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Research Article

Promoters of the Effective Transfer of University Knowledge and Technology in Developing Countries

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ABSTRACT

Universities have evolved to become key players in the social and economic development of their areas of influence, especially in countries with developed economies, adopting a third mission of interaction with their environment to complement their two traditional missions of education and research. This study delves into the concept of the third mission and proposes a model focused on promoting the Transfer of Knowledge and Technology (KTT) to society and the market for universities in developing countries, which are in the early stages of appropriation and development of the third mission. The model is based on the following components: (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), and (v) University-Industry Collaboration (UIC). This study was based on a review of the scientific literature and semi-structured interviews conducted in 2022 with 26 executives and research leaders from universities in southwestern Colombia, selected by convenience. Using ATLAS.ti version 24 software, five categories corresponding to the components of the model were analyzed, and semantic networks were generated with 21 codes and 1,019 citations. The results of the research and the validation of the model in a university that is the subject of this study show clear progress in the appropriation of the model.

Keywords: Research group; universities; knowledge transfer; technology transfer; innovation; research results; university-business collaboration.

1. Introduction

Universities have evolved since the Middle Ages, initially as institutions for training human talent. In the 19th century, under the leadership of Wilhelm von Humboldt, German research universities established a new mission focused on the creation and dissemination of knowledge, known as the "first academic revolution". In recent decades, knowledge and technology have emerged as crucial factors for social and economic development, and universities have taken on a new role as the main generators of these resources. Universities in developed countries have driven the "second academic revolution" by generating social value through the application of their research results, adopting a third mission of interaction with the environment, in addition to the two main missions of training and research. This third mission positions them as key players in the social and economic development of their regions (Karlsdottir et al., 2023; Marchigiani & Garofolo, 2023; Coşkun et al., 2022; Matthews, 2022; Stolze & Sailer, 2021; Audretsch & Belitski, 2021; Klein & Pereira, 2021; Etzkowitz, 1998).

In this context, universities in developed countries are no longer considered "ivory towers," a term that refers to institutions of higher education with little interaction with society and under the authority of an academic elite that prioritizes prestige through theoretical instruction, fundamental research, and academic publication. These universities show a high resistance to change and a lack of direct consideration for the problems of communities and businesses. In addition, they interact minimally with public and private entities in their research processes, underscoring their limited emphasis on the practical application of research results. Most professors and researchers at these universities are satisfied with publishing scientific articles and books and participating in national and international academic events (Khelifi, 2023; Sun, 2023; Matthews, 2022; Koekkoek et al., 2021).

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1.1. The third university mission

The third university mission refers to activities aimed at interaction with society and the market, beyond teaching (first mission) and research (second mission), and may include outreach, outreach, KTT, academic entrepreneurship, and contributions to public policy, among others (Marchigiani & Garofolo, 2023; Padilla Bejarano et al., 2023; Taxt, 2023; Thomas et al., 2023). In Colombia and other developing countries, universities are in the early stages of the transformation process involved in adopting this third mission, as evidenced by the limited scientific literature on cases in Colombia and other countries with similar characteristics (Arboleda Muñoz & Plazas Teno-rio, 2024; Cardona-Cano et al., 2024; Cuesta-Delgado et al., 2024; Leon-Roa et al., 2024; Rome-ro-Sánchez et al., 2024). Some of the definitions found in the literature review that explain the meaning of this new mission are presented in Table 1.

Table 1. *Definitions of the third mission of universities*

Author	Third university mission
(Clark, 1998)	This corresponds to activities carried out by universities with the third source (Third Stream) of financial resources they receive from external organizations, which are complementary to teaching activities (first source of resources, which comes from public funds or student tuition) and research activities (second source of resources, which mostly comes from government entities or international cooperation).
(Etzkowitz, 2003)	The third mission has given rise to "a model of entrepreneurial university based on the process of commercializing university knowledge and technology resources."
(Molas-Gallart & Castro-Martínez, 2007)	The third mission refers to "all activities related to the generation, use, application, and exploitation, outside the academic sphere, of the knowledge and other capabilities available to universities."
(Montesinos et al., 2008)	The third university mission encompasses three interrelated dimensions: social, business, and innovation. The social dimension is manifested in actions that seek to strengthen the social fabric, promote inclusion and sustainable development, and create strategic alliances with various social actors, contributing to improving the quality of life of the population and consolidating their image as agents of change. The business dimension focuses on KTT to the productive sector, the creation of technology-based companies, and the exploitation of research results, contributing to the financial sustainability of institutions and promoting local and regional economic development. The innovative dimension encourages the generation of new knowledge and its application in solving social and productive problems through innovative products, services, and processes that have a positive impact on society.
(Naranjo Africano & Mejía Reatiga, 2018)	The third mission corresponds to an evolution of what in Latin America has been called the social outreach or projection of the university, which corresponds to a commitment to social actors in the territory to contribute to the solution of their problems. The third mission includes cooperation and/or commercialization activities to transfer knowledge and technology to public and private organizations, as well as the promotion of the creation of spin-off and start-up companies based on the exploitation of research results.
(Sánchez-Barrioluengo & Benneworth, 2019)	The third university mission is aimed at obtaining results as a product of strong interaction with the environment, through activities such as

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	commercialization of research results (patents, licenses, spin-offs, among others) and soft activities (collaborative research, contract research, teacher and student internships, consulting) aimed at strengthening external organizations and thereby contributing to local and regional economic development.
(Frondizi et al., 2019)	Strengthening the interaction between the three components of university intellectual capital (human capital, structural capital, and relational capital) and the external environment.
(Blasi et al., 2019)	It is developed through activities aimed at valuing research results, i.e., the transformation of knowledge and technological developments into goods that are useful to society; and activities that have indirect effects on society in general, such as continuing education, consulting and advisory services, new regulations, and other cultural and social contributions.
(Meetei et al., 2024)	The third mission arises in response to the growing expectations, over several decades, of governments, businesses, and society regarding the contribution of universities to innovation and regional economic development. The concepts of entrepreneurial university, civic university, and engaged university, as well as the triple helix model, have been used to describe this mission of universities.

Source: Own elaboration based on a review of scientific literature.

1.2. University research groups

A university research group is composed of professors, undergraduate and graduate students, and external professionals who cultivate robust relationships of trust and execute science, technology, and innovation (STI) projects that yield novel knowledge and technological advancements. These endeavors aspire to enhance the state of the art in science and to address pressing social, environmental, cultural, and economic challenges (Arboleda Muñoz & Plazas Tenorio, 2024; Cabeza-Pullés et al., 2020). The entities in question are distinguished by their foundation within academic institutions, more specifically within the research subsystem. However, they are not formally incorporated into the institutional structure, as they do not bear any administrative or academic responsibilities (Aguiar-Díaz et al., 2016). These entities adopt an interdisciplinary approach to address complex societal and market-related issues, necessitating multidisciplinary collaboration and the establishment of connections with organizations in the productive, social, and governmental domains for the co-creation of solutions (Castrillón-Muñoz et al., 2020; Gusberti & Dewes, 2017).

The research groups are structured around lines of research, which are defined based on the interests of the research professors associated with the group and global trends in the areas of knowledge addressed by the group (Arboleda Muñoz & Plazas Tenorio, 2024). The development of these lines is primarily facilitated by the implementation of STI projects, which are predominantly financed through external resources that are managed by group members when they participate in national and international calls for proposals. The aforementioned projects yield novel knowledge products, which are disseminated through scientific publications and presentations. In addition, they yield technological development and innovation products, such as patents, licenses, business consulting, and the creation of technology-based companies (spin-offs). Furthermore, products from collaboration networks within the framework of the triple, quadruple, and quintuple helix are also generated. Moreover, products of social appropriation of knowledge with communities, production chains, and public entities are produced. Finally, human talent is trained through research seedbeds with undergraduate, master's, and doctoral students (Cabeza-Pullés et al., 2020; Cullen et al., 2020). To achieve these results within the research groups, well-defined roles are assigned and projects are managed, so that they function

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similarly to knowledge organizations or "quasi-firms" (Etzkowitz, 2003).

Research groups play a pivotal role in the knowledge and technology transfer processes implemented by universities. These groups are instrumental in generating the outcomes of STI projects and spearheading the valorization of knowledge and technologies. These technologies and insights serve as the foundation for open innovation processes with private and public organizations with which the group has established or is interested in establishing collaborative relationships (Bürger & Fiates, 2024; Leon-Roa et al., 2024).

1.3 Facilitators and barriers in university KTT

Universities carry out their mission as bureaucratic organizations, with a vertical authority that must reconcile its characteristics with the groups of professionals who make up the different academic departments and research groups, which work with disciplinary autonomy (Clark, 1995). The theory of bureaucracy is one of the great contributions of Max Weber (1864–1920), a German philosopher, economist, jurist, historian, political scientist, and sociologist, considered one of the founders of the modern study of sociology and public administration (Etzkowitz, 2011; López Gallego, 1999; Schoen et al., 2014). According to Weber, bureaucratic organization is characterized by rationality, and among its most important aspects are operation according to standardized norms, defined organizational areas, and a hierarchical structure with gradual levels of authority that function with impersonal norms (López Gallego, 1999). A bureaucratic organization seeks to build trust among the actors with whom it interacts by specifying each procedure in detail, including resources and timelines, with a view to being effective and efficient in the various matters that are important for the functioning of the entity (López Gallego, 1999). According to Muñoz (2019), bureaucracy in universities is essential for them to be organized and fulfill their institutional missions and objectives.

From an organizational perspective, universities in Colombia have four subsystems that interact in the development of KTT activities carried out by research groups with organizations in the surrounding area: i) Management Subsystem, ii) Administration Subsystem, iii) Teaching Subsystem, and iv) Research/Interaction with the Environment Subsystem. These subsystems combine the mechanical bureaucratic organization typical of the management and administration subsystems with the professional bureaucracy that characterizes academic and research work in traditional universities, or the adhocracy that characterizes entrepreneurial and innovative universities, which have highly flexible structures and the ability to adapt to environmental conditions (Clark, 1995; Muñoz, 2019; Siegel et al., 2003).

These different types of organization within universities generate strong tensions that affect the performance of the “Teaching” and “Research/Interaction with the Environment” subsystems, since the “Management” and “Administration” subsystems normally impose themselves on the others because they are “backed” by national laws, internal regulations generated in the development of university autonomy, and the dependence of academia on the university administration for the management of human talent and material and financial resources (Muñoz, 2019). On the other hand, the subsystems “Teaching” and “Research/Interaction with the Environment” are made up of disciplinary departments and research groups that have their own dynamics, cultures, and varied experiences of interaction with the local, regional, national, and international environment.

The main barriers that researchers have identified in relation to university KTT are the high disconnect between the respective subcultures of research professors and administrative staff (Bradley et al., 2013; Siegel et al., 2004); university bureaucracy; the lack of university policies, regulations, and structures that promote university-business interaction and the management of intellectual property associated with research processes; weak university governance; excessive teaching loads for research professors; the absence of awards and incentives for researchers; high centralization of university decision-making; high turnover of management and administrative staff; leadership conflicts among middle and senior university management; insufficient R&D capacity; 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).

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With regard to university bureaucracy in activities involving interaction with the environment and KTT in general, the results of the study conducted by Miranda Zea et al. (2019) are noteworthy, showing evidence of obstacles that arise for members of the university community due to the rigidity and inefficiency, and sometimes absence, of regulatory and process support structures and a weak institutional culture associated with the third mission of universities, even when there is verbal support from university administrators. Research professors and other members of the STI project team face daily obstacles associated with university bureaucracy whenever they carry out a procedure that falls outside the autonomy of the research group and the respective academic program (faculty or department), such as the acquisition of goods and services, hiring staff, or signing a confidentiality agreement or contract with an external actor of interest to the project, since bureaucratic processes are extremely long, in addition to being rigid, cumbersome, and inefficient (Ravi & Janodia, 2022; Salomaa & Charles, 2021). Some of the facilitators that researchers have found in relation to university KTT are: the human talent of research professors and students who carry out undergraduate and graduate research; a commitment from university management that is evident in the institutional development plan and budget; the existence within the organizational structure of areas responsible for relations with the environment and the management of intellectual property associated with research results (López-Mendoza & Mauricio, 2018). The existence of a university culture conducive to interaction with society and public and private organizations is very important for strengthening the motivation of professors to become involved in TST processes (Farrell et al., 2022; Liboreiro et al., 2022).

1.4. Death Valley in university KTTs

KTT associated with research results from universities in developing countries is highly relevant to regional and national innovation ecosystems, HEIs, and public and private organizations interested in increasing their productivity and competitiveness by leveraging the R&D results generated by research groups (Farrell et al., 2022; Meetei et al., 2024). However, one of the reasons for the few formal processes and low effectiveness of KTT carried out by universities is the low level of knowledge that has been developed in emerging countries about the management required in the stages known as the "Technological Valley of Death" and the "Commercial Valley of Death" (Bhattacharya et al., 2022; Budi & Aldianto, 2020; Pujotomo et al., 2023). The "Technological Valley of Death" occurs within university research groups when the technology under development has completed its process in the laboratory, with majority funding from government sources, and is moving into a new phase where it must demonstrate its usefulness in conditions closer to real operating conditions (relevant environment or pilot) and link up with external actors (public and/or private) interested in the potential commercialization of the technology, who normally express fears about the high level of uncertainty that the technology has due to its laboratory level of development. The lack of support from university management and administration, as well as from a university ecosystem that supports KTT and external sources of funding for the activities specific to this phase, which are not normally covered in full by the state or by entrepreneurs, since governments focus on funding research activities (basic, applied, and experimental development) and companies invest their resources mainly in activities related to production and marketing in the market, means that many research results with high potential impact on society and the market do not continue their development process and only satisfy the academic interests of professors and institutions in the form of scientific articles, books, and presentations at national and international events. The "Commercial Death Valley" occurs when the technology has successfully passed validation in conditions known as a pilot environment (low-capacity industrial characteristics) and requires large investments and important external partners (public and/or private) to deploy it in real operating conditions within organizations interested in implementing the innovation. This requires joint work between the university and the external organization to put the technology into operation in its operating environment and conduct pre-commercial and commercial testing with end

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customers. The lack of a relevant university KTT model for developing countries, as well as external sources of funding for universities and organizations interested in the technologies, means that research results that have managed to overcome the "Technological Valley of Death" fail to translate innovation into products and services, depriving society and the market of the return on investment that most university R&D activities should demonstrate (Bhattacharya et al., 2022; Bong et al., 2020; Budi & Aldianto, 2020; Pujotomo et al., 2023). In these "valleys of death," it is necessary to carry out activities such as: improvement of technological prototypes, demonstration of operation in pilot plants, and validation in the operational environment (real environment) of public and private organizations interested in the technology, pre-commercial and commercial proof of concept, compliance with national and international regulations, and final product adjustments. which requires the allocation of significant human and financial resources with an unclear return on investment and a high failure rate, since according to Jucevicius et al. (2016), nine out of ten investment projects related to the use of research results in innovation fail.

1.5. KTT models in universities

According to Baglieri et al. (2018), there are four models of KTT in universities: catalyst, smart bazaar, traditional shop, and orchestrator of local buzz.

The "Catalyst" model refers to universities that are global players in university-industry collaboration for the development of disruptive innovations. They have international visibility and focus on the triple helix innovation model and on increasing their income through exclusive licensing agreements with large corporations, rather than on maximizing the number of patents obtained or the number of technology-based companies created per year. Examples of universities that develop this model are (Baglieri et al., 2018): Stanford University (https://www.stanford.edu), founded in 1891 and located in California's Silicon Valley, has played a key role in global development; the Massachusetts Institute of Technology - MIT (USA) (http://web.mit.edu), founded in 1861 with the aim of "assisting in the advancement, development, and practical application of science," has driven some of the most important innovations for the world in recent decades. Similarly, The Ohio State University (https://oied.osu.edu), by developing this model, is among the top 100 organizations in 2024 that have received the most revenue from licensing, an activity it carries out through the Ohio State Innovation Foundation (OSIF) (Global Licensing Group, 2024). Also in the top 10 of Reuters' list of the World's Most Innovative Universities (Reuters & Ewalt, 2019) are: Harvard University (http://www.harvard.edu), University of Pennsylvania (http://www.upenn.edu), University of Washington (http://www.washington.edu), University of North Carolina Chapel Hill (https://www.unc.edu), Belgium's KU Leuven University (https://www.kuleuven.be), University of Southern California (http://www.usc.edu), Cornell University (https://www.cornell.edu) and Imperial College London (http://www.imperial.ac.uk). The "smart bazaar" model refers to universities that consolidate discoveries and make them accessible to external actors, seeking to contribute to solving the needs and problems of society in general, with a special emphasis on vulnerable populations and not on financial income from technology sales or licensing. They involve society in the production and dissemination of knowledge and do not seek exclusive technology licensing agreements in order to broaden the social impact of their research results. Johns Hopkins University (https://www.jhu.edu) (USA) applies this model insofar as it has promoted the dissemination of technologies generated by its researchers and the conclusion of non-exclusive licensing agreements seeking to expand their application in society (Baglieri et al., 2018). In Canada, the University of Victoria (https://www.uvic.ca) develops this model with a priority on community involvement in its research processes to generate positive effects on the planet and people's lives (Conway et al., 2009). The "traditional shop" model corresponds to universities that view KTT as a process to promote research results by creating a significant patent base and giving lower priority to the negotiation of intellectual property rights and the creation of technology-based companies. Universities with this model show lower financial income from KTT activities. This model is applied by the https://www.usf.edu (USA), which ranks high in the

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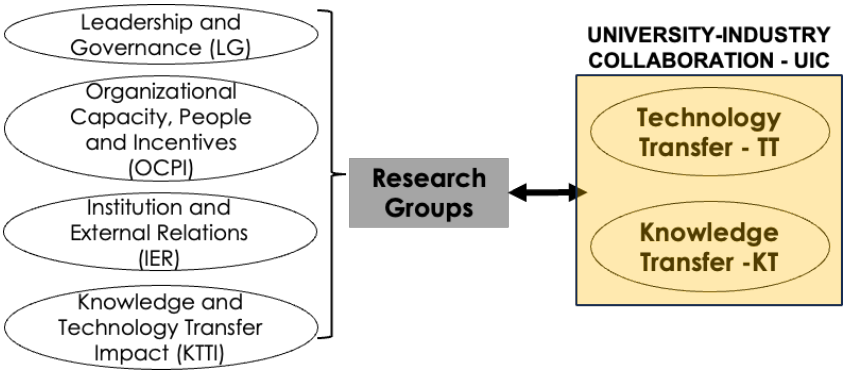
ranking of universities with patents, but low in the ranking of income from licensing (Baglieri et al., 2018). The "orchestrator of local buzz" model refers to universities that prioritize the exploitation of research results to boost local economic development through the creation of technology-based companies: spin-offs and start-ups. They seek to expand their business network and access public funds to train researchers in entrepreneurship and promote an entrepreneurial culture in local environments. This model is being developed by New York University (https://www.nyu.edu) (USA), which has academic entrepreneurship as one of its priorities (Baglieri et al., 2018). In Spain, the University of Mondragón (https://www.mondragon.edu) has been developing this model since its foundation, committing to a model of collaborative research in conjunction with technology centers and companies, seeking the social and economic development of the Basque Country (Conway et al., 2009). In Chile, this model is being developed by the group of universities that make up HUBTec Chile (https://www.hubtec.cl), a technology transfer platform that seeks to promote innovation and impact the country's economic and social development. It is made up of seven universities and four scientific-technological centers: Pontificia Universidad Católica de Chile (UC), Pontificia Universidad Católica de Valparaíso (PUCV), Universidad de La Frontera (UFRO), the University of Valparaíso (UV), the University of Los Andes (UAndes), the University of Development (UDD), the Andrés Bello University (UNAB), the University of Magallanes (UMAG), the Regional Center for Food and Health Studies (CREAS), the Chilean Nuclear Energy Commission (CChEN), and the Water Technology Center (CETAQUA). In Spain, the Polytechnic University of Madrid (UPM) (https://www.upm.es) is ranked as one of the most innovative universities in Europe, with more than 500 patents created by its 205 research groups, a figure to which approximately 50 new patents are added each year. The UPM has created more than 230 companies, with a 70% survival rate after three years, which have attracted more than €53 million in investment.

2. KTT model for universities in developing countries

As a result of reviewing scientific articles and studying the guiding framework for universities developed by the European Organization for Economic Cooperation and Development (OECD, 2012), a model is proposed to promote KTT in universities in developing countries that are taking their first steps in the appropriation and development of the third mission, based on the following components: (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), and (v) University-Industry Collaboration (UIC) (Figure 1).

Figure 1. Model for promoting KTT in universities in developing countries



Source: Own elaboration based on literature review.

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Leadership and Governance (LG) in universities in relation to KTT refers to the fact that some institutions include it in their mission statements, vision, and strategic objectives, but there are no concrete elements for the development of KTT in their strategies and operational plans (Abu-Rumman & Ahliyya, 2019; OECD, 2012, 2022). It is considered important that everything related to KTT is known and understood by the institution's senior and middle management and is considered a new mission by the entire university community: faculty, administrators, and students (Atta-Owusu & Fitjar, 2022; Baglieri et al., 2018; Veltri et al., 2022). Researchers have found that universities face significant challenges in establishing effective KTT collaborations with businesses, government, and society given the rigidity of institutional governance and organizational models, as well as the lack of alignment between university strategic plans and KTT objectives. Therefore, some research proposes that universities adapt their internal structures and processes to promote greater flexibility and autonomy in the units responsible for interaction with the external environment (Cunningham et al., 2021; Matthews, 2022).

Organizational Capacity, People, and Incentives (OCPI) in relation to KTT in universities refers to the fact that organizational structures and approaches hinder the implementation of KTT activities, generating barriers associated with bureaucracy, different visions between administrative and management staff versus those of professors and researchers, internal regulations and poor management of intellectual property, high teaching workload, high turnover of management and administrative staff, and little interest in interacting with public and private entities in the surrounding area (Alarcón & Brunner, 2024; Arboleda Muñoz & Plazas Tenorio, 2024; Godonoga & Sporn, 2023; Liboreiro et al., 2022). KTT activities require a specific professional profile that universities do not normally have, as academic staff have a solid foundation in teaching and research, but their skills in linking with the environment are limited. This is accentuated by the absence of adequate incentives to reward KTT activities, as traditional incentive models, focused on scientific production, are insufficient to promote KTT towards the productive sector and society in general, especially in developing countries (Alarcón & Brunner, 2024; Atta-Owusu & Fitjar, 2022; Baglieri et al., 2018; Calde-rón-Hernández et al., 2020; Godonoga & Sporn, 2023).

Institution and External Relations (IER) in universities refers to the fact that KTT activities require the institution to strengthen itself internally in terms of its competencies, infrastructure, and results associated with research, as well as in the management of relations with external entities, seeking to position itself as an actor committed to the development of the knowledge society in the territory (Abu-Rumman & Ahliyya, 2019; Baglieri et al., 2018; OECD, 2022). In this sense, it is necessary to strengthen its links with the social and productive environment through a transformation of the institutional culture, seeking to promote the third university mission and the adaptation of internal regulatory frameworks to facilitate collaboration with external actors, which implies streamlining administrative processes and granting greater flexibility to the institution (Etzkowitz, 2004; Godonoga & Sporn, 2023; Kirihata, 2024; Naranjo Africano & Mejía Reatiga, 2018).

Knowledge and Technology Transfer Impact (KTTI) refers to the need to continuously evaluate the results of KTT activities and communicate this evaluation to the university community and external actors, so that there is ongoing monitoring of the implementation of strategies and operational plans, as well as the level of commitment of managers and institutional units to the goals set for KTT activities (Baglieri et al., 2018; della Volpe & Esposito, 2020). It is also important to evaluate and communicate the impact that KTT activities have on the other two university missions: teaching and research; as well as the level of satisfaction of external actors (Boh et al., 2016; Compagnucci & Spigarelli, 2020).

University-Industry Collaboration (UIC), in this study, focuses on the desirable two-way interaction between university research groups and industries (companies) interested in carrying out KTT activities that support their business innovation processes, i.e., through UIC, research results are converted into innovative products and services, which is more common in developed countries, but is scarce in developing countries (Bürger & Fiates, 2024; Figueiredo & Ferreira, 2022; Meetei et al., 2024). UIC is particularly important for developing countries, given that the business structure is mainly made

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up of micro and small companies that do not have sufficient human and financial resources to carry out research, technological development, and innovation that would allow them to diversify and open high-potential markets with innovative products. On the other hand, universities traditionally have few financial resources to valorize their research results and little interaction with organizations in their environment, which explains the relatively low relevance of their research results according to the perception of society and the market (Padilla Bejarano et al., 2023; Romero-Sánchez et al., 2024; Yang et al., 2024).

3. Methodology

KTT from universities is a fundamental aspect for the development of countries. Therefore, this study aimed to use a qualitative approach through case studies (Yin, 2014) to understand the current situation of research group products in a developing country such as Colombia and to validate the model described for promoting KTT at a university.

Primary sources of evidence (interviews and non-participant observation) and secondary sources (institutional documents and data available from the Ministry of Science, Technology, and Innovation – Minciencias of Colombia) were used. Procedures associated with use cases, pretesting, the use of various sources, data triangulation, and verification with interviewees of the data collected and the interpretations made by the researcher were adopted to ensure the validity of the research (Yin, 2014).

The following methodology was developed (Ceballos-Herrera, 2009): 1. Selection of the case study, 2. Access to the field, 3. Data collection, 4. Data analysis, 5. Conclusions.

3.1 Case Study Selection

The research groups that participated in the "National Call for the Recognition and Measurement of Research, Technological Development, or Innovation Groups and for the Recognition of Researchers in the National Science, Technology, and Innovation System – 2021" (Minciencias, 2021), carried out by the Ministry of Science, Technology, and Innovation – Minciencias of Colombia, were selected as the object of study. The research groups are classified into five categories: A1, A, B, C, and recognized, with A1 groups being classified as groups of excellence, for which the products they registered in the following categories are taken into account: i) new knowledge, ii) technological development and innovation, iii) social appropriation of knowledge and scientific dissemination, and iv) human resource training.

3.2 Field access and data collection

This research conducted semi-structured interviews between November and December 2022 with 26 executives and directors of research groups at HEIs located in southwestern Colombia, selected through convenience sampling based on the participants' accessibility to the researchers (Robinson, 2014). The instrument was structured into five components and reviewed by two experts to ensure clarity, wording, and the final variables to be measured. During the interviews, the questions were adjusted according to the participants' responses, allowing for greater flexibility in the collection of relevant information. Figure 2 shows the methodological procedure used.

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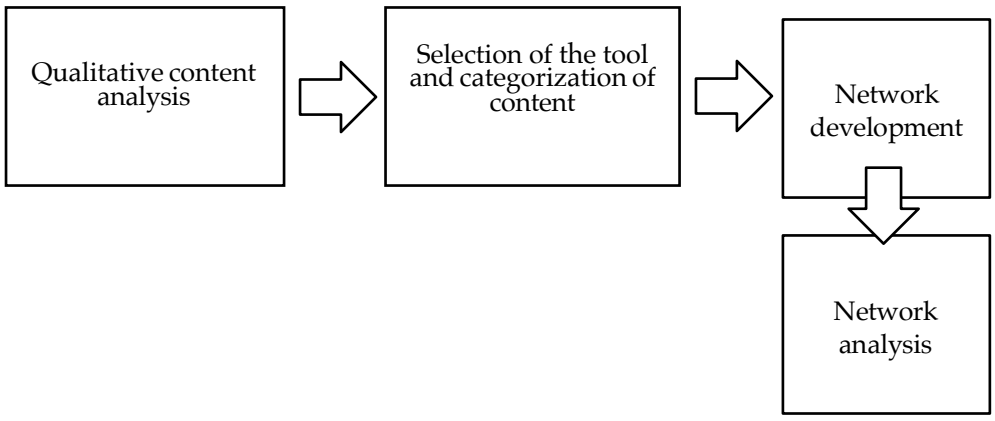
Figure 2. *Methodological Procedure*



Source: own elaboration based on Braun & Clarke (2006), Govers et al. (2007), Woods et al. (2016).

A qualitative content analysis was conducted, using a research technique that allows valid inferences to be drawn from a set of data within a specific context, considered an appropriate method for the objective, systematic, and qualitative description of content (Braun & Clarke, 2006; Govers et al., 2007; Woods et al., 2016).

ATLAS.ti version 24 software was used to analyze the interview responses, coding the information into five study categories: (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), and (v) University-Industry Collaboration (UIC) (see Table 2).

A semantic network was constructed that grouped 21 codes. Similarly, for the five categories that make up the study, semantic networks were developed that allowed for a more detailed visualization of five types of relationships between codes and categories: (i) "is a cause of," (ii) "is associated with," (iii) "is a," (iv) "contradicts," and (v) "is a property of." Finally, the results were analyzed taking into account the interpretation and expertise of the researchers (Braun & Clarke, 2006; Govers et al., 2007; Woods et al., 2016).

Table 2. *Methodological aspects of the interviews*

Qualitative approach			
Location	Cauca, Valle del Cauca, Quindío, Risaralda, Caldas, Antioquía, Cundinamarca.		
Collection of primary information			
Technique	Instrument	Records	Participants
Interview	Semi-structured interview	26	• University administrators. • Directors of research groups.
Information analysis			
Categories	Codes	Operationalization	
Leadership	Prioritization of KTT in	Assess the level of importance that the HEI gives to KTT	

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and Governance (LG)	the institutional strategy	in its overall strategic planning.
	Senior management commitment at KTT	Measure the degree of involvement and support of managers in the implementation and monitoring of KTT activities.
	Coordination and management of KTT activities	Assess the mechanisms for internal integration and collaboration that facilitate the development of KTT activities.
	Regional recognition of KTT	Measures the level of recognition that the HEI has in its environment for its role as an agent of economic and social development, specifically through its KTT activities.
Organizational Capacity, People and Incentives (OCPI)	Budget allocation for KTT	Evaluates the process by which the HEI obtains financial resources for the implementation of KTT.
	Management of external financing for KTT	Measures the capacity to obtain financial resources from external, national, and international sources.
	Area responsible for KTT development	Evaluates the perception of management of this area or unit with the KTT strategy.
	Incentives and recognition for KTT	Analyzes the incentive and/or recognition mechanisms awarded to members of the university community who participate in KTT activities.
	Participation of the Administrative Area in KTT	Evaluates the participation of the administrative area in the management, coordination, and execution of the KTT strategy.
	Participation of the Legal Area in KTT	Evaluates the involvement of the legal department in the regulation, advice, and management of contracts, agreements, and intellectual property protection in KTT activities.
Institution and External Relations (IER)	Participation in KTT networks and associations	Evaluate the spaces, such as networks, associations, and forums, in which the HEI participates to promote KTT with local, regional, national, and international actors.
	Opportunities for university community participation in KTT activities	Measure the ways in which the HEI creates spaces that facilitate the participation of the university community in KTT activities with organizations in the surrounding area.
	Support for the mobility of the university community	Evaluate the mechanisms that the HEI has in place to promote the mobility of the university community to the surrounding area.
	Internal regulations for	Analyzes the existence of internal regulations or

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	KTT	guidelines that the HEI has defined to support and regulate the development of KTT-related activities and strategies.
	Administrative support for KTT activities	Examines the processes, procedures, and administrative structures that facilitate the effective development of KTT activities.
Knowledge and Technology Transfer Impact (KTTI)	Evaluation of KTT results and impact	Analyzes the methods and tools that the HEI uses to measure the success and results of KTT activities and strategies.
	Periodic monitoring and control of KTT	It examines the mechanisms established to monitor the progress and compliance of KTT activities.
	Communication of KTT results to the university community	It evaluates the communication strategies and channels that the HEI uses to inform the university community about the progress, results, and impact of KTT activities.
University – Industry Colaboration (UIC)	Opportunities for improvement at UIC	It identifies areas where the HEI can improve its links and collaborations with the business sector.
	Success Cases at UIC	It examines cases in which UIC has generated successful results.
	Failure cases at UIC	It analyzes cases in which UIC did not achieve the expected results.

Source: Author's elaboration

4. Results

Figure 3 shows the semantic network generated with the ATLAS.ti program, which visualizes the relationships identified between 21 codes with a total of 1,019 citations. This network made it possible to identify key areas for intervention and improvement in KTT policies and activities within HEIs. Based on the above, the following relationships between codes were observed: 8 associations, 5 casual relationships, 4 contradictions, 3 definition relationships, and 4 ownership relationships.

On the other hand, Figure 4 shows the frequency of the 21 codes. In this regard, the most substantiated category corresponds to opportunities for improvement in KIC (162 citations), followed by coordination and management of KTT activities (96). The least substantiated code is cases of failure in KIC, with 4 citations. These results reveal a positive trend among the 26 interviewees in this study, since the code for opportunities for improvement in KIC is more frequent than that for cases of failure in KIC, which has a more critical focus.

Table 3 shows the analysis of the semantic networks in Figures 5, 6, and 7. Figure 5 shows the semantic network of LG and OCPI exercised by the HEIs in this study. According to the responses provided by the interviewees, they agree that there are high barriers to the implementation of KTT, which are associated with a lack of adequate structure and funding and low motivation among researchers, which is consistent with the findings of some researchers (Atta-Owusu et al., 2021; Matthews, 2022).

Figure 6 shows the semantic network of IER, which, based on the responses provided by the interviewees, highlights the importance of the interactions and relationships that HEIs maintain with external actors, such as other institutions, governments, academic entities, and commercial partners to

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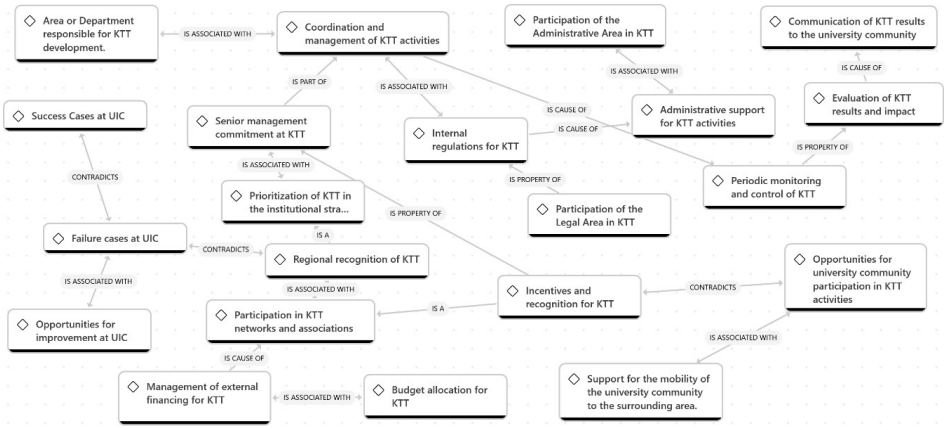
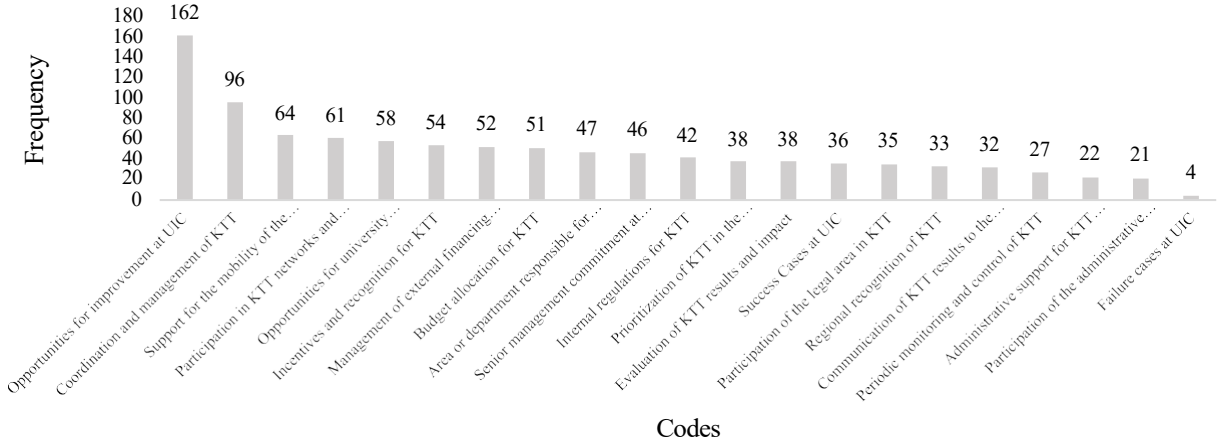
promote KTT, which is in line with what was proposed by Baglieri et al. (2018), and Naranjo Africano & Mejía Reatiga (2018).

Figure 3. Semantic network



Source: own elaboration using Atlas.ti 24.

Figure 4. *Bar Code Diagram*



Source: own elaboration using Atlas ti 24.

Table 3. *Semantic network analysis of codes.*

Category	Code	Theoretical Argument	Authors	Empirical Contribution of the Interviews
Leadership and Governance (LG)	Prioritization of KTT in the institutional strategy	Knowledge and technology are strategic assets that, through KTT, expand and transform, enabling organizations to	(Atta-Owusu & Fitjar, 2022; Matthews, 2022; Nonaka & Takeuchi, 1995;	P17. E.17: ..."In terms of priority in discourse and planning, it is number one, that is fundamental, but in the field of investment, that is where we are lagging behind."

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		innovate and adapt in competitive environments.	OECD, 2022; Veltri et al., 2022)	
	Senior management commitment at KTT	Support from senior management is key in KTT, as it drives strategy, overcomes internal barriers, and creates a favorable environment for innovation.		P4. E.4: …"Our institutional educational project is framed by an institutional philosophy and is based on the commitment of senior management."
	Coordination and management of KTT	Coordination in KTT ensures common objectives through clear roles and facilitates internal and external KT, which is key to creating and using knowledge.		P5. E.20: … "There are strategic plans that we manage from the vice-rector's office for research and extension that are coordinated with some activities of the academic programs. If we are talking about scientific production and the generation of innovation and entrepreneurship, then let's say that there is a process underway"…
	Regional recognition of KTT	Institutional recognition and regional legitimacy in KTT facilitate social support, the consolidation of resources, and collaborative networks for sustainability.		P3. E.18: …"I believe that we are a benchmark not only for our knowledge, but also for the credibility of the University"…
Organizational Capacity, People and Incentives (OCPI)	Budget allocation for KTT	Financial resources are essential in KTT to foster innovation and competitiveness. Adequate	(Abu-Rumman & Ahliyya, 2019; Baglieri et al., 2018; Calderón-	P.8 E.23: …"The budget for transfers to the sector has been improved. We would probably like it to be higher, but yes, there are specific areas of investment

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		funding drives the creation and application of knowledge and strengthens academic collaboration.	Hernández et al., 2020; OECD, 2022)	and highly qualified staff dedicated to this."
	Management of external financing for KTT	Diversification and proper management of financial sources are essential for long-term sustainability in KTT, avoiding external dependence that affects continuity and adaptability.		P15. E.6: ..."There are international cooperation projects being implemented, both with public resources and in coordination with other public entities."
	Area or department responsible for KTT development	Centralizing KTT functions in specific areas optimizes knowledge management, promoting its storage, transfer, and efficient application between levels and areas.		P22. E.13: ..."The technology transfer unit was created, as well as the entrepreneurship park"...
	Incentives and recognition for KTT	Incentives foster a culture of learning and facilitate the adoption of innovations, motivating participation in change processes.		P12. E.25: ..."There are bonuses and the university recognizes part of the intellectual property rights of the researcher"...
	Participation of the administrative area in KTT	Management coordinates key resources and standardizes processes to facilitate		P9. E.24: ..."This participation is very effective and necessary because, for example, in this whole area of relations,

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		effective and sustainable KT, creating an environment conducive to its management.		everything has to be done formally"...
	Participation of the legal area in KTT	Legal and regulatory support is essential to protect intangible assets and ensure the secure transfer and effective adoption of knowledge and innovations.		P13. E.4: ... "we receive full support from the legal department. Our legal department reviews all agreements and everything related to legal matters"...
Institution and External Relations (IER)	Participation in KTT networks and associations	Participation in networks is key to organizational learning and innovation, facilitating access to resources and shared knowledge.	(Baglieri et al., 2018; Naranjo Africano & Mejía Reatiga, 2018; OECD, 2022)	P16. E.26: ..."effective coordination between universities, businesses, and the state, already in place at this time, particularly in the case of the governor's office, where for several years now we have been participating as a university in the formulation and implementation of development plans"...
	Opportunities for university community participation in KTT activities	In the Triple Helix model, university participation is essential for KTT, strengthening the connection between academia, industry, and government.		P2. E.10: ..."the University continuously holds workshops on the social appropriation of knowledge, both internally and externally; together with SENA and other entities, appropriation workshops are held, encouraging research seedbeds"...
	Support for the mobility of the university community to the surrounding area	Mobility facilitates knowledge exchange and collaboration, promoting the		P5. E.20: ... "we participate in events with other universities and our researchers participate in national and international events. In terms of

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		adoption of KTT through proximity and direct interactions.		technology transfer, we have not established a process where we can sit down with a company and tell them what we have to transfer. We have created spaces for dialogue with companies to see what their needs are"...
	Internal regulations for KTT	A solid regulatory structure efficiently guides resources and efforts in the innovation process, aligning them with organizational objectives.		P18. E.8: '...the University has its regulations, the problem lies in their implementation due to their novelty. The University has its intellectual property regulations, which are very well defined'...
	Administrative support for KTT activities	Organizational support, including administrative areas, is vital to the success of KT by providing the necessary infrastructure.		P3. E.18: ... "The legal and administrative areas of the University are very focused on serving the University in all its dynamics. If one reflects carefully on the issue of transfer, specialized personnel are needed for this task because the dynamics of research and transfer are completely different from the ordinary dynamics of the university."
Knowledge and Technology Transfer Impact (KTTI)	Evaluation of KTT results and impact	Assessing the impact of KTT is key to measuring results and its contribution to institutional and social development.	(Baglieri et al., 2018; Bozeman, 2000; De Silva et al., 2023; OECD, 2022)	P21. E.12: ..."the university monitors progress every six months and holds meetings with companies and researchers to validate how things are going, difficulties, progress, and so on."
	Periodic monitoring and control of KTT	Continuous monitoring improves innovation management and ensures		P13. E.4: ... "we have a planning office that monitors the management and execution of the development plan. We monitor quarterly from the

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		alignment with organizational objectives.		community relations area. We meet twice a year to evaluate community relations."
	Communication of KTT results to the university community	KTT is not complete until information is effectively communicated to stakeholders.		P3. E.18: ..."The university, and specifically the vice-chancellor's office, has a communications team that monitors all actions taken to communicate with society in a simple, clear, and forceful manner, through social media and all the means available to the university for this purpose"...
University – Industry Colaboration (UIC)	Opportunities for improvement at UIC	Continuous improvement in collaborations is essential to maximize the impact of KTT.	(Bozeman et al., 2015; Etzkowitz & Leydesdorff, 2000; Osorno-Hinojosa et al., 2022)	P18. E.8: ..."There is still a long way to go. I believe that, within 15 to 20 years, the university must become the most innovative and knowledge-based entrepreneurial institution in Latin America"...
	Success Cases at UIC	Studying successful cases provides valuable insights into how relationships can facilitate innovation and transfer.		P5. E.20: ... "A very important success story was that of Alimentos Cárnicos, a company belonging to the Nutresa group. The mechatronics engineering program developed a prototype, which is in the process of being patented"...
	Failure cases at UIC	Learning from failures isas important as celebrating successes.		P14. E.5: ..."Lack of knowledge about intellectual property became a legal issue that has affected some processes"...

Source: own elaboration. Note: Q: question - E: interview.

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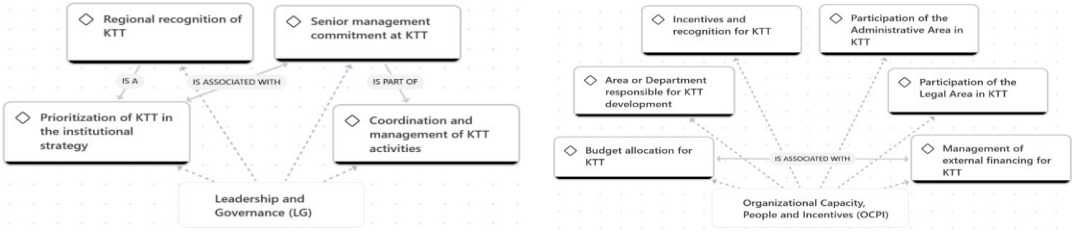
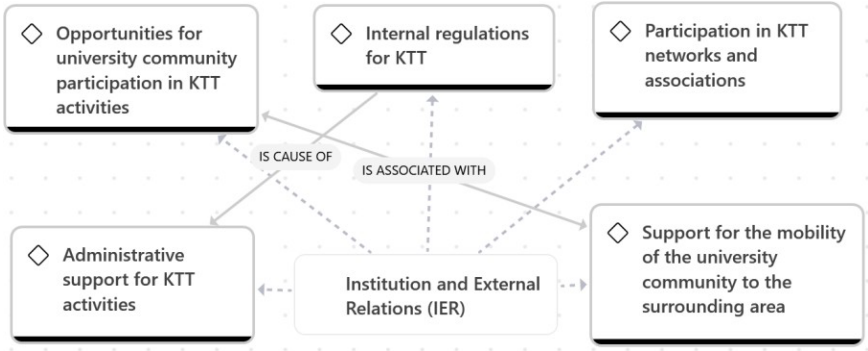
Figure 5. *LG and OCPI*



Source: own elaboration using ATLAS.ti 24.

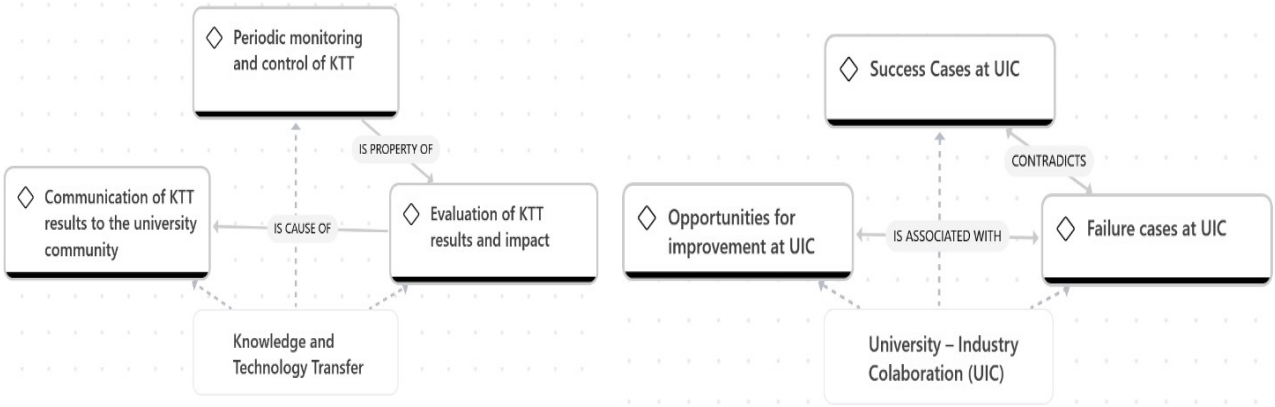
Figure 6. *IER*



Source: own elaboration using ATLAS.ti 24.

Figure 7 shows the semantic network of KTTI and UIC, constructed from the responses provided by the interviewees, who highlight the significant impact of KTT on the performance of HEIs, improving their institutional recognition. Furthermore, interactions between universities, industry, and government, following the Triple Helix model, are fundamental for technological development and knowledge dissemination, which is consistent with the findings of Baglieri et al. (2018) and De Silva et al. (2023).

Figure 7. *KTTI and UIC*



Source: own elaboration using ATLAS.ti 24.

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5. Model validation

In the context of the Republic of Colombia, the Mission de Sabios Colombia (2020) explicitly stated that "there needs to be real social integration of knowledge for its effective use in the country's problems" and made, among others, the following proposals related to KTT: i) Reevaluate the role of intellectual property protection to enable KTT to be more effective; ii) Promote the creation and operation of autonomous organizations (centers, institutes, etc.) to serve as an interface between stakeholders; iii) Establish pilot and demonstration plants to support researchers and companies; iv) Promote the creation of knowledge-based companies, links between researchers and the productive and social sectors, and facilitate internships in companies and research projects with the participation of companies and productive organizations in general.

The University of Cauca – Unicauca is a public HEI founded in 1827 in the city of Popayán, Colombia, South America, which has 9 faculties, 56 undergraduate programs, and 66 graduate programs, of which 11 are doctoral programs. Its university community is made up of 1,368 professors, 572 administrative employees, and a student population of 17,474. Since its creation nearly 200 years ago, it has been an important player in the regional development of the Colombian Pacific region (comprising the departments of Cauca, Chocó, Nariño, and Valle del Cauca), which stretches from the border with the Republic of Ecuador to the border with the Republic of Panama. It covers an area of approximately 350,000 km², representing 25% of the national territory. The population of the Colombian Pacific region is approximately 3.5 million people, representing 7% of the country's total population. It is a biodiverse region rich in natural resources, but it also has high rates of poverty, inequality, and public order problems.

Unicauca has 88 research groups (made up of 285 researchers) categorized in 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 - SNCTI 2021" carried out by the Colombian Ministry of Science, Technology, and Innovation (Minciencias, 2021). These 88 research groups generate the following STI products (see Table 4): 63% are "new knowledge products" (articles, books, and book chapters, among others), 1% are "technological development and innovation products" (industrial prototypes, technical concepts, innovations in procedures and services, regulations and standards, software, among others), 17% are "products for the social appropriation of knowledge and public dissemination of science" (scientific events, final research reports, and working documents, among others), and 19% are "human resource training products" (undergraduate and graduate theses, among others) (Minciencias, 2022).

Table 4 also presents information on STI products from research groups in the four departments that make up the Pacific region and the consolidated figures for the entire country. As can be seen in Colombia, and with greater emphasis in the Pacific region, there is what some researchers call the "Innovation Paradox" or "Innovation Gap" (Calderón-Hernández et al., 2020; Chukhray & Mrykhina, 2019; Dalmarco et al., 2018; Khelifi, 2023), in the sense that there is a high emphasis on the part of the state, universities, and researchers on generating new knowledge products and very few actions to valorize knowledge and technologies that convert research results into technological development and innovation products, thereby generating a tangible social and economic impact on the population and businesses.

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Table 4. *STI products of research groups*

	University of Cauca	Depar tment of Cauca	Depar tment of Chocó	Depart ment of Nariño	Valle del Cauca Department	Colombia
New knowledge products	63%	52%	53%	47%	53%	52%
Technological development and innovation products	1%	2%	1%	4%	3%	5%
Products for social appropriation of knowledge and public dissemination of science	17%	22%	23%	28%	18%	18%
Human resource training products	19%	24%	23%	22%	26%	25%

Source: Colombian Ministry of Science, Technology, and Innovation (https://minciencias.gov.co/la-ciencia-en-cifras/grupos)

Taking as a reference the model described for strengthening KTT in universities in developing countries, with the support of Unicauca's management and, more specifically, the Vice-Rector's Office for Research, a process to strengthen the university's third mission began in 2018. This process involved implementing actions that strengthened the components of the model: (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). Among other things, the following results were achieved: Awareness-raising among the management team, administrative staff, and professors about the university's third mission; inclusion in the institutional development plan of the "Program to Strengthen Innovation and Transfer Management" with a budget and performance indicators; updating of internal regulations related to KTT and incentives for teachers; strengthening of human talent and financial resources in the area responsible for KTT (Division of Entrepreneurship, Innovation and Coordination with the Environment (DAE)); design and implementation of a KTT roadmap and its application in 33 technologies (Leon-Roa et al., 2024), including support in interaction with companies with potential interest; support for research groups in the formulation of STI projects with the most mature technologies and management of national and international cooperation sources; construction and publication of a portfolio with the most mature technologies (University of Cauca, 2022), among others.

Similarly, specific work was carried out with the CYTBIA (Science and Technology of Biomolecules of Agroindustrial Interest) research group at Unicauca, one of Colombia's leading groups in the field of biodegradable materials from roots and tubers, which over the last 10 years has carried out STI projects worth around US$10 million, achieving 12 patents registered in Colombia and some in the USA, and training more than 150 undergraduate and postgraduate students. They were advised on establishing relationships with external actors and on the implementation of a knowledge transfer project with a large multinational food company, which ultimately led to the valuation of wheat by-products, the manufacture of an edible spoon from wheat by-products, and the sale of the technology.

Support was also provided to the CYTBIA research group at Unicauca in the formulation and implementation of the KTT project "Consolidation of knowledge and technology transfer processes for the production of biodegradable materials developed in the department of Cauca" - BioTransferencia, financed with US$2.5 million by the General Royalty System of Colombia, which ended in 2024 and implemented the final phase of an R&D process that CYTBIA began in the early 2000s. The aim is for the results of research and technological development obtained in the field of flexible biodegradable and compostable materials from cassava to have a positive impact on society and the market through

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products and services deployed by companies in the plastics industry interested in creating new environmentally friendly lines of business. The project was a real-world exercise in implementing the Quintuple Helix Innovation Model, involving national, regional, and local public entities, national and international academic institutions, cassava producer associations, rural cassava starch processing companies, and companies in the plastics industry, laboratory and industrial equipment supply, and agro-industry in general.

The results of this research led to the formulation, approval, and implementation of two high-impact KTT projects for the Pacific region of Colombia: "Strengthening innovation in micro, small and medium-sized enterprises based on the re-search results of the HEIs of the department of Cauca" financed with $1.5 million by the General Royalty System of Colombia, and "Strengthening innovation in micro, small and medium-sized enterprises based on the re-search results of HEIs in the department of Valle del Cauca" financed with $1.3 million by the General Royalty System of Colombia.

These research results were the basis for advising the technology-based company Agro360 SAS on the creation and strengthening of a line of work in KTT in biodegradable packaging, which has made it possible to support open innovation processes with companies from different sectors interested in carrying out innovation processes based on research results from universities and the appropriation of technologies in new biodegradable materials developed by large companies around the world.

6. Conclusions

For developing countries such as Colombia, it is essential to take advantage of the results generated by research groups, most of which are funded by public resources. The validation of the model presented to strengthen KTT in universities sought to raise awareness among the university community about the third mission of universities and to improve the university in the areas of Leadership and Governance (LG), Organizational Capacity, People and Incentives (OCPI), Institution and External Relations (IER), and Knowledge and Technology Transfer Impact (KTTI).

The role of university administrators in the entire KTT process is fundamental insofar as, since this is a new university mission, the community needs to know and feel that institutional leadership is committed to this task through the strategic plan, its indicators, and the institutional budget. At Unicauca, the commitment to KTT was strengthened with the application of the model presented in this article, and its management, administrative staff, and professors improved their knowledge of the third university mission. Progress is being made in its appropriation and articulation with the other two missions: education and research.

Unicauca's research subsystem comprehensively strengthened the Entrepreneurship Division, Innovation, and Coordination with the Environment (DAE), which is responsible for leading KTT. Staff improved their qualifications in intellectual property management, intangible asset valuation, technology scaling based on management in the technological and commercial valleys of death, and knowledge and technology negotiation. Actions were taken to improve interaction with companies, productive organizations, and public organizations in relation to the use of research results for their innovation processes.

The UniCauca administrative subsystem is becoming more aware of the third university mission based on the cases of knowledge and technology transfer and sale that have been managed through the KTT strengthening process described in this article. although work continues to overcome barriers related to very long hiring times for personnel and the acquisition of goods and services, major inefficiencies in the management of agreements and contracts with external organizations, and high mistrust in the work performed by contracted professors and researchers, among others.

Limitations in this research are related to the low number of managers and universities involved, as well as the validation of the model in a single university. Therefore, future research could validate the model in a large number of universities with different characteristics, and then consolidate

the findings and build a detailed guide for implementing the model to strengthen KTT in universities in developing countries.

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. All authors discussed and contributed to the final manuscript. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement:

Not applicable for this study.

Informed Consent Statement:

Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest

The authors declare no conflict of interest.

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Ethical statement

Ethical Statement is not applicable to our research. No primary data collection or experiments involving human subjects or animals were conducted during the course of our research.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Carlos Leon-Roa reports financial support was provided by National Doctoral Training Program of Call 840 of 2019 of Minciencias and the department of Huila, Doctorate in business administration from the University of San Buenaventura Cali and the company Agro360 SAS with its research group. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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