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Tecnura

https://revistas.udistrital.edu.co/index.php/Tecnura/issue/view/1201

DOI: https://doi.org/10.14483/22487638.19706

INVESTIGACIÓN

Factors Influencing University Technological Transfer in Colombia

Determinantes de la Transferencia Tecnológica Universitaria en Colombia

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Fecha de Recepción: 19 de Julio de 2022 **Fecha de Aceptación**: 22 de Junio de 2023

Cómo citar: Sarmiento-Suárez, J.E. y Galvis-Ciro, J.C. (2023). Factors Influencing University Technological Transfer in Colombia. *Tecnura*, **27**(78), 73-102. https://doi.org/10.14483/22487638.19706

Abstract

The formal university technology transfer (TTU) in Colombia can contribute significantly to the country's economic development. Based on the Theory of Resources and Capacities, this paper investigates the determinants of transfer in Colombian public and private universities. For this, we used structural equations methodology from data collected through a survey of 20 Colombian universities. The results of the estimates empirically confirm the significance of the financial, commercial, cultural, and human dimensions in the technology transfer process. Among the main factors that positively influence the TTU are: 1. the importance of external financial resources, 2. having a technological portfolio, 3. the time that transfer activities have been carried out, and 4. the people in charge's experience.**:** The study shows us that it is necessary to strengthen policies within universities and improve their articulation with firms to achieve more successful technology transfer processes.

Keywords: Technology transfer, structural equations, resources.

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Resumen

La transferencia tecnológica universitaria (TTU) formal en Colombia puede contribuir de manera significativa al desarrollo económico del país. Basado en la Teoría de los Recursos y las Capacidades, este trabajo investiga los determinantes de la transferencia en las universidades públicas y privadas colombianas. Para esto, es utilizada la metodología de ecuaciones estructurales a partir de datos recopilados mediante una encuesta a 20 universidades colombianas. Los resultados de las estimaciones confirman empíricamente la significancia de las dimensiones financiera, comercial, cultural y humana en el proceso de transferencia tecnológica. Entre los principales factores que influyen positivamente en la TTU, se encontró: 1. la importancia que tienen los recursos financieros externos, 2. el contar con un portafolio tecnológico, 3. el tiempo que se lleva realizando actividades de transferencia y 4. la experiencia de las personas encargadas. El estudio nos muestra que es necesario fortalecer las políticas al interior de las universidades y mejorar su articulación con las empresas para lograr procesos de transferencia tecnológica más exitosos.

Palabras clave: Transferencia tecnológica, ecuaciones estructurales, recursos.

1. Introduction

The university-industry relationship is important for the development of science and technology in each country (Méndez *et al.*, 2016) (Andrade *et al.*, 2016) (Liew *et al.*, 2012). In general, it can be said that this relationship is the nucleus for research, development, and technology transfer processes for economic growth. In the last decade, the creation of academic spin-offs has strengthened or revitalized the economy in regions that had a decline in their traditional industries (Gorman & McCarthy, 2006). Likewise, they have become a driving force for high-tech industrial clusters. (Rogers *et al.*, 2001). Consequently, the transfer of technology between the university and the industry is a relevant factor in creating competitive advantages for the host organizations and helps to generate wealth in the environment in which it is developed.

To strengthen the university-industry relationship, the United States, facilitated the passage of legislative acts such as the Bayh-Dole Act, the Stevenson-Wydler Technology Innovation Act, the National Cooperative Research Act, the Federal Technology Transfer Act, and the National Law of Transfer and Advancement of Technology. These laws created an environment conducive to strengthening the relationship between the university and the industry while facilitating technology transfer processes. In Latin American countries, laws have also been passed to enhance research, development, and innovation. In the Colombian case, Law 29 of 1990 to promote scientific research, Decree 585 of 1991 that created the National Council of Science and Technology, and Law 128 of 2009 that transformed

Colciencias stand out.

In Latin America, technology transfer processes in the business sector have not yet been consolidated despite enacting of different laws, although governments and universities have made great efforts to strengthen them (Vazquez, 2017). Since 2015, Latin American universities have sought to differentiate themselves in a career in which the importance of their work and the possibilities for development depend on the ability to evolve and find new ways and structures to put knowledge at the service of society (Arechavala & Sanchez, 2017) , Latin American universities have defined strategies to institutionalize the transfer processes and carry out the commercialization of goods or services to the communities closest to their surroundings.

In the case of Colombia, the problems have been diverse. Despite efforts to try to strengthen collaboration between universities and companies, these relationships have not been effective. (Méndez *et al.*, 2016) confirms a gap between entrepreneurs and researchers and identify factors affecting both. These factors include the lack of empathy between the parties, lack of conditions to obtain face-to-face feedback with the business community, lack of resources, poor communication between the employer, the researcher, and the government, among others (Méndez *et al.*, 2016)

It is also important to note that the Congress of the Republic of Colombia, to encourage the dissemination and transfer of technology from universities, approved Law No. 1838 of July 6, 2017. This law seeks to promote science, technology, and innovation in the country by creating technology-based companies. The objective is to promote innovative entrepreneurship in universities and take advantage of research results to benefit society (Congreso de Colombia, 2017). The norm enables public and private universities to create spin-offs, with researchers who develop essential technologies for the company, combined with tax incentives to exploit intellectual creations (Spin-Off Colombia, 2018).

Law 1838 is essential to promote technology transfer. The relationship between universities and companies is fundamental, but it is necessary to have a base of resources and capacities that create of a conducive and suitable environment for transferring university technology in Colombia. Not only is it enough for universities to declare themselves entrepreneurs, but they must also adapt their policies and organizational structures, giving space, for example, to the Research Results Transfer Office (OTRIs for its acronym in Spanish) (Algieri *et al.*, 2013). It is also necessary to help universities fulfill the role of administrators and protectors of the intellectual property generated within them, the gene-

ration of incentive policies for university personnel, among other relevant aspects in the dynamics of transfer and management of technological innovation (Berbegal *et al.*, 2015). In conclusion, the challenge for Colombian universities is related to detecting, analyzing, and managing the factors that influence technology transfer and, in this way, guiding administrators to improve these processes.

This paper focuses on inter-organizational university-company technology transfer based on the traditional theoretical model associated with business opportunities. The objective is to identify the determinants of the technology transfer process of the universities and analyze how the transfer is taking place in Colombian universities (public and private). For this, this research seeks to establish what are the existing relationships between the different resources (commercial, institutional, financial, human) of the universities that allow understanding the transfer process, based on the number of license agreements, technological cooperation, and creation of technology-based companies that have registered. Given the complexity of the situation to be studied, are used multivariate techniques, especially the partial least squares method for structural equations. The results show that financial, commercial, human, and cultural resources are significant for Colombian universities. Mainly, the indicators related to human capital determine factors, such as researchers, the technology portfolio that the institution has, the time it has been carrying out technology transfer activities, and the external financial resources that support research and development.

The structure of the document is as follows: In section 2, the literature review. Section 3 the methodology. Section 4 presents the estimates and results. Finally, section 5 presents the conclusions of the work.

2. LITERATURE REVIEW

There is scientific literature that shows how universities can make relevant contributions to increase the economic performance of companies and meet social needs, both in developed and developing countries. (Klofsten *et al.*, 2019); (Audretsch & Link, 2017); (Cassiman *et al.*, 2010); (Maculan & Carvalho, 2009); (Perkmann & Walsh, 2009).

Empirical studies demonstrated the contribution of technology transfer processes carried out, mainly, by universities in North America and Europe, which positively impacted their environments. The results of these processes were measured in terms of contributions to the creation of a specialized

workforce (Bound *et al.*, 2019); (Ishengoma & Vaaland, 2016); (Bessette, 2003), income obtained from patents, research and development collaborations (Siegel, Waldman, & Link, 2003), spillover effects (Audretsch *et al.*, 2005) and total college income, among other results (Goldstein, 1990).

On the other hand, the main expenses to develop the transfer are associated with the direct costs to build the innovations (Bessette, 2003); (Goldstein, 1990), the fees to register patents, and the personnel costs (Roessner *et al.*, 2013); (Siegel *et al.*, 2003); (Martin, 1998). Other studies also relate the economic impact of transfer processes with the change in the countries' gross domestic product (GDP) (Roessner *et al.*, 2013); (Martin, 1998).

In the case of developing countries, there is little evidence and information regarding the impacts and measurement of technology transfer from the perspective of universities. Most of the studies that exist are descriptive in nature and serve as a means of obtaining essential information to diagnose the current state of the transfer (Dutrenit & Arza, 2015); (Medina *et al.*, 2014); (Caldera & Debande, 2010); (Cimoli *et al.*, 2005).

In this regard, (Dutrenit & Arza, 2015) analyzed the interaction between universities and companies and took the countries of Argentina, Brazil, Costa Rica, and Mexico as a case study. They used two types of surveys; one aimed at R&D companies and managers, and the other at academic researchers. The study showed that the commercial channel is relatively unimportant in transfer processes, while informal interactions are relatively more used, such as conferences or different types of informal information exchange. Additionally, researchers from the four countries assigned greater importance to any channel other than companies. They also found that researchers from Brazil and Costa Rica tend to prefer traditional channels (publications and conferences). In Argentina, they like the service channel (consultancies), and in Mexico, the bidirectional channel (joint R&D). On the business side, channels are concentrated in the traditional media, like, hiring recent graduates.

In the case of Colombia, few studies have been carried out on the transfer of technology from universities to the industry to explain why some universities are more successful in these processes. There is, for example, the study by (Vasquez, 2008) , who considers that a more effective relationship between industry and the university in Colombia is essential. To this end, cooperation agreements are proposed that allow basic and applied research to move to a faster commercialization process to enable universities to obtain economic benefits in the short term.

In another study, (Arias & Aristizábal, 2011) consider that the community should be a natural recipient of the knowledge created by universities in addition to Industry and the State. In their results, the most common mechanisms used by the analyzed universities were public disclosure and public contracting to carry out social projects.

There is another crucial empirical work, and it is the one carried out by (Lizarazo *et al.*, 2015). This study found that public universities are interested in commercializing their technologies, but more than half have not achieved this objective, which could be the product of little experience in transfer processes.

(Méndez *et al.*, 2016), analyze the gap between the entrepreneur and the researcher in Colombia. This study shows some of the cognitive, affective, and situational factors that influence the approach of the company-researcher relationship in R&D or Transfer projects. According to (Méndez *et al.*, 2016), there is a gap of interests between the entrepreneur and the researcher because the actual needs of this complex relationship are not taken into account to achieve efficient and effective collaboration.

On the other hand, Donneys and Blanco (2016) affirm that the research of public and private universities in Colombia and the transfer of its results present difficulties due to the miniature tradition in this field and little investment by the state, which has caused some universities to undertake research corporately. In turn, according to (Donneys & Blanco, 2016), Colombian companies that invest in research do so mainly for technological modernization and use a tiny percentage for research and development. They also find that in Colombia, the orientation of researchers towards technology transfer is shallow, the promotion of business culture is weak, the university identification of opportunities to create companies presents problems and the technology transfer offices have a low level of independence in the aspects of financing, objectives, actions, and location. In short, according to the existing literature, the factors identified as critical in the technology transfer processes (human, cultural, institutional, financial, and commercial resources) present a dynamic that does not favor the transfer of technology from universities to the Colombian economy.

3. METHODOLOGY

Design.

Public resources obtain an essential return in the hands of the universities due to their potential so-

cial and economic effects. According to (Foltz *et al.*, 2000), public financing of university research processes is vital to strengthen technology transfer. Furthermore, authors such as (O'Shea *et al.*, 2005) consider that public resources make it easier for researchers to develop a specific variety of technology for subsequent commercialization.

Although public funding is essential, it is also important to note that studies indicate that industry funding is a necessary factor in technology transfer (see (Link & Siegel, 2005)). This type of alliance promotes, among other aspects, technology licensing activities and finances expenses for the protection of intellectual property (Chapple *et al.*, 2005). Given these aspects, the first hypothesis of the work is:

H1: Public and private financial resources positively affect university technology transfer.

On the other hand, as (O'Shea *et al.*, 2005), pointed out, having quality scientists promotes university transfer processes since it increases the probability of contributing basic and applied discoveries. Other studies, such as that of (Lach & Schankerman, 2004), consider that the size of the teaching body or the number of full-time researchers are critical inputs for technology transfer since the most prominent universities have greater capacities to carry out research work.

Transfer offices also play an essential role in the commercialization of technology; for this reason, authors such as (Chang *et al.*, 2006), consider that the size of these offices is a determining factor in the performance of the technology transfer process. Given this, the second hypothesis proposed in this work is the following:

H2: Human resources positively affect university technology transfer.

The transfer is a process that requires marketing skills. Authors such as (Mian, 1996) consider that intermediaries in transfer processes, such as having business incubators and marketing offices, play an essential role in the commercialization of technologies. For their part, (Lichtenthaler & Ernst, 2010) consider that the patent portfolios offered to the market are key in technology transfer processes since they are a sample of universities' past experiences in these processes. Given this, the third hypothesis

of the work is:

H3: Commercial resources have a positive impact on university technology transfer.

According to the academic literature, there are cultural factors that promote transfer processes. Authors such as (Siegel *et al.*, 2007) detected that the culture of the organization and the incentives help capture the collaboration of researchers towards the technology commercialization processes. On the other hand, (O'Shea *et al.*, 2005) consider that participation in royalties or profits positively affects technology transfer.
The work of (Siegel *et al.*, 2004) considers that having experienced employees in the transfer offices of the universities can more efficiently promote the commercialization of technology to the industry. Other studies show that the location of the university and the surrounding cultural context are factors that significantly affect the performance of university technology transfer. From this, the fourth hypothesis of the work is:

H4: Cultural resources positively affect university technology transfer.

In sum, to evaluate technology transfer in Colombian universities, this work proposes a theoretical model based on financial, cultural, human, and commercial factors as determinants of transfer. According to the hypotheses, the general model is the following:

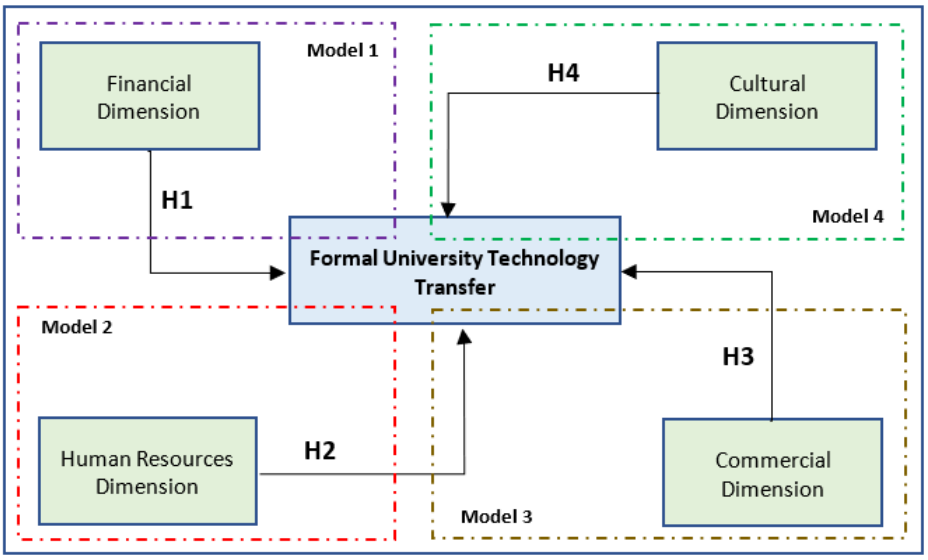

Figure 1. Research hypothesis

Source: *Authors*

Based on measurement scales from other empirical studies, the model variables were measured. The following table shows the number of indicators or items used to measure the different variables:

Table 1. Dimensions, indicators y authors

Source: *Authors*

Input variables		Authors
Dimension	**Indicators**	
Financial	4	(O'Shea, Allen, Morse, O'Gorman, & Roche, 2007; Chang, Chen, Hua, & Yang, 2006; Chapple, Lockett, Siegel, & Wright, 2005; Lizarazo M. , Jaime, Camacho, & Martinez, 2015; Bessette, 2003)
Human	4	(O'Shea, Allen, Morse, O'Gorman, & Roche, 2007; Lach & Schankerman, 2004; Friedman & Silberman, 2003; Chang, Chen, Hua, & Yang, 2006)
Commercial	4	(Mathews & Hu, 2007; Chapple, Lockett, Siegel, & Wright, 2005; Lichtenthaler & Ernst, 2010; Lizarazo M. , Jaime, Camacho, & Martinez, 2015)
Cultural	6	(Chapple, Lockett, Siegel, & Wright, 2005; Friedman & Silberman, 2003; Chang, Chen, Hua, & Yang, 2006; Carlsson & Fridh, 2002; Mathews & Hu, 2007; Siegel D. , Waldman, Atwater, & Link, 2004)
Output variable		
Formal University Technology Transfer	3	(Daim & Ozdemir, 2012; Siegel, Waldman, & Link, 2003; Simha, 2005)

Next, each item used by dimension is presented, along with the measurement scale used:

i) Indicators associated with the Financial Dimension: in this case, four items associated with owner financing, protection expenses, government financing, industry financing, and operating income were used.

Table 2. Measurement of the Financial Dimension

Source: *Authors*

Identifier	***Determinant***	***Measurement***
P4.2_Por_Rec_Pro_ID	Own financing	Indicates the percentage of own resources allocated by the university to R&D activities about operating income.
P5.2_Por_Rec_Pub_ID	Government financing	Shows the percentage of public resources received from State entities allocated by the university to R&D activities concerning operating income.
P6.2_Por_Rec_Priv_ID	Industry financing	Mesures the percentage of private resources received from companies destined by the university to R&D activities about operating income.

ii) Indicators associated with the Human Dimension: this dimension was measured by four items associated with the number of researchers and their quality, the size of the transfer offices, and the number of research groups.

Table 3. Measurement of the Human Dimension.

Source: *Authors, All variables are quantitative*

Identifier	***Determinant***	***Measurement***
P2.1_Num_Inv_S	Number of Senior researchers	It measures the number of researches classified as Senior accoding to Minciencias.
P2.2_Num_Inv_A	Number of associated researchers	It measures the number of researches classified as Associate accoding to Minciencias.
P16_Num_prof	Size of technology transfer offices	It presents the number of professionals who support the commercialization and technology transfer process at the university.
P2.5_Tot_Gr_A1_A	Number of research groups	It indicates the total number of research groups in categories A1 y A.

iii) Indicators associated with the Commercial Dimension: this dimension was measured by four items associated with the patent portfolio, international patents, invention disclosures, and interme-

diaries.

Table 4. Measurement of the Commercial Dimension

Source: *Authors, All variables are quantitative*

Identifier	***Determinant***	***Measurement***
P33_Pat_inv_con	National patent portfolio	It measures the total number of invention patents and utility models thet have been granted to universities by the SIC (Superintendence of Industry and Commerce) to date.
P35_Pat_inv_PCT	International patent portfolio	Indicates the number of invention and utility model patents that have been granted to universities by the PCT (Patent Cooperation Treaty) to date.
P31_Div_sel	Disclosures of the invention	Indicates the bumber of disclosures of technologies selected to protect per year between 2009 and 2018.
P12.2_Cant_Inter	Intermediaries	Measures the number of intermediaries that the university has to promote University Technology Transfer (Incubators and Techology Transfer Offices)

iv) Indicators associated with the Cultural Dimension: this dimension was measured by six variables related to the age of the transfer offices, the staff's experience, the tradition of research, the incentive policy, and the participation in royalties.

Table 5. Measurement of the Cultural Dimension

Source: *Authors, All variables are quantitative*

Identifier	*Determinant*	*Measurement*
P14.2_Ano_Ant_OTT	Transfer office age	Measures the number of years that the unit or position in charge of technology transfer and commercialization activities has been created.
P15_An_Exp_Resp	Transfer manager experience	Indicates the number of years of experience in charge or technology transfer and commercialization activities.
P0.2_Rank	Tradition in research	It contains the university's position concerning the U-Sapiens Classification Ranking of 2019.
P24.2_Can_Inc_TTU	Incentive policy	Indicates the total number of incentives used by the university to promote technology transfer.
P26_Porc_Reg	Royality share	Indicates the percentage of royalities assigned to inventors due to the commercialization of their inventions.
P41_IDIC	Innovation index associated with the university's location	It is a departamental innovation index that seeks to consider the enviroment where each university is located.

The primary variable of this study, technology transfer, was used three items to measure the transfer classified as formal. These were the sum of all the transfer indicators (the total number of paid and free license agreements, technological cooperation contracts, and the number of Spin-Off companies), the number of licenses, and the number of licenses generated revenue.

Participants.

This study used Colombian public and private universities with high research indicators as a data sample since, according to the literature, there is a strong relationship between research and technology transfer (Pich, 2020); (Audretsch & Link, 2017).

The specialized ranking in Colombia that classifies universities according to research criteria is the U-Sapiens ranking prepared by the consulting firm Sapiens Research, an entity recognized by the international observatory IREG. Based on the above, it was selected a sample of universities that were part of the 2019 classification. This classification determines only 74 institutions from more than 360 active higher education institutions in Colombia, which became the reference framework for this study. Within the 74 institutions that appear in the ranking, the headquarters of some of these

Table 6. Indicators of University Technology Transfer

Source: *Authors, All variables are quantitative*

Identifier	*Determinant*	*Measurement*
P10.1_Suma	Sum of all formal transfer indicators	It presents the total number of paid and free license agreements, technological cooperation contracts, and the number of Spin-Off companies carried out during five years (2014 – 2018) by the universities.
P38_Lic	Number of licenses	Indicates the number of licenses carried out by universities broken down by national or international without taking software licensing into account.
P39_Num_Lic_Ing	Number of revenue generating licenses	It mesuares the number of licenses that have generated income for universities.

institutions are included. By eliminating the venues, only 61 institutions remain in the order.

About the size of the sample, in this work, the criterion exposed by (Falk & Miller, 1992) and (Bentler & Chou, 1987), was used, which suggests collecting information from 5 cases for each latent variable that, in the more complex model presented in this work, contemplates three latent variables. Therefore, it is necessary to have a minimum number of 15 cases or units. Based on this criterion, information was initially collected from 15 public and private universities in Colombia in this study. However, additional information was collected from another five universities to obtain better results. In total, the sample size was 20 universities.

Instruments.

For the collection of information, this work used a survey made up of 40 questions that sought to measure the different aspects related to the financial, cultural, human resources, and commercial dimensions linked to the formal technology transfer process of the universities.

Different literature was reviewed to prepare the survey. The works carried out by authors such as (Lizarazo *et al.*, 2015), (Hsu *et al.*, 2015), (Yeverino, 2015), among others, who analyzed the technology transfer process in universities, were essential for the preparation of the survey. Before applying the study, it was validated with four experts in technology transfer; two researchers and two heads of technology transfer offices. They made observations and suggestions taken into account to prepare the final survey.

The information collection period was between June 2019 and May 2020. The people involved in providing the information were headed by the research vice-chancellors, academic vice-chancellors, and those responsible for the technology transfer processes of the University. The survey was sent via email and is available upon request to the authors.

4. RESULTS

This study uses the method of structural equations with least squares to estimate four models that correspond to the financial, commercial, cultural, and human dimensions. It is essential to note that the number of marketing mechanisms used by universities to bring technologies to the business sector (P10.1_Suma), the number of licenses carried out (P38_Tot_Lic), and the number of permits that have generated revenue (P39_Num_Lic_Ing) are the dependent variables used for each model. The results are presented below.

Model proposed for the Financial Dimension

The model presents two first-order constructs, called "Internal Resources" and "External Resources" Next, the proposed model is presented with the path coefficients and the external loads corresponding to the relationship between the constructs and their indicators.

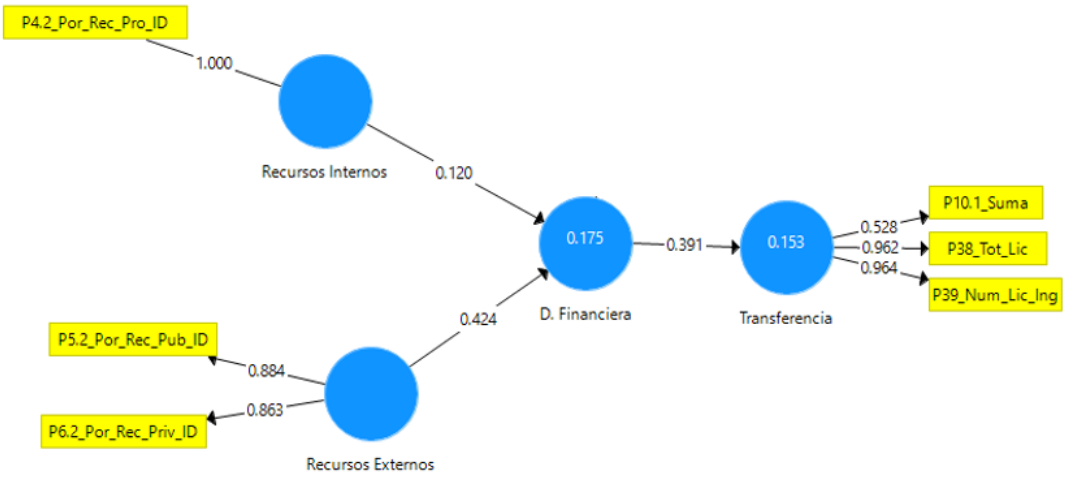

Figure 2. PLS Results proposed model Financial Dimension

Source: *Authors*

Next, the model goodness-of-fit statistics for the reflective and structural models are presented. Table

7, shows that the model meets: the criteria of convergent validity, internal consistency reliability, discriminant validity, and collinearity.

Table 7. Reflective measurement model results

Source: *Authors*

Variable latente	Indicadores	VALIDEZ CONVERGENTE		FIABILIDAD DE CONSISTENCIA INTERNA	
		Cargas (λ)	AVE	Alfa de Cronbach	Fiabilidad Compuesta
		≥ 0,40	≥ 0,50	≥ 0,60	≥ 0,60
	P4.1_Rec_Pro_ID	1,000	1,000	1,000	1,000
Recursos Externos	P5.1_Rec_Pub_ID	0,884	0,763	0,691	0,866
	P6.1_Rec_Priv_ID	0,863			
Transf_Tecn_Formal	P10.1_Suma	0,528	0,711	0,766	0,874
	P38_Tot_Lic	0,962			
	P39_Num_Lic_Ing	0,964			

Table 8. Discriminant validity

Source: *Authors*

VALIDEZ DISCRIMINANTE				
Criterio de Fornell – Larcker				
Variable latente	Dimensión Financiera	Recursos Externos	Recursos Internos	Transferencia
D. Financiera	1,000			
Recursos Externos	0,402	0,874		
Recursos Internos	0,039	-0,190	1,000	
Transferencia	0,391	0,832	-0,057	0,843

The proposed model showed that the two constructs (Internal Resources and External Resources) jointly explain 17.5 % of the variance of "Financial Dimension,.ªnd the latter explains 15.3 % of the endogenous construct Formal Technology Transfer variance.

The results show that only the indicators corresponding to External Resources present significant coefficients and effects. In addition, the coefficient associated with the Financial Dimension is essential in explaining the transfer (see table 9).

Source: Author. Note: * $p < 0,05$; ** $p < 0,10$; NS (Not significant).

The results show that only the indicators corresponding to External Resources present significant coefficients and effects (see, Table 11). Specifically, .External Resources"have a more significant effect $(0,424)$ on the Formal Technological Transfer of Universities (Transf_Tecn_Formal) and the coefficient

Table 9. Total effects significance test results

Source: *Authors*

	Efecto total	Valor t	Valor p	Significancia
D. Financiera -> Transferencia	0,391	3,760	0,000	*
Recursos Externos -> D. Financiera	0,424	2,916	0,004	*
Recursos Externos -> Transferencia	0,266	2,768	0,006	*
Recursos Internos -> D. Financiera	0,120	0,682	0,495	NS
Recursos Internos -> Transferencia	0,047	0,508	0,611	NS

associated with the Financial Dimension is essential in explaining the transfer.

Model proposed for the Commercial Dimension

Two constructs were proposed for the model that supports the Commercial Dimension: "Technological Portfolio.ªnd Ïntermediaries."Next, the proposed model is presented with the path coefficients and the external loads corresponding to the relationship between the constructs and their indicators.

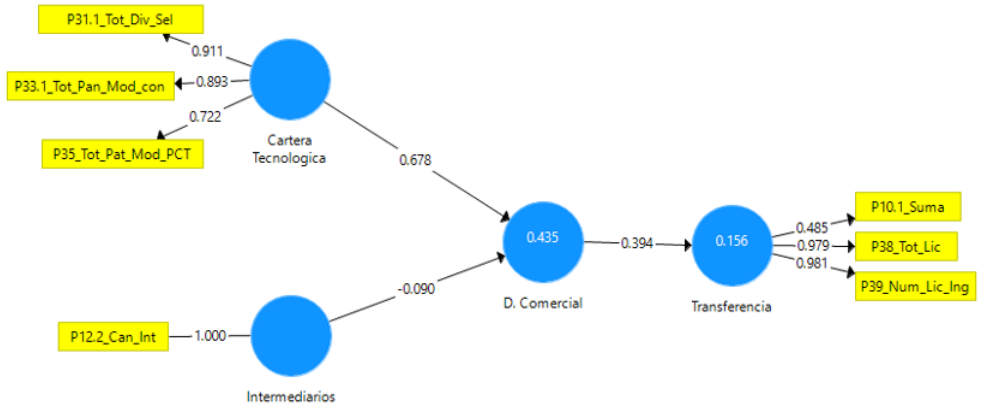

Figure 3. PLS Results proposed model Commercial Dimension

Source: *Authors*

The different tests are presented to determine the validity of the measurement model. According to the results, the model is reliable.

Table 10. Convergent validity and internal reliability results

Source: *Authors*

Variable latente	Indicadores	VALIDEZ CONVERGENTE		FIABILIDAD DE CONSISTENCIA INTERNA	
		Cargas (λ)	AVE	Alfa de Cronbach	Fiabilidad Compuesta
		≥ 0,40	≥ 0,50	≥ 0,60	≥ 0,60
Cartera Tecnológica	P31.1_Tot_Div_Sel	0,911	0,716	0,799	0,882
	P33.1_Tot_Pan_Mod_con	0,893			
	P35_Tot_Pat_Mod_PCT	0,722			
Intermediarios	P12.2_Can_Int	1,000	1,000	1,000	1,000
Transferencia	P10.1_Suma	0,485	0,719	0,777	0,876
	P38_Tot_Lic	0,979			
	P39_Num_Lic_Ing	0,981			

Table 11. Discriminant validity

Source: *Authors*

VALIDEZ DISCRIMINANTE				
Criterio de Fornell – Larcker				
Variable latente	Cartera Tecnologica	Dimension Comercial	Intermediarios	Transf_Tecn_Formal
Cartera Tecnologica	0,846			
D. Comercial	0,654	1,000		
Intermediarios	0,269	0,092	1,000	
Transferencia	0,834	0,394	0,346	0,848

In the proposed model, two constructs (Technology Portfolio and Intermediaries) jointly explain the 43.5 % of the variance of Çommercial Dimension,.ªnd the latter explains 15.6 % of the variance of the Transfer endogenous construct.

Table 12. Total effects significance test results

Source: *Authors. Note: * $p < 0,05$; ** $p < 0,10$; NS (Not significant)*

	Efecto total	Valor t	Valor p	Significancia
Cartera Tecnológica -> D. Comercial	0,678	7,137	0,000	*
Cartera Tecnológica -> Transferencia	0,267	2,707	0,007	*
D. Comercial -> Transferencia	0,394	3,828	0,000	*
Intermediarios -> D. Comercial	-0.090	0,482	0,630	NS
Intermediarios -> Transferencia	-0,035	0,353	0,724	NS

According to the results obtained and based on the relative importance of the exogenous constructs (path coefficients) that explain the technological transfer, it is observed that the Technological Portfolio is the crucial determinant in these processes, as opposed to the different types of intermediaries created to commercialize the technologies. In conclusion, the Technology Portfolio contributes significantly to the consolidation of the transfer process and has a more significant effect $(0{,}678)$.

The Technological Portfolio has a powerful total effect on the Commercial Dimension $(0{,}267)$ concerning the Total Effects. In contrast, the impact of the Intermediaries is negative $(-0{,}035)$, although the parameter was not significant.

Model proposed for the Cultural Dimension

For the model that supports the Cultural Dimension, three constructs are postulated: Characteristics of the OTRI (Carac_OTRI), Incentives, and Environment. Next, the proposed model is presented with the path coefficients and the external loads corresponding to the relationship between the constructs and their indicators.

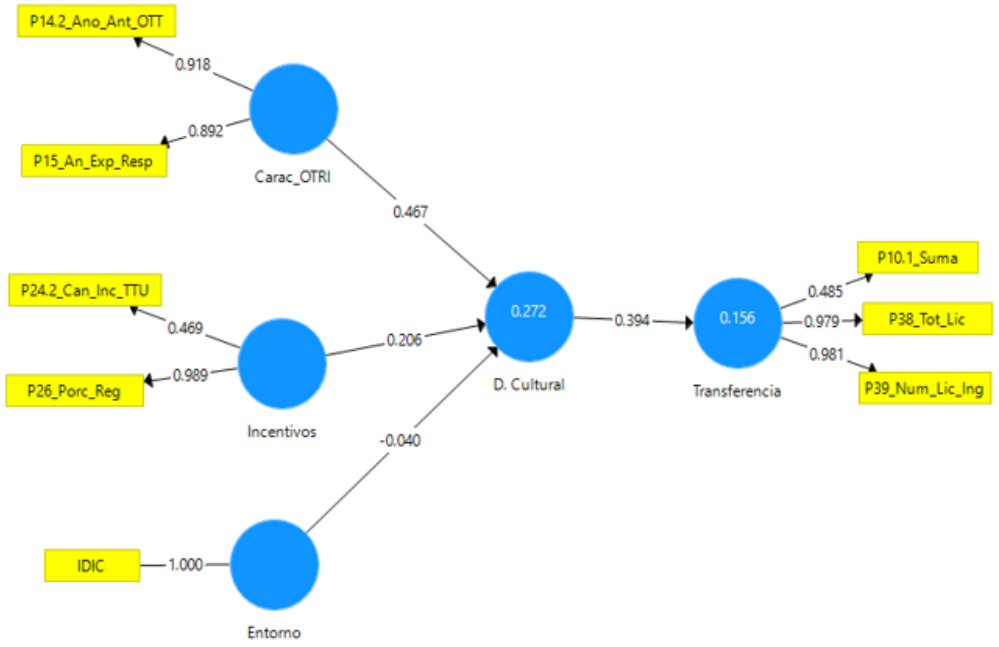

Figure 4. PLS Results proposed model Cultural Dimension

Source: *Authors*

To evaluate the model, we present the results concerning the evaluation of the individual reliability of the item, the internal consistency of the construct, the convergent validity, and the discriminant

validity. According to the results, the estimated model is reliable.

Table 13. Convergent validity and internal reliability results

Source: *Authors*

Variable latente	Indicadores	VALIDEZ CONVERGENTE		FIABILIDAD DE CONSISTENCIA INTERNA	
		Cargas (λ)	AVE	Alfa de Cronbach	Fiabilidad Compuesta
		≥ 0,40	≥ 0,50	≥ 0,60	≥ 0,60
Carac_OTRI	P14.2_Ano_Ant_OTT	0,918	0,819	0,781	0,901
	P15_An_Exp_Resp	0,892			
Incentivos	P24.2_Can_Inc_TTU	0,469	0,599	0,600	0,726
	P26_Porc_Reg	0,989			
Entorno	IDIC	1,000	1,000	1,000	1,000
Transferencia	P10.1_Suma	0,485	0,719	0,777	0,876
	P38_Tot_Lic	0,979			
	P39_Num_Lic_Ing	0,981			

Table 14. Discriminant validity

Source: *Authors*

VALIDEZ DISCRIMINANTE					
Criterio de Fornell – Larcker					
Variable latente	Carac_OTRI	Dimension Cultural	Entorno	Incentivos	Transf_Tecn_Formal
Carac_OTRI	0,905				
Dimensión Cultural	0,477	1,000			
Entorno	0,095	-0,009	1,000		
Incentivos	0,065	0,239	-0,061	0,774	
Transf_Tecn_Formal	0,240	0,394	-0,008	0,256	0,848

Since the results are different from zero, affirming that the model has predictive relevance in the latent variables analyzed (Hair *et al.*, 2014). In the model, the three constructs (Characteristics of the OTRI, Incentives, and Environment) jointly explain 27.22 % of the variance of the Çultural Dimension.ªnd, the latter, explains 15.6 % of the variance of the endogenous construct Formal Technology Transfer. According to the results (see table 15), only the parameter associated with the characteristics of the OTRI is significant in explaining the cultural dimension. The parameters associated with the environment and incentives does not define the Cultural Dimension.

Table 15. Total effects significance test results

Source: *Authors. Note: * $p < 0,05$; ** $p < 0,10$; NS (Not significant).*

	Efecto total	Valor t	Valor p	Significancia
Carac_OTRI -> D. Cultural	0,467	3,070	0,002	*
Carac_OTRI -> Transferencia	0,193	1,969	0,049	*
D. Cultural -> Transferencia	0,394	3,809	0,000	*
Entorno -> D. Cultural	-0,040	0,197	0,844	NS
Entorno -> Transferencia	-0,016	0,147	0,883	NS
Incentivos -> D. Cultural	0,206	0,622	0,534	NS
Incentivos -> Transferencia	0,081	0,458	0,647	NS

Model proposed for the Human Dimension

Two constructs explain the Human Dimension: Researchers.ªnd .ºTRI."Next, the proposed model shows the path coefficients and the corresponding external loads between the constructs and their indicators.

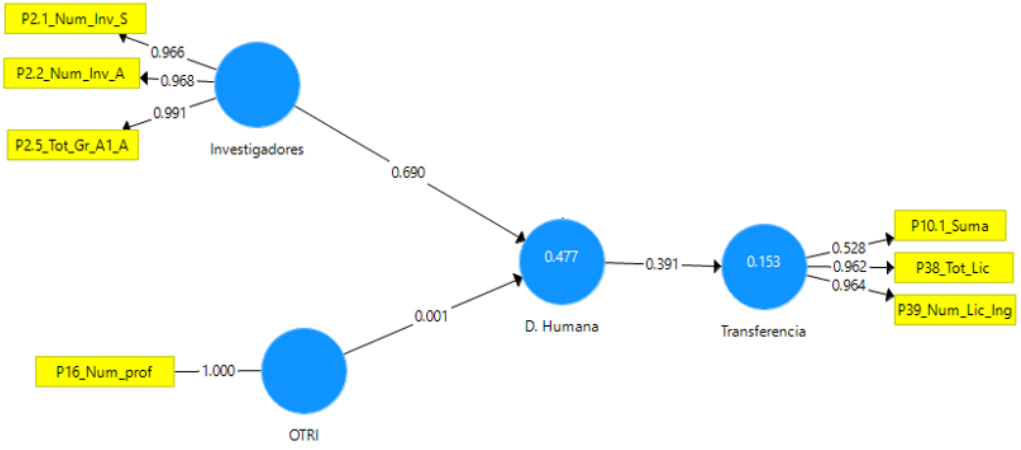

Figure 5. PLS Results proposed model Human Dimension

Source: *Authors*

The results of individual reliability, the internal consistency of the construct, the convergent validity, and the discriminant validity are presented to evaluate the model's reliability.

Table 16. Convergent validity and internal reliability results

Source: *Authors*

Variable latente	Indicadores	VALIDEZ CONVERGENTE		FIABILIDAD DE CONSISTENCIA INTERNA	
		Cargas (λ)	AVE	Alfa de Cronbach	Fiabilidad Compuesta
		≥ 0,40	≥ 0,50	≥ 0,60	≥ 0,60
Investigadores	P2.1_Num_Inv_S	0,966	0,950	0,974	0,983
	P2.2_Num_Inv_A	0,968			
	P2.5_Tot_Gr_A1_A	0,991			
OTRI	P16_Num_prof	1,000	1,000	1,000	1,000
Transf_Tecn_Formal	P10.1_Suma	0,528	0,711	0,766	0,874
	P38_Tot_Lic	0,962			
	P39_Num_Lic_Ing	0,964			

Table 17. Discriminant validity

Source: *Authors*

VALIDEZ DISCRIMINANTE				
Criterio de Fornell – Larcker				
Variable latente	Dimension Humana	Investigadores	OTRI	Transf_Tecn_Formal
Dimension Humana	1,000			
Investigadores	0,691	0,975		
OTRI	0,309	0,445	1,000	
Transf_Tecn_Formal	0,391	0,800	0,355	0,843

The R^2 values of the endogenous latent variables are in the following table. In the proposed model, the two constructs (Researchers and OTRI) jointly explain 47.7 % of the variance of the Human Dimension, and the latter explains 15.3 % of the variance of the construct endogenous called Formal Technology Transfer.

According to the results, only the Researchers are significant to the Human Dimension, while the coefficient associated with the OTRI was not significant. In addition, the coefficient associated with the Human Dimension mainly explains the transfer.

Table 18. Total effects significance test results

Source: *Authors. Note: * $p < 0{,}05$; ** $p < 0{,}10$; NS (Not significant).*

	Efecto total	Valor t	Valor p	Significancia
D.Humana -> Transferencia	0,391	3,841	0,000	*
Investigadores -> D. Humana	0,690	5,277	0,000	*
investigadores -> Transferencia	0,270	2,578	0,000	*
OTRI -> D. Humana	0,001	0,007	0,955	NS
OTRI -> Transferencia	0,000	0,005	0,996	NS

In the study, the number of Senior and Associate Researchers and the number of research groups (Researchers) have greater importance with a value of 0.690 than the number of professionals attached to the transfer units (OTRI), which has a value of 0.001. The above is consistent with the results obtained and based on the relative importance of the exogenous constructs (path coefficients) that explain technology transfer. In fact, in the Total Effects, it is observed that the Investigators have the most substantial total effect on the Human Dimension $(0{,}270)$ since the OTRIs have an impact equal to zero.

5. DISCUSSIONS

In the case of the Financial Dimension, it found that obtaining private financial resources is an essential factor for technology transfer. Similar results are reported by (O'Shea *et al.*, 2005), (Link & Siegel, 2005), and (O'Shea *et al.*, 2007). Second, public resources stand out as levers of transfer processes, as (Lach & Schankerman, 2004), (O'Shea *et al.*, 2005) and (Chang *et al.*, 2006). Finally, the allocation of resources of the universities for research and development processes and the expenses associated with the protection of intellectual property was not significant, contrary to what was stated by (Chang *et al.*, 2006), (Chapple *et al.*, 2005) and (Lockett & Wright, 2005).

Regarding the Commercial Dimension, the study shows that having a technological portfolio made up of: the number of invention disclosures (Chapple *et al.*, 2005); (Link & Siegel, 2005); (Siegel *et al.*, 2003) and the patent portfolio (Lichtenthaler & Ernst, 2010), is a significant component for technology transfer processes. On the other hand, having intermediaries (TTO and Incubators) as defined organizational structures within the university was not substantial, in contrast with previous studies on

the importance of incubators (Lichtenthaler & Ernst, 2010) or the transfer units (Mian, 1996); (O'Shea *et al.*, 2005); (Mathews & Hu, 2007). For this reason, the results indicate that Colombian universities should define invention disclosure processes and focus on having an established technological portfolio to facilitate their formal technology transfer processes.

About the Cultural Dimension, the study showed that the time transfer activities take and the years of experience of those responsible for carrying out the transfer processes are important variables to explain technology transfer. A similar result is reported by (Link & Siegel, 2005), (Chapple *et al.*, 2005) and (Lockett & Wright, 2005).

Incentives can be configured in structures that facilitate or hinder transfer processes, according to (Stezano, 2011). Despite its importance, the results related to the number of incentives show no statistical significance of these aspects in the formal transfer processes in Colombian universities. The incidence of the environment in the university-company transfer processes was not statistically significant either. This result thus constitutes a contribution of the present work to the literature.

For the Human Dimension, the relevance of human capital made up of the number of quality researchers (Senior and Associates) and the number of research groups (A1 and A) can be evidenced as the main determinants of formal transfer processes. These results have also been reported in the literature by authors like (Foltz *et al.*, 2000), (Friedman & Silberman, 2003) and (Lach & Schankerman, 2004). In contrast, the number of professionals dedicated to transfer activities was not significant.

6. CONCLUSIONS

Technology transfer seeks to expand innovative knowledge and new technologies in companies through formal and informal channels. Due to its importance, several studies have sought to establish the main factors that determine the dynamics of this transfer in the universities of developed countries. However, little has been explored in the context of emerging economies, and studies in the Colombian case are scarce. This work took a sample of data from Colombian universities. It integrated the technique of structural equations to identify the most critical factors of the transfer and made the following findings.

First, the significance of the financial, cultural, commercial, and human dimensions in the processes of technology transfer is confirmed theoretically and empirically. The results obtained show, in the

financial dimension, the importance of external financial resources (public and private) in the formal transfer processes, while own resources allocated to R&D were not significant. The foregoing could be linked to the fact that, in the majority of calls for the allocation of external resources, specific results are requested as a result of previous needs, whether from public or private organizations, while the internal resources allocated to R&D may not necessarily be due to needs of the environment and are subject to the institutional interests of the universities.

Concerning the commercial dimension, the study makes it possible to show that a statistically significant component is having a technological portfolio, which is the product of both the number of invention disclosures selected to be protected and the patent portfolio (filed before the SIC and the PCT) that the institution has. The important thing is that this technological portfolio must obey previous technical surveillance to identify potential clients interested in the technologies produced by the university and a series of capacities that allow the effective development of business. It should be noted that approximately half of the universities in the sample consider that they have an average level in aspects related to the ability to develop businesses, skills to negotiate with clients, and skills to detect and contract venture capital and seed funds. On the other hand, it was not significant in the study to have organizational structures created as intermediaries in the transfer processes, such as incubators or research results transfer offices.

The study also shows that, regarding the cultural dimension, the statistically significant determinants are associated with the time transfer activities carried out in the institution and the experience of those responsible for these processes. These criteria show that intermediaries in formal transfer processes are not necessary. The relevant thing is to have an entrepreneurial tradition and to have as a criterion the experience of those in charge of said processes. On the other hand, the number of incentives offered to teachers who are immersed in research and transfer activities was not significant, which invites Colombian university institutions to reflect on what could be the motivational factors that facilitate learning processes transfer. Another important finding of the study is that there was no incidence of the environment in the university-business transfer processes, which suggests a lack of articulation between the different actors that are part of the innovation ecosystem.

Regarding the human dimension, the relevance of concentrated human capital in the Colombian case to Senior and Associate researchers according to the Minciencias classification and the number of

A1 and A type research groups was evidenced. The preceding shows the importance of human resources as an agent that generates inventions; for this reason, it is necessary to strategically align this resource to the needs of society to achieve successful technology transfer processes that contribute to the environment and impact the development of the country. In contrast, the number of professionals dedicated to transfer activities was not significant, a result that goes along the same path as the non-significance of organizational structures in charge of transfer processes.

In short, the evidence indicates that the main factors to improve university technology transfer are: the development of a technological portfolio, the hiring of personnel experienced in transfer processes, high-profile researchers, and the consolidation of research groups of the maximum quality.

FUNDING

This article is a product derived from the doctoral thesis research "Determinants of university technology transfer in Colombia based on the theory of resources and capabilities," which was completed in June 2021

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