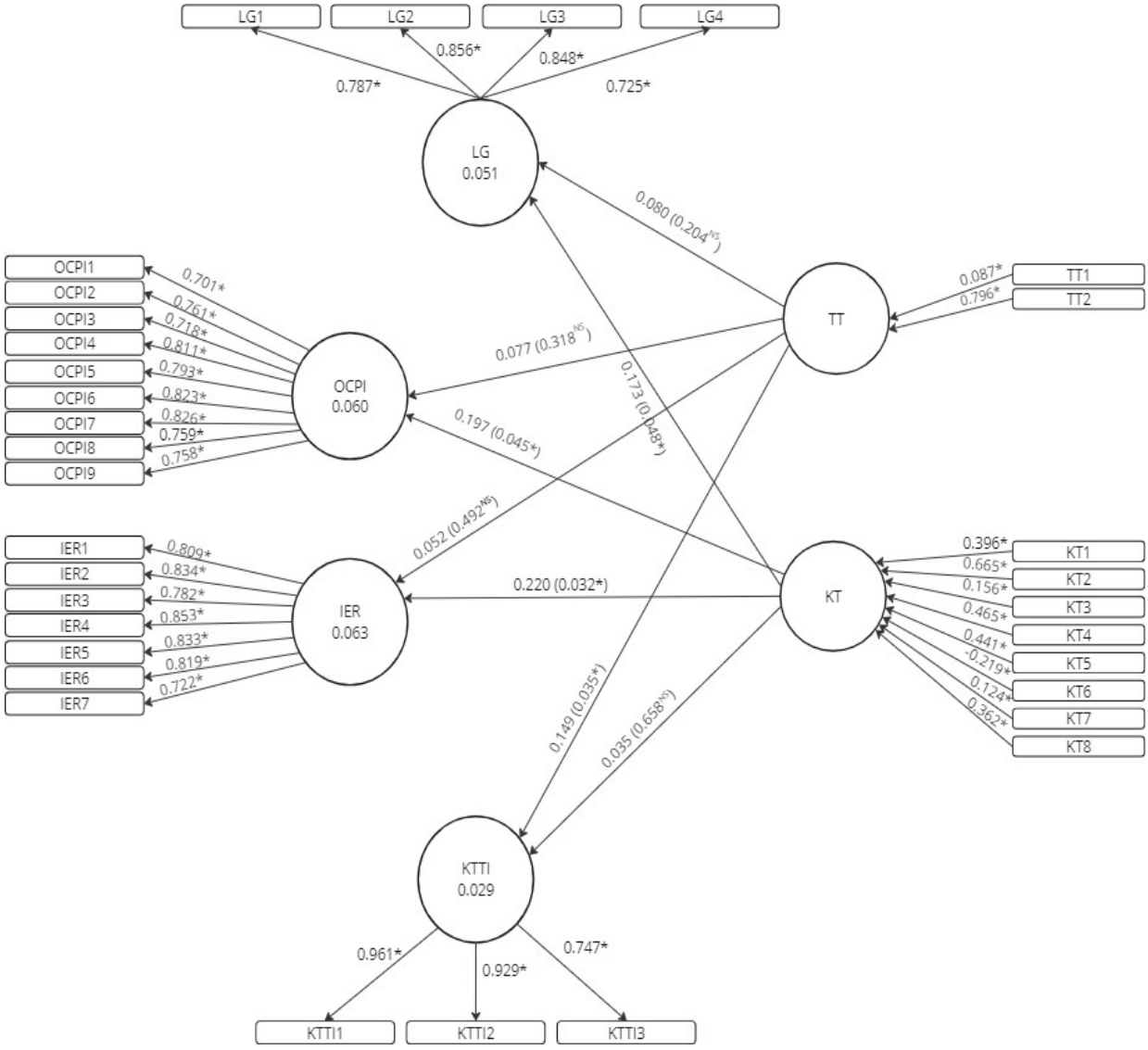
Figure 4. Structural model.



Note: own elaboration. S= supported NS= not supported.

Table 2. Measurement scales, reliability and validity of the model

Construct	Item description code	*t*-test	Collinearity (VIF)	Authors	Item loadings	Cronbach's Alpha (α)	Composite reliability (rho_A)	CR	AVE
Leadership and Governance (LG)	LG1. Institutional strategy	16.128	2.015	(Abu-Rumman & Ahliyya, 2019; Cullen et al., 2020; Cunningham et al., 2021; Hamilton & Philbin, 2020; Koekkoek et al., 2021; Liu & van der Sijde, 2021; Matthews, 2022; OECD, 2022; Veltri	0.787	0.81	0.88	0.93	0.65
	LG2.Commitment	42.205	2.362		0.856				
	LG3.Coordination	21.974	1.992		0.848				
	LG4.Autonomy	10.205	1.354		0.725				

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Construct	Item description code	*t*-test	Collinearity (VIF)	Authors	Item loadings	Cronbach's Alpha (α)	Composite reliability (rho_A)	CR	AVE
				et al., 2022)					
Organizational Capacity, People and Incentives (OCPI)	OCPI1. Budget	16.058	1.834	(Abu-Rumman & Ahliyya, 2019; Baglieri et al., 2018; Calderón-Hernández et al., 2020; OECD, 2022; Partha & David, 1994)	0.701	0.91	0.96	0.93	0.59
	OCPI2. External funding	17.265	2.067		0.761				
	OCPI3. Interdisciplinary	15.456	2.299		0.718				
	OCPI4. People recruitment	21.043	3.154		0.811				
	OCPI5. Staff development	23.898	2.652		0.793				
	OCPI6. Incentives	28.279	2.090		0.823				
	OCPI7. Participation of the administrative area	33.609	2.501		0.826				
	OCPI8. Participation of the legal area	22.423	2.080		0.759				
	OCPI9. Intergenerations	19.073	2.376		0.758				
Institution and External Relations (IER)	IER1. Commitment	27.135	2.601	(Abu-Rumman & Ahliyya, 2019; Baglieri et al., 2018; Naranjo Africano & Mejía Reatiga, 2018; OECD, 2022; Vázquez González, 2017)	0.809	0.91	0.92	0.94	0.75
	IER2. TCT spaces	24.149	2.652		0.834				
	IER3. External linkage	21.237	2.152		0.782				
	IER4. Community participation in TCT	34.104	2.967		0.853				
	IER5. Mobility	33.239	2.222		0.833				
	IER6. TCT training and research	23.802	2.315		0.819				
	IER7. Recognition of external actors	14.999	1.740		0.722				
Knowledge and Technology Transfer Impact (KTTI)	KTTI1. Monitoring and control	47.874	2.990	(Abu-Rumman & Ahliyya, 2019; Baglieri et al., 2018; Naranjo Africano & Mejía Reatiga, 2018; OECD, 2022)	0.961	0.88	1.06	0.91	0.78
	KTTI2. Environment	54.615	3.108		0.929				
	KTTI3. Communication of results	10.032	1.975		0.747				
Knowledge Transfer (KT)	KT1. Scientific technical consulting	1.762	1.74	(Minciencias, 2021; Naranjo Africano & Mejía Reatiga, 2018; Vázquez González, 2017)	0.396	n/a	1.00	n/a	n/a
	KT2. Consulting in arts, architecture and design	2.943	2.516		0.665				
	KT3. Spaces for citizen participation	0.827	2.473		0.156				
	KT4. Artistic events	2.512	2.325		0.465				
	KT5. New genetic sequence	2.190	2.350		0.441				
	KT6. Citizen participation in science, technology and innovation (STI) projects	1.090	2.190		-0.219				
	KT7. Creative workshops	0.561	1.946		0.124				

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Construct	Item description code	*t*-test	Collinearity (VIF)	Authors	Item loadings	Cronbach's Alpha (α)	Composite reliability (rho_A)	CR	AVE
	KT8. Concepts and technical reports	1.856	2.714		0.362				
Technology Transfer (TT)	TT1. Spin-off	0.253	1.822	(Minciencias, 2021; Naranjo Africano & Mejía Reatiga, 2018; Vázquez González, 2017)	0.087	n/a	1.00	n/a	n/a
	TT2. Business management innovation	4.074	1.822		0.796				

Note: own compilation using SmartPLS 3.

Table 3. Fornell-Larcker criterion, discriminant validity

	KT	TT	OCPI	KTTI	IER	LG
Knowledge Transfer (KT)						
Technology Transfer (TT)	**0.518**					
Organizational Capacity, People and Incentives (OCPI)	**0.237**	**0.179**	**0.773**			
Knowledge and Technology Transfer Impact (KTTI)	**0.112**	**0.167**	**0.745**	**0.884**		
Institution and External Relations (IER)	**0.247**	**0.166**	**0.812**	**0.725**	**0.808**	
Leadership and Governance (LG)	**0.215**	**0.170**	**0.701**	**0.600**	**0.696**	**0.806**

Note: own compilation

Table 4. HTMT, discriminant validity

	OCPI	KTTI	IER	LG
Organizational Capacity, People and Incentives (OCPI)				
Knowledge and Technology Transfer Impact (KTTI)	**0.833**			
Institution and External Relations (IER)	**0.900**	**0.811**		
Leadership and Governance (LG)	**0.844**	**0.695**	**0.815**	

Note: own compilation

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Table 5. Path coefficients, PLS-SEM validity

Hypothesis	Path coef.	Supported hypothesis	*t*-statistic	*p*-values
H1A KT -> LG	0.173	S	2.031	0.048*
H1B TT -> LG	0.080	NS	1.288	0.204
H2A KT -> OCPI	0.197	S	2.056	0.045*
H2B TT -> OCPI	0.077	NS	1.009	0.318
H3A KT -> IER	0.220	S	2.205	0.032*
H3B TT -> IER	0.052	NS	0.692	0.492
H4A KT -> KTTI	0.035	NS	0.446	0.658
H4B TT -> KTTI	0.149	S	2.168	0.035*

Note: own compilation. S= supported NS= not supported. Significant at level of *p ≤ = 0.05

4. DISCUSSION

H1A, which examines the relationship between *knowledge transfer* (KT) and *leadership and governance* (LG), was supported in the structural model, as the results show a path coef. = 0.173, with a *p*-value = 0.048 and *t*-value = 2.031 (Table **5**), indicating that there is a direct and positive relationship between KT and LG in the HEIs. In the literature, it has been shown that collaboration between HEIs and surrounding organizations for open innovation processes generates significant pressure to strengthen governance mechanisms in the HEIs, as well as the level of leadership of their managers, to the extent that it is necessary to provide a timely and effective response to companies and other external organizations interested in carrying out, in very short times, KT and TT processes for innovation purposes, given the high pressure they have from the market due to increasingly shorter technological cycles and high level of competition at all levels (Abu-Rumman & Ahliyya, 2019; Bašić, 2023; Clauss et al., 2018; Cullen et al., 2020; Cunningham et al., 2021; OECD, 2012, 2022; Stolze & Sailer, 2021; Veltri et al., 2022).

H2A, which examines the relationship between *knowledge transfer* (KT) and *organizational capacity, people and incentives* (OCPI), was supported in the structural model, since the results show a path coef. = 0.197, with a *p*-value = 0.045 and *t*-value = 2.056 (Table **5**), indicating that there is a direct and positive relationship between KT and OCPI in HEIs. Researchers have shown that HEIs that have made progress in successful KT processes with external organizations have strengthened their organizational structures and approaches, and have carried out important awareness-raising processes in the third mission with professors and researchers and management and administrative staff; they have also implemented efficient processes and procedures, as well as policies, regulations and incentives that promote university-company-community interaction and the intellectual property management in KT and TT (Abu-Rumman & Ahliyya, 2019; Alarcón & Brunner, 2024; Godonoga & Sporn, 2023; López-Mendoza & Mauricio, 2018; OECD, 2022; Romero- Sánchez et al., 2024; Veer Ramjeawon & Rowley, 2020)

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H3A, which examines the relationship between *knowledge transfer* (KT) and *institution and external relations* (IER), was supported in the structural model, as the results show a path coef. = 0.220, with a *p*-value = 0.032 and *t*-value = 2.205 (Table **5**), indicating that there is a direct and positive relationship between KT and IER in the HEIs. It is demonstrated in scientific literature that the participation of a variety of stakeholders, internal and external, in KT processes in HEIs has created value for the institution and society. Relationships with internal collaborators and external entities (public sector, companies, unions, productive and social associations, alumni and NGOs, among others) have been built and fortified, thus strengthening the KT strategy in the HEIs and thereby improving their positioning as a proactive actor in the regional innovation ecosystem (Abu-Rumman & Ahliyya, 2019; Baglieri et al., 2018; Marr & Phan, 2020; OECD, 2012, 2022; Vázquez González, 2017).

H4B, which examines the relationship between *technology transfer* (TT) and *knowledge and technology transfer impact* (KTTI), was supported by the structural model, since the results show a path coef. = 0.149, with a *p*-value = 0.035 and *t*-value = 2.168 (Table **5**), indicating that there is a direct and positive relationship between KT and KTTI in the HEIs. Researchers have shown that successful TT activities have positively impacted the university community and the external partners involved, since the development of TT and internal and external communication actions, with the results of high social, economic and environmental impact of said activities, has strengthened the level of commitment of managers, professors and administrators with TT strategies and the development of the other missions of the HEI (Baglieri et al., 2018; della Volpe & Esposito, 2020; Naranjo Africano & Mejía Reatiga, 2018; OECD, 2022).

In relation to the hypotheses not supported in this structural model: H1B (TT -> LG), H2B (TT -> OCPI), H3B (TT -> IER), previous studies already referenced in the scientific literature have identified the direct and positive relationship between *technology transfer* (TT) and *leadership and governance* (LG), *organizational capacity, people and incentives* (OCPI) and *Institution and External Relations* (IER), but in this study one reason for the result found is that the HEIs in the context of the Republic of Colombia and in particular in the HEIs to which the people who responded to the questionnaire are attached suffer from a low level of development in KT and TT processes. In particular there is little experience in TT activities of the spin-off type (average of 1.9; of the 59 HEIs, 68% have not created any, 15% have created 1, 8% have created between 2 and 3, and the remaining 9% have created 4 or more) and business management innovation (average of 1.7; of the 59 HEIs, 70% have not generated any, 5% have generated 1, 7% have generated between 2 and 3, and the remaining 18% have generated 4 or more).

5. CONCLUSIONS

In the higher education institutes of Colombia, knowledge transfer (KT) activities are mainly supported by the flourishing scientific production. As a result of national regulations, such production accrues economic gains for HEI professors, putting pressure on the HEIs to improve *leadership and governance* (LG), *organizational capacity, people and incentives* (OCPI) and *institution and external relations* (IER). The HEIs as a result must provide a prompt, effective response to KT cases driven by research professors (leaders in the development of the third mission) collaborating with public and private organizations that seek to implement open innovation processes leveraging research findings. These organizations seek to respond to strong pressure from the market due to increasingly shorter technological cycles and a high degree of competition at all levels.

To HEIs interested in advancing in the third mission in developing countries, this allows us to propose prioritizing within their initial strategies, focusing the available financial resources toward knowledge and technology valorization processes, personalized support for research professors and the respective research groups and centers already enjoy some kind of relationship with external organizations interested in benefiting from their research results. Neither should support be neglected for processes of valorization of other research results with a high potential to generate innovations.

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Thus, it is also recommended to prioritize strengthening internal organizational structures created to support interaction with the local environment.

Technology transfer (TT) activities represent a huge challenge for HEIs in the context of Colombia. Worldwide, such transfer is represented mainly by the licensing and sale of patented technologies, as well as the creation of technology-based spin-off companies. The difficulty for Colombian HEIs is seen clearly by the fact that only one of the hypotheses was supported, revealing a direct, positive relationship between *technology transfer* (TT) and *knowledge and technology transfer impact* (KTTI), given that the few TT activities that have been successfully carried out have positively impacted the university community and the companies involved, while both the commitment level of directors, professors and administrators with TT strategies and the development of the other missions of the HEI have been strengthened.

Most of the literature in large databases such as Scopus refers to studies carried out in developed countries. Few publications feature knowledge or technology transfer in HEIs in developing countries. This is particularly true of countries such as Colombia, predominantly rural, with a low business presence in most of its cities. The problem is compounded by high levels of mistrust between the actors that comprise its national and regional science, technology, innovation and competitiveness systems. This is due to multiple background situations that relate to a high level of unmet basic needs, the low level of economic development, and the presence of armed actors.

The results of this research thus have the potential to generate a high impact in accordance with the extent that they are made known to leaders and authorities in developing countries and these in turn decide to create national and regional programs fostering and encouraging the transfer of knowledge and technology from HEIs. This involves taking advantage of research and technological development projects, primarily funded with public resources, to drive open innovation processes in organizations. This, in turn, contributes to improving regional competitiveness.

Developing countries such as Colombia need to strengthen their national system and regional systems of science, technology, innovation and competitiveness. To enhance the quality of life of their citizens, such countries need to achieve better levels of development of their companies and of public and private organizations in general. A fundamental actor to strengthen in light of such aims are the higher education institutions. The HEIs are pursuing not merely their traditional education and research with high quality, they are also beginning to develop the third mission, that of interaction with society, with companies and with organizations around them interested in benefitting from the knowledge and technologies that represent the fruits of their research processes.

Strengthening the third mission in the HEIs requires significant improvements in *leadership and governance* (LG), *organizational capacity, people and incentives* (OCPI), *institution and external relations* (IER) and *knowledge and technology transfer impact* (KTTI). Making these improvements entails a lot of work within the HEIs, but it is important to be able to depend on regulatory and state policy support capable of providing foundations for the modernization process these entities require.

The legislators in developing countries such as Colombia are coming late to a broad and flexible regulation that allows HEIs to strengthen knowledge transfer and technology transfer, such that they are able to facilitate concrete social and economic impacts. The HEIs need to update and adjust their KT and TT models, which, for the most part, copy processes from developed countries, processes anchored in intellectual property (patenting and licensing). This can only indicate that they fall short, since such patenting and licensing involves long processes due to the various mental barriers of many teachers and administrators, of leadership and governance, of administrative processes, among others that exist in the HEIs. Moreover, the increasingly shorter and shorter duration of technological cycles in the knowledge era discourages external organizations from establishing relationships in KT and TT with HEIs seeking to carry out open innovation processes.

It is therefore necessary to build regulations and policies, both state and internal to HEIs, specifically aimed at strengthening KT and TT through *leadership and governance* (LG), *organizational capacity, people and incentives* (OCPI), *institution and external relations* (IER) and

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knowledge and technology transfer impact (KTTI).

Regarding limitations and future research, the study of the KT and TT from HEIs in developing countries could include key aspects for social development such as the lack of infrastructure, the disconnection between universities and the productive sector in rural versus urban areas, the effectiveness of public policy and the cultural or organizational barriers faced by the implementation of the digital transformation of both educational and non-educational organizations. In light of the above, future research could explore new models of collaboration between universities, governments and companies, studying the impact of digitalization on these models; assessing the role of human capital in KT and TT, analyzing public policies that encourage innovation, and developing metrics to measure the impact of these transfers on economic and social development.

Future research could involve surveying more HEIs to enhance generalizability. Limitations arose associated with the low level of development of the third mission in most HEIs. Several of the hypotheses could not therefore be supported in the study. Further research is recommended since in recent years progress in the knowledge era has pressured HEIs to develop KT and TT processes for society and the market. It would be important to conduct studies in the context of developing countries to identify transferable items in relation to knowledge and technologies developed in HEIs, beyond the licensing or sale of patented technology, as well as to regulate the existence of for-profit and not-for-profit transfer processes, given that the first phase of third mission´s development involve building trusting relationships with external partners and demonstrating all of the potential of HEIs to contribute to the regional and national innovation ecosystem.

The research did not delve into one of the causes of the few formal processes and low effectiveness of the KT and TT carried out by HEIs to external public and private organizations, which is the low knowledge that has been developed, in the context of developing countries, on the management to be carried out in the stages called the "Technological Valley of Death" and the "Commercial Valley of Death". It is therefore suggested that future research does so.

Analyzing barriers to knowledge transfer in HEIs and external organizations requires new research that details the institutional and environmental conditions, so that, in the future, KT and TT models customized to different territories can be built with the aim of generating endogenous development processes in developing economies.

Author contributions

C.L., A.Z., and H.V. conceived the presented idea, supervised the study and analysis; C.L. developed the methodology and performed the study and drafted the manuscript. J.S. supported the development of methodology. All authors discussed and contributed to the final manuscript. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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Declaration of Competing Interest

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financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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