

# Motivations for University-Industry Interaction: A Typology of Academic Scientists at the National University of Colombia\*

Darío Reyes Reina<sup>1</sup>, Márcia Siqueira Rapini<sup>2</sup>, Ariane Agnes Corradi<sup>3</sup>

## KEYWORDS

Academic scientist, Colombia, interaction channels, motivations, university-industry interaction

## JEL CODES

O31, O32, O38

## RECEIVED

18/11/2021

## APPROVED

10/11/2022

## PREPRINT

05/08/2023

## PUBLISHED

15/12/2023

## SECTION

Aportes a la docencia y a la investigación

Esta obra se publica bajo una licencia Creative Commons Atribución-No\_Co-mercial-Sin\_Derivadas 4.0 Internacional (CC BY-NC-ND 4.0)

**Abstract:** In recent decades there has been an intensification of reflections on university-industry interaction as a mechanism for promoting innovation in countries, especially those characterized by a fragile collaboration between science and technology organizations and the productive apparatus. This article examines Colombian academic scientists who collaborate with industry, understanding their motivations and the interaction channels they use. To do this, a qualitative-type research study was conducted through semi-structured interviews with fifteen scientists and three employees involved in technology transfer programs at the National University of Colombia. As a result, we identified heterogeneous positions regarding the university-industry interaction and proposed four groups: i) "Circumstantial collaborators," who have sporadic contact with industry; ii) "Independent," who develop their own initiatives through spin-offs with sporadic contacts with industry; iii) "Integrated," who see industry as a strategic partner and do not wish to undertake entrepreneurship; and iv) "Academic entrepreneurs," who create spin-offs and see industry as a strategic partner. The main contribution of this work is the typology of academic scientists in the context of a Latin American country, which has implications for technology transfer offices in universities, with a recommendation towards creating typology-based programs, since the incentives that work for one type of scientist may not be the right fit for others.

**Suggested citation:** Reyes-Reina, D., Siqueira-Rapin, M., & Agnes-Corradi, A. (2024). Motivations for University-Industry Interaction: A Typology of Academic Scientists at the National University of Colombia. *Innovar* 34(91). e99300 <https://doi.org/10.15446/innovar.v34n92.99300>

\* This paper derived from master's thesis titled "University-Industry Interaction: Motivations and interaction channels preferred by researchers at a Colombian university. Case of the National University of Colombia - Bogotá," presented to the Federal University of Minas Gerais, Belo Horizonte (Brazil) by Darío Reyes Reina (<http://hdl.handle.net/1843/33961>). This study was funded by CNPq Process n. 314360/2020-4.

<sup>1</sup> M. Sc. in Technological Innovation and Intellectual Property; Researcher, Federal University of Minas Gerais; Belo Horizonte, Brazil; Author's role: intellectual; [dario.reyes.re@gmail.com](mailto:dario.reyes.re@gmail.com); <https://orcid.org/0000-0002-9431-3344>

<sup>2</sup> Ph. D. in Economics; Researcher, Federal University of Minas Gerais; Belo Horizonte, Brazil; Research group: Center for Development and Regional Planning (CEDEPLAR); Author's role: intellectual; [msrapini@cedeplar.ufmg.br](mailto:msrapini@cedeplar.ufmg.br); <https://orcid.org/0000-0002-8035-3003>

<sup>3</sup> Ph. D. in Development Studies; Researcher, Federal University of Minas Gerais; Belo Horizonte, Brazil; Research group: Center for Development and Regional Planning (CEDEPLAR); Author's role: intellectual; [acorradi@ufmg.br](mailto:acorradi@ufmg.br); <https://orcid.org/0000-0002-3023-3425>

## MOTIVACIONES PARA LA INTERACCIÓN UNIVERSIDAD-INDUSTRIA: UNA TIPOLOGÍA DE LOS CIENTÍFICOS ACADÉMICOS DE LA UNIVERSIDAD NACIONAL DE COLOMBIA

Resumen: en las últimas décadas se ha experimentado un crecimiento en el número de trabajos de reflexión en torno a la interacción universidad-industria como mecanismo para promover la innovación en los países, especialmente aquellos caracterizados por una colaboración frágil entre las organizaciones de ciencia y tecnología y el aparato productivo. Este artículo estudia a los científicos académicos colombianos que colaboran con la industria con el fin de comprender sus motivaciones y los canales de interacción empleados por estos. Con ese objetivo, se llevó a cabo una investigación de tipo cualitativo mediante entrevistas semiestructuradas con quince científicos y tres funcionarios involucrados en programas de transferencia de tecnología adscritos a la Universidad Nacional de Colombia. Como resultado, se identifican posiciones heterogéneas con respecto a la interacción universidad-industria, por lo que se propone la clasificación de estos actores en cuatro grupos: i) “Colaboradores circunstanciales”, que tienen contacto esporádico con la industria; ii) “Independientes”, que desarrollan sus propias iniciativas a través de *spin-offs* con contactos esporádicos con la industria; iii) “Integrados”, que ven a la industria como un socio estratégico y no desean emprender; y iv) “Emprendedores académicos”, quienes crean *spin-offs* y consideran a la industria como un socio estratégico. La principal contribución de este trabajo es la formulación de una tipología para los científicos académicos en el contexto de un país latinoamericano, lo cual tiene implicaciones para las oficinas de transferencia de tecnología en las instituciones de educación superior, a las que se hace un llamado a considerar la creación de iniciativas basadas en las tipologías propuestas, puesto que los incentivos que resultan ser de interés para un tipo de científico pueden no ser adecuados para otros.

Keywords: científico académico, Colombia, canales de interacción, motivaciones, interacción universidad-industria.

## MOTIVAÇÕES PARA A INTERAÇÃO UNIVERSIDADE-INDÚSTRIA: UMA TIPOLOGIA DOS CIENTISTAS ACADÊMICOS DA UNIVERSIDAD NACIONAL DE COLOMBIA

Resumo: nas últimas décadas houve um aumento do número de estudos sobre a interação universidade-indústria como mecanismo de promoção da inovação em alguns países, especialmente aqueles caracterizados por uma frágil colaboração entre as organizações de ciência e tecnologia e o setor produtivo. Este artigo estuda os cientistas acadêmicos colombianos que colaboram com a indústria, a fim de compreender as suas motivações e os canais de interação por eles utilizados. Com esse objetivo, foi realizada uma pesquisa qualitativa através de entrevistas semiestructuradas com quinze cientistas e três funcionários envolvidos em programas de transferência de tecnologia junto à Universidad Nacional de Colombia. Como resultado, foram identificadas posições heterogêneas com relação à interação universidade-indústria, portanto, propõe-se classificar esses atores em quatro grupos: 1) “colaboradores circunstanciais”, que têm contatos esporádicos com a indústria; 2) “independentes”, que desenvolvem as suas próprias iniciativas através de *spin-offs* e que mantêm contatos esporádicos com a indústria; 3) “integrados”, que veem a indústria como um parceiro estratégico e não desejam empreender; e 4) “empreendedores acadêmicos”, que criam *spin-offs* e consideram a indústria um parceiro estratégico. A principal contribuição deste trabalho é a formulação de uma tipologia para cientistas acadêmicos no contexto de um país latino-americano, o que tem implicações para as instâncias de transferência de tecnologia das instituições de ensino superior, que são convidadas a considerar a criação de iniciativas baseadas nas tipologias propostas, uma vez que os incentivos que interessam a um tipo de cientista podem não ser apropriados para outros.

Palavras-chave: cientista acadêmico, Colômbia, canais de interação, motivações, interação universidade-indústria.

## INTRODUCTION

With the purpose of building knowledge-based societies and boosting innovation, in recent decades reflections on university-industry (U-I) interaction have intensified. Different lines of research have emerged trying to understand the factors that stimulate and inhibit collaboration, the characteristics and forms it takes, the motivations behind collaboration efforts, and the results they generate (Ankrah & Al-Tabbaa, 2015).



This research focused on understanding a key player in U-I interaction: the academic scientist. This is an actor whose relevance is so significant that some researchers place them as the starting point of their U-I interaction studies, arguing that precisely at this individual level determinant decisions are made about interacting or not, as well as the characteristics that this interaction may have (Perkmann *et al.*, 2013). In this sense, different studies have taken researchers as the unit of analysis, identifying their motivations to collaborate with companies, the interaction channels they use, and attempting to systematize their positions on U-I interaction (Jain *et al.*, 2009; Lam, 2010; Miller *et al.*, 2018; Würmseher, 2017). It is noteworthy that most of these studies, including those covering literature reviews (Fabiano *et al.*, 2020; Mascarenhas *et al.*, 2018; Miller *et al.*, 2018; Perkmann *et al.*, 2013), are focused on European countries or the United States, while little is analyzed about the phenomenon in developing countries (Chatterjee *et al.*, 2017).

Taking into account the particularities of the national innovation systems (NIS) of Latin American countries, characterized by low collaboration between universities and industry (Albuquerque *et al.*, 2015; Dutrénit & Arza, 2015) and by incomplete learning processes that limit innovation because science and technology capacities are not integrated in productive sectors (Arocena *et al.*, 2018), it is necessary to investigate the role of academic scientists in the U-I interaction in this region. The underlying assumption of this study is that analyses made in developed countries do not necessarily apply to the Latin American context. To help fill in this gap, this research aimed to study academic scientists of a Colombian university that perform U-I interaction activities, specifically understanding their motivations to collaborate and the interaction channels they use.

In the following section, we present a literature review on academic scientists and U-I interaction. Then, we describe the qualitative approach that guided the research and the characteristics of participating scientists and of the National University of Colombia (UNAL, hereinafter). The main motivations of academic scientists to interact with industry and the interaction channels used are also presented. Afterwards, a typology that classifies academic scientists according to their positions on U-I interaction is proposed. Finally, we present a discussion focused on the theoretical and practical implications of our results, especially in the design of public policies in science, technology, and innovation in emerging countries.

## LITERATURE REVIEW

From a macro perspective, U-I interaction studies are part of a large discussion within the sociology and economics of science and technology about long-term capacity building and interaction between different institutions, such as universities, government, industry, and society. The NIS approach (Freeman, 1995; Lundvall, 1992; Nelson, 1993) helps us understand that beyond linear explanatory models, advances in science, technology and innovation are nourished by working in complex networks of multiple actors, whose collaboration influences competitive advantages in the globalized world.

This approach claims that universities play the role of human resources trainers and of business partners in generating innovation through collaborative research and development activities (Paranhos *et al.*, 2018). Specifically, it argues that U-I interaction strengthens the absorptive capacities of NIS firms, favoring knowledge exchange and the consolidation of competencies and routines that drive innovation within organizations (Fosfuri & Tribó, 2008; Sun & Anderson, 2010; Zahra & George, 2002). In fact, one of the main lessons learned is that within the great diversity of U-I interaction mechanisms, direct hiring or temporary work with professionals and scientists is a unique alternative to innovate, as it holds a series of capabilities, practices and tacit knowledge that are difficult to transfer by means of other mechanisms (Jensen *et al.*, 2007; Lundvall, 2006).

Additionally, the U-I interaction can also be analyzed from a micro perspective. That is, instead of focusing on large institutions, it takes individual actors as the unit of analysis, a bottom-up perspective that delves into students, academic scientists, entrepreneurs, and investors, among others, who make U-I interaction possible. This perspective relates with a neo-institutional approach of the interaction between individuals and institutions, in which individuals are agents whose motivations are driven by their subjective

perceptions of reality. The diversity in these subjective perceptions is explained by the individuals' limited rationality to make sense of the complexities of the environment. The resulting complex mix of motivations shape the individual's choices and patterns of interactions. These, in turn, shape institutions through the creation of rules and codes of conduct that ensure the reduction of uncertainty in exchange relations. Dialogically, institutions affect individual preferences and behaviors, charging a price on the expression of the individual's own preferences, and influencing individual choices (North, 1990, 1991). Once individual preferences and motivations are situational and context-dependent, they require systematic examination to understand and explain how social actors exert their agency within existing institutional boundaries (Scott, 2001). This is particularly relevant to understanding the engagement of academic actors in U-I interaction in developing countries. Here, we focused on academic scientists, trying to understand their personal characteristics, what their main motivations are for interacting with industry, and what channels they prefer to use.

Regarding characteristic traits, Shane (2004), in a significant study, points out that these researchers were generally characterized by being in a "mature" academic life cycle, that is, they had a long and outstanding trajectory and, in addition, held the particularity of having previous experience in entrepreneurship or working in the productive sector.

For their part, Perkmann *et al.* (2013) and Fabiano *et al.* (2020) reached similar conclusions and added other findings. These authors point to a higher prevalence of participation in U-I interaction activities by scientists with a high degree of seniority, outstanding academic trajectory, high productivity in publications, being a "star scientist," mostly male, with experience in applying for research funding, a large social network of contacts, and a previous trajectory in the productive sector. Apparently, an outstanding academic trajectory added to business experience outside academia are characteristic elements of these scientists.

Another important characteristic of academic scientists is their motivations for U-I interaction. From a psychological perspective, motivations are understood as objective-targeted actions that are persistent in time, activated by a set of needs, emotions, values, goals and expectations, and result from the interaction between the individual and the environment (Latham & Pinder, 2005; Salanova *et al.*, 1996). Here, the motivations for participating in U-I activities are influenced by the macro characteristics of the NIS and by the expectations, values, and personal goals of academic scientists.

These factors encompass varied themes, such as the desire to bring knowledge and technologies into practice (Shane, 2004), financial stimulus (Lam, 2011; Shane, 2004), quest for independence (Shane, 2004), reputation and status (Lam, 2011; Shane, 2004; Tartari *et al.*, 2014), a desire to continue to climb to higher positions in their professional career and personal development (Lam, 2011; Shane, 2004), in addition to the objective of continuing to strengthen their research lines (Perkmann *et al.*, 2013) and the potential social impact of their work (Iorio *et al.*, 2017; Lam, 2010; Perkmann *et al.*, 2013). In fact, due to the great variety of motivations, Lam (2011), for instance, have classified academic scientists into 3 large groups: the "gold," which refers to financial rewards; the "ribbon," related to the reputational/career rewards; and the "puzzle," which relates to the intrinsic motivation of the individual for the satisfaction of taking on a new intellectual and personal challenge.

Lam's (2011) and other typologies seek to synthesize the different ways in which academic scientists relate with the industry. Jain *et al.* (2009) argue that U-I interaction and entrepreneurship in universities would be generating an expansion and negotiation of the role of some researchers who, in addition to being academics, would have some entrepreneurial characteristics. Similarly, Miller (2018) points out the transformation of academics into two new roles, academic entrepreneurs, and entrepreneurial academics. Würmseher (2017) identifies three types of scientists corresponding to three distinct types of entrepreneurship approaches. Type 1, who directly takes on the role of an entrepreneur and does not look for people to help him in the commercial area; Type 2 who has no interest in managing a spin-off or getting involved in commercial activities and is only willing to offer technological knowledge; and Type 3, who would be willing to start a venture if he finds a partner with business experience.

Lam (2010) argues that there is greater diversity among scientists and proposes a typology, probably the one that has had the greatest impact on the literature, which classifies them into four groups: traditional academics in the "ivory tower," the hybrid academic, the hybrid entrepreneur, and the academic entrepreneur. Although Lam's proposal covers various levels of analysis, we consider that the focus of his typology is on interaction channels, understood as the various mechanisms through which universities and scientists transfer knowledge and development to companies. Thus, Lam (2010) finds that hybrid entrepreneurs and entrepreneurs use more commercial interaction channels, such as licensing and spin-off, while traditional and hybrid academics use collaborative interaction channels such as consulting or joint research.

Last, it is worth highlighting the study by Dutrénit and Arza (2015) on U-I interaction in four Latin America countries: Argentina, Brazil, Costa Rica, and Mexico. In order to understand the phenomenon, these authors divide the interaction channels used by academic scientists into four types: i) traditional channels, such as publications and participation in academic congresses; ii) services, such as consulting projects and staff training; iii) bidirectional, the case of joint research; and iv) commercial channels, such as patent licensing and the creation of spin-offs. With this division, their work focused on identifying and analyzing the channels most used by academic scientists, finding that in Latin America most of them explore traditional and service channels, while commercial channels are the least used (Dutrénit & Arza, 2015).

## METHOD

### Methodological approach

This research applies a qualitative approach as a strategy to understand and interpret the point of view and actions of people and social groups. The purpose is to understand the phenomena from the meaning that social actors give to these actions, for which it is essential to have a comprehensive view that covers their experiences, beliefs, values, feelings, and the contexts in which these meanings develop (Martínez, 2011).

Such an approach was chosen for two reasons. First, because it allows the voices of academic scientists to be heard; and second, because a previous literature review on U-I interaction identified that most studies



in this area have had a quantitative focus (Perkmann *et al.*, 2013), so qualitative approaches could broaden the understanding of the phenomenon, especially in a new development context.

Specifically, 18 semi-structured interviews were conducted, fifteen with academic scientists from UNAL and three with employees of the same university (table 1). These academic scientists were selected intentionally, with two inclusion criteria: i) they had conducted some activity of U-I interaction and ii) they belonged to different faculties and areas of knowledge, in order to capture possible singularities in their relationships with the productive sector. The research followed the principle of theoretical saturation to reach the final number of interviews, according to which data collection is interrupted “when it is found that new elements to support the desired (or possible in those circumstances) theorization are no longer deduced from the field of observation” (Fontanella *et al.*, 2011, p. 1).

For their part, the three participating employees oversaw the design and implementation of technology transfer and innovation programs at the university, all of them with more than five years of experience in the area. In this case, guided by the principle of triangulation, the intention was to add the point of view of key experts in the understanding of the phenomenon under study, since they know the operation of the university and have permanent contact with academic scientists who interact with the productive sectors, so they understand well their characteristics, expectations, and difficulties. Following the principles of saturation and triangulation in the selection of participants, the relevance of the sample and the methodological rigor of the study are ensured.

**Table 1.**

*Interviewees general information.*

ID number	Department	Gender	Years of teaching experience
1	Nursing	Female	Between 5 and 10 years
2	Nursing	Female	Between 5 and 10 years
3	Social service	Female	Between 5 and 10 years
4	Pharmaceutical chemistry	Male	Less than 5 years
5	Pharmaceutical chemistry	Female	More than 20 years
6	Electronic engineering	Male	More than 20 years
7	Electrical engineering	Male	More than 15 years
8	Systems engineering	Male	More than 20 years
9	Systems engineering	Male	More than 20 years
10	Development Research Center	Male	More than 20 years
11	Agronomy	Male	More than 20 years
12	Biotechnology Institute	Male	More than 20 years
13	Agronomy	Male	More than 20 years
14	Biology	Male	More than 20 years
15	Chemistry	Male	More than 15 years
Staff ID number	Area	Gender	Years of experience
16	Directorate of Extension, Transfer, Intellectual Property, and Innovation	Male	More than 5 years
17	Directorate of Extension, Transfer, Intellectual Property, and Innovation	Female	More than 5 years
18	Directorate of Extension, Transfer, Intellectual Property, and Innovation	Female	More than 5 years

**Source:** authors.

The initial contact with the academic scientists and the university staff was by e-mail. With those who voluntarily decided to participate, face-to-face interviews were conducted at the Bogotá campus of the UNAL between June and July 2019, upon signature of a consent form about the research objectives, their right to ensure their anonymity and, if desired, the possibility of excluding their testimonies from the research. Prior to their publication, results were shared with the participants, both academics and the university staff, to receive their feedback.

The interviews focused on understanding the academic scientists' positions about the U-I interaction, the main motivations to interact, and the interaction channels they prefer to use. Once conducted, interviews were transcribed and analyzed using thematic content analysis (Bardin, 2011). This analysis followed three key stages: i) Pre-analysis, through a floating reading to familiarize with the data and generate the first assessments; in this phase, an open coding of the transcripts was carried out, resulting in a first categorization of 352 statements; ii) Exploration of the material, consisting of critical reading exercises and comparative analyses, which help to create larger categories depending on the similarities and differences between pieces of evidence; and iii) Inference and interpretation of results, where more robust interpretations were carried out, the relationships between categories analyzed, findings were contrasted with the previous literature, and explanatory models generated. This resulted in a synthesis of academic scientists' motivations to interact with companies in three major groups (figure 1), the identification of the interaction channels they prefer to use (figure 2), and, by bringing these two elements together, the elaboration of a typology that clusters academic scientists into four groups with particular characteristics (figure 3).

### Context and study scenario

In Colombia, the NIS is still in the process of maturing. In 2019, investment in research and development (R&D) as a percentage of GDP in this nation was 0.32%, while in similar Latin American countries, such as Argentina, it was 0.46%, and in world leaders, such as Israel, reached 2.47% (OECD, 2022). According to the "Mission of Sages," an interdisciplinary group that recently (2019-2020) diagnosed the Colombian NIS, there are a series of structural flaws that affect the system: the main economic sectors are in low value-added activities that are not intensive in science and technology, universities are primarily responsible for R&D, and there are deficiencies in programs and institutions that facilitate technology transfer between universities and industry (Misión de Sabios, 2020). An example illustrates this situation well: in 2017, only 2.5% of the country's researchers worked for public or private companies, while 95.7% worked for universities and the rest for government or non-governmental organizations (RICYT, 2020).

Whitin this context, the study scenario chosen was the National University of Colombia (UNAL), due its relevance within the Colombian NIS. UNAL is the main public university in the country, concentrating the academic community with the highest capacities in science and technology in qualitative and quantitative terms. In 2018, it was estimated that approximately 11% of all registered research groups in the country and 26% of all doctoral programs belonged to this university (Universidad Nacional de Colombia, 2019). As for the intellectual production, UNAL is responsible for the publication of 12% of the national scientific journals (Universidad Nacional de Colombia, 2019). In addition, the University is also the national leading institution in deposits of resident patent applications, with 61 applications for evaluation between 2015 and 2017 (SIC, 2016, 2017, 2018).



## RESULTS

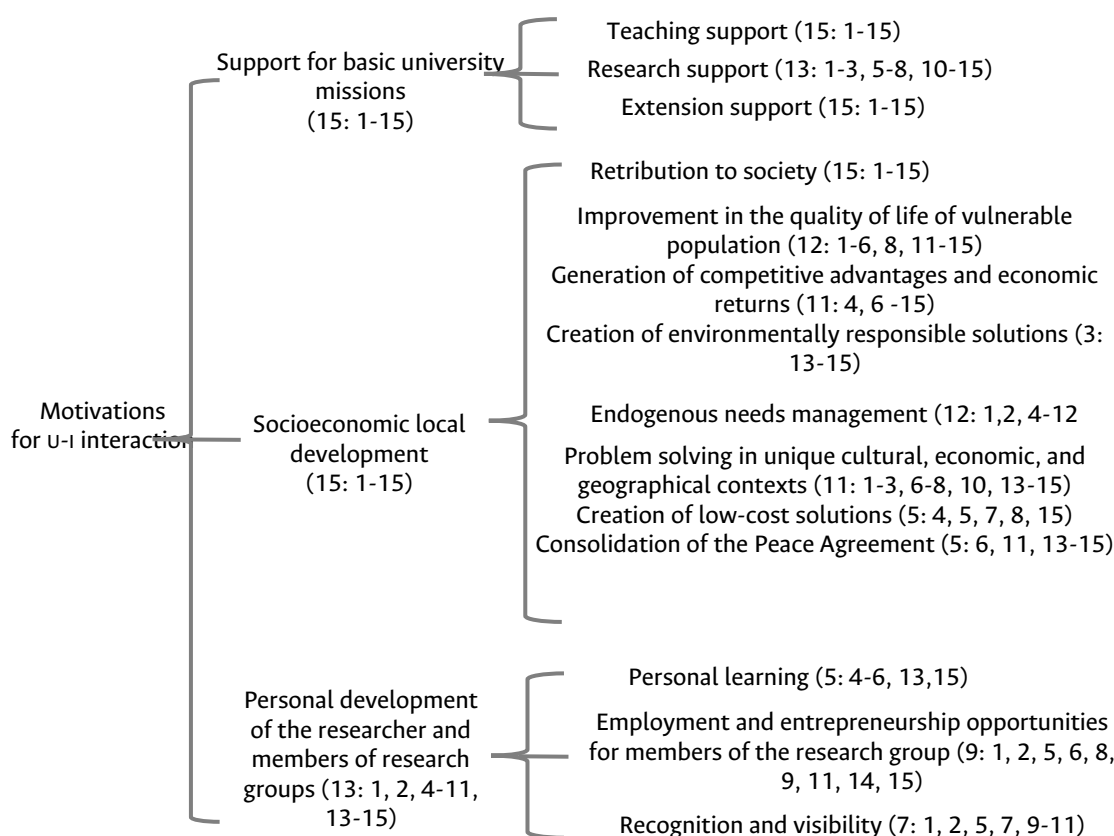
This section is divided into three parts. It first presents the results for the academic scientists' motivations to interact with industry, then describes the interaction channels they use, and closes with the proposed typology of academic scientists who engage in university-industry interactions.

### Motivations of academic scientists to interact with industry

Three categories of academic scientists' motivations for participating in U-I interaction were identified. The first group of motivations refers to the recognition that U-I interaction activities support the development of the three basic functions of the university: teaching, research, and outreach activities. The second group deals with the possibilities that U-I interaction offers for strengthening the role of the university as an actor contributing to local, economic, and social development. Last, the third group is related to the opportunities that U-I interaction offers for the personal development of researchers and other members of their research groups. Figure 1 summarizes the three categories of motivations identified with the 15 academic scientists interviewed. In parentheses, we refer to the number of researchers who expressed each motivation, followed by the numerical identification for each one. For example, the motivation "Research Support (13: 1-3,5-8,10-15)" was evidenced in thirteen researchers identified by the numbers 1 to 3, 5 to 8, and 10 to 15.

Regarding the first category of motivations related to the basic functions of the university, in the teaching mission, the role of interactions in students' integral education is valued by offering enriching experiences that enable students to get to know the social and labor realities they will face when they graduate. In relation to research, the participants recognize that interaction allows the identification of opportunities for new research studies that are relevant from the scientific and applied point of view, allowing the procurement of hard-to-reach inputs and access to particular sites for research. As for outreach, researchers see in U-I interaction projects an opportunity to strengthen the university's relationship with society, that is, the knowledge generated in the contexts controlled by the academy circulates in other spheres. For example, Scientist 7 points out that thanks to a U-I interaction project:

There was training with undergraduate students during the project and there were dissertations that developed from this; in research there was a paper in a high impact journal, participation [of researchers] in six congresses, and there were also patents. As for the outreach side, the project served to open a field that was about intelligent transport systems [...]. After that, we started to work in the Ministry of Transportation in structuring public policies for intelligent transport, so indirectly there were also extension results' (authors' translation).



**Figure 1.** Summary of the motivations of academic scientists. **Source:** authors.

Thus, U-I interaction generates learning for researchers and students as a result of efforts to practice their knowledge. This boost of learning through participation in activities that require specialized knowledge can be understood as a unique opportunity for “learning by solving [complex] problems” (Arocena & Sutz, 2010).

The second category of motivations among academic scientists is related to the idea that the traditional results of their work, publications and training of students are insufficient, so they actively seek to generate other types of benefits. It is in this context that researchers explore U-I interaction initiatives as a mechanism to promote greater impacts on the external environment of the university and to enhance local socioeconomic development.

Specifically, two subsets of motivations were identified in this regard, the first subset related to retribution to society and the second to meeting endogenous needs. Retribution to society was manifested with U-I interaction initiatives that directly or indirectly impacted the well-being of vulnerable populations, the desire of academic scientists to help generate competitive advantage in key sectors that subsequently translate into economic and social gains, and the intention to generate a positive environmental impact by transferring green solutions to productive sectors. The second subset refers to the potential of the U-I interaction in meeting needs endogenous to the country. Thus, academic scientists develop U-I interaction

projects seeking to solve Colombia's own problems, considering its cultural, economic, and geographical singularities, and the need to create low-cost technological solutions for low-income families and organizations. In addition, they respond to particular circumstances, such as the peace agreement signed with the FARC guerrilla group in 2016, through advisory services to new enterprises generated by former guerrillas and victims of the conflict. Regarding this motivation, Scientist 15 argued:

When we export fruit, we lose up to 30% through over ripening. It is so incredible that the packaging that Colombian industry uses is developed in Israel! Israel has no tropical fruits, so how are they going to develop packaging for tropical fruits? They don't. Chile, which is not a tropical country either, has a packaging industry, but no tropical country does. So, we said: "Let's develop this industry," and we are working on packaging for bananas, avocados and gulupa [a tropical fruit] (authors' translation).

The third category of motivations is related to the opportunities for personal and professional development that U-I interaction offers to academic scientists and the members of their research groups. On the one hand, researchers recognize that U-I interaction initiatives are a valuable source of personal learning, as most of these deal with complex problems that require multidisciplinary treatment, which represents an enriching challenge when trying to replace departmentalization and specialization with more integrated approaches that cover new areas of knowledge. Furthermore, they are motivated to participate in U-I interaction activities because it is a mechanism to obtain recognition and visibility, arguing that interacting with entities outside the university is seen as a sign of high degree of maturity of their research activities. Finally, researchers are interested in the U-I interaction, as they consider that it helps their professional growth and that of other members of their research groups, through the creation of new enterprises and greater opportunities to conquer job vacancies. It is worth noting that, in addition to personal concern, there is a strong motivation of researchers to offer their bachelor and graduate students job opportunities and avoid brain drain to other countries, as stated by Scientist 6:

I have a permanent position, a fixed salary, the spin-off is not my life project. Now, my project is to help others, but me, doing a company at this age? No, it is for people who are 30 or 40 years old. What I do is go along with them [...]. There are two members doing their Ph. D. in Europe and their alternative is to return at some point to Colombia; it will depend on what? That the spin-off happens, that it already starts offering them everything. They are exceptionally good professionals, we cannot lose them, where are we going to find people with these capabilities? (authors' translation).

### Interaction channels used by the academic scientists

The second focus of the research was the analysis of the interaction channels used by academic scientists to engage with industry, for which we drew on the proposal of Dutrénit and Arza (2015), who classify interaction channels into four: traditional, service, bidirectional, and commercial.

Preferences for each type of channel are summarized in figure 2 (p. 13). Traditional channels are represented by the lighter gray of the first column. As expected, all academic scientists explore traditional channels in their routine exercise of academic work, through publications, participation in academic congresses and training of qualified personnel. However, as was pointed out in the previous section on the motivations for interacting with industry, these academic scientists recognize that it is not enough to just publish and train students, what justifies delving into other types of channels for interaction. Scientist 14:

If we conduct research studies, publish papers, a few masters and Ph. D. students are trained, that's all very well. But after all that, what do people get? (authors' translation).

The second group of interaction channels that researchers were more accustomed to exploring were those in which industry was characterized by having a more passive role, acting as recipient of the knowledge transferred to it by the university, as in the case of continuing education courses, consulting projects, and laboratory services. Dutrénit and Arza (2015) call these channels “services,” characterized as such because knowledge flows unilaterally from the university to the industry in exchange for resources.

In the background appeared other interaction channels that require a more active participation by the industry, such as joint research and development projects, holding events in partnership with the productive sector, open innovation programs and funding graduate students who do their research on topics of interest to industry and academia. Dutrénit and Arza (2015) call these channels bidirectional, characterized by both parties providing key knowledge, which allows it to flow in both directions.

According to the participants, their attempts to develop bidirectional interaction channels have faced several difficulties, mainly due to the low demand for science and technology-intensive activities by companies, the predominance of a short-term vision that makes it impossible to develop projects that only generate returns in the long run, and the bureaucratic processes that hinder the establishment of partnerships. In summary, researchers hardly find an interlocutor within companies who understands the logic and timing of research and development projects. Scientist 14 and participant 17:

We try joint research, but this has a limit because, to produce a development, for the first development you have to work 10 years. Work and work every day. Which company is willing to economically follow up the process for all that time? With this company we were working for 6 years, we were already close to having a result (a new vegetable variety of rice) and they cancelled the funding allocated to our project (authors' translation).

We try to work on joint research, but it is difficult. Colombian companies have little capacity to implement their research processes, so when they say “research” is to hire you to do research. There is really no joint research, there is no one on the other side to help in the research. Participant 17 (authors' translation).

The last set of interaction channels are what Dutrénit and Arza (2015) call commercials, such as licensing and the creation of spin-offs, which were the least explored alternatives by the participating academic scientists at the Colombian university. In general terms, these interaction mechanisms are very recent, both at the university and in the country: it was only until 2017 that the Colombia Congress approved Law 1838 (Congreso de la República de Colombia, 2017), which regulates the participation of academic scientists in the creation of spin-offs. At the time of fieldwork for this study, the university's technology transfer office was still working on designing internal regulations and the standardization of the processes for the creation of these companies and patent licensing.

In this sense, most of the cases analyzed are initiatives that are under consolidation. Of the seven academic scientists involved in patent or trademark licensing processes, only one has an agreement signed with a partner that already generates royalties for the university. As for spin-offs, of the six academic scientists who have deployed this alternative, only two, from the same research group, formalized the creation of the company.

In summary, if we exclude the traditional interaction channels —understood to be part of the academic scientists' routine— we find that the service type channels (continuing education courses, consulting, and laboratory services) were the most deployed by these academic scientists. To a certain extent, the

predominance of interaction via services can be explained by the academic scientists' familiarity with the traditional linear model of innovation, in which the university oversees producing knowledge that it transfers to society through the dissemination of research results, technical reports and training of students. This is a phenomenon that fits the characterization of the "Consulting University" made by Arocena and Sutz (2005) about higher education institutions in Latin America. When constrained by the search for resources and the weaknesses of national innovation systems, the university ends up relating to the productive sectors through activities of low technical and scientific complexity.

Under this logic, it is not surprising that bidirectional and commercial channels were the least used by academic scientists as they face a series of circumstances that constrain their exploitation. However, this does not mean that these academic scientists do not exploit these types of interactions. In fact, some testimonies indicated that interaction with the industry via service provision or through small initiatives is the starting point to initiate bidirectional and commercial interaction channels with greater assertiveness as the result of a learning and interaction process between the agents.

Some of the testimonies suggest that the interaction can become more sophisticated over time. Starting with small and simple interactions, following the model of "consulting" university, can facilitate the gradual creation of trust relationships and the alignment of objectives, capacities, and commitment between the parties. In other words, long-term relationships could be associated with greater complexity in the university's interaction with industry, an argument consistent with Fischer *et al.* (2018), who highlight the importance of higher quality of interactions over their quantity. That is, the U-I interaction is a cumulative process. Scientist 15, for example, argued about his research group interaction with a chemical company:

We started with a quite simple first job, some problems they had with stains on certain materials. They saw that we solved it, and we gained their trust. This made them hire a chemist (member of the research group). Soon, more serious problems came, and the relationship began to expand, until the relationship became extraordinarily strong. They already have four chemists hired (members of the research group). We have done many jobs together. Every time they have a problem, they call us (authors' translation).

	Department	Interaction channels									
		Traditional (15)	Services			Bidirectional			Commercials		
			Extension courses (10)	Consulting (9)	Laboratory services (7)	Joint R&D (8)	Events in partnership with the industry (4)	Open innovation (1)	Funding for graduate students (1)	Spin-off Creation (6)	Patent Licensing (5)
Type 1: Circumstantial collaborators	1. Nursing										
	2. Nursing										
	3. Social service										
Type 2: Independent	4. Pharmaceutical chemistry										
	5. Pharmaceutical chemistry										
	6. Electronic engineering										

		Department	Interaction channels										
			Traditional (15)	Services			Bidirectional			Commercials			
				Extension courses (10)	Consulting (9)	Laboratory services (7)	Joint R&D (8)	Events in partnership with the industry (4)	Open innovation (1)	Funding for graduate students (1)	Spin-off Creation (6)	Patent Licensing (5)	Brand Licensing (2)
Type 3: Integrated	7.Electrical engineering												
	8. Systems engineering												
	9. Systems engineering												
	10. Development Research Center												
	11. Agronomy												
	12. Biotechnology Institute												
Type 4: Academic entrepreneur	13. Agronomy												
	14. Biology												
	15. Chemistry												

**Figure 2.** Preferred U-I interaction channels. **Source:** authors.

### Typology of academic scientists who interact with the industry

Considering the various positions of these academic scientists with respect to U-I interaction, in particular their motivations for establishing relationships and the channels they exploit to do so, a typology that classifies them into four profiles is proposed. Figure 3 shows these four profiles, as well as the classification of the fifteen academic scientists interviewed.

The horizontal axis shows the type of relationship that academic scientists establish with industry. Academic scientists located in the quadrants to the right-hand side identify several shared objectives and benefits with industry, which facilitates collaboration; they see industry as a strategic partner and systematically exploit multiple interaction channels. These academic scientists were the ones who most used bidirectional interaction channels, possibly indicating a recognition of companies as interlocutors who have valuable knowledge and skills. For example, eight of the nine researchers on the right-hand side of figure 3 have advanced joint research projects with the industry and two of them were the only ones who developed open innovation initiatives or had partnerships with the productive sector to finance the training of graduate students and members of the research group working in areas of mutual interest.

The left-hand quadrants group the academic scientists who have sporadic contacts with industry and explore a few interaction channels. For them, on many occasions, the objectives and logic of university and



industry are divergent: for the university, the generation of knowledge and the fulfillment of a social function take a prominent role, while for the industry the main motivation is the generation of economic benefits.

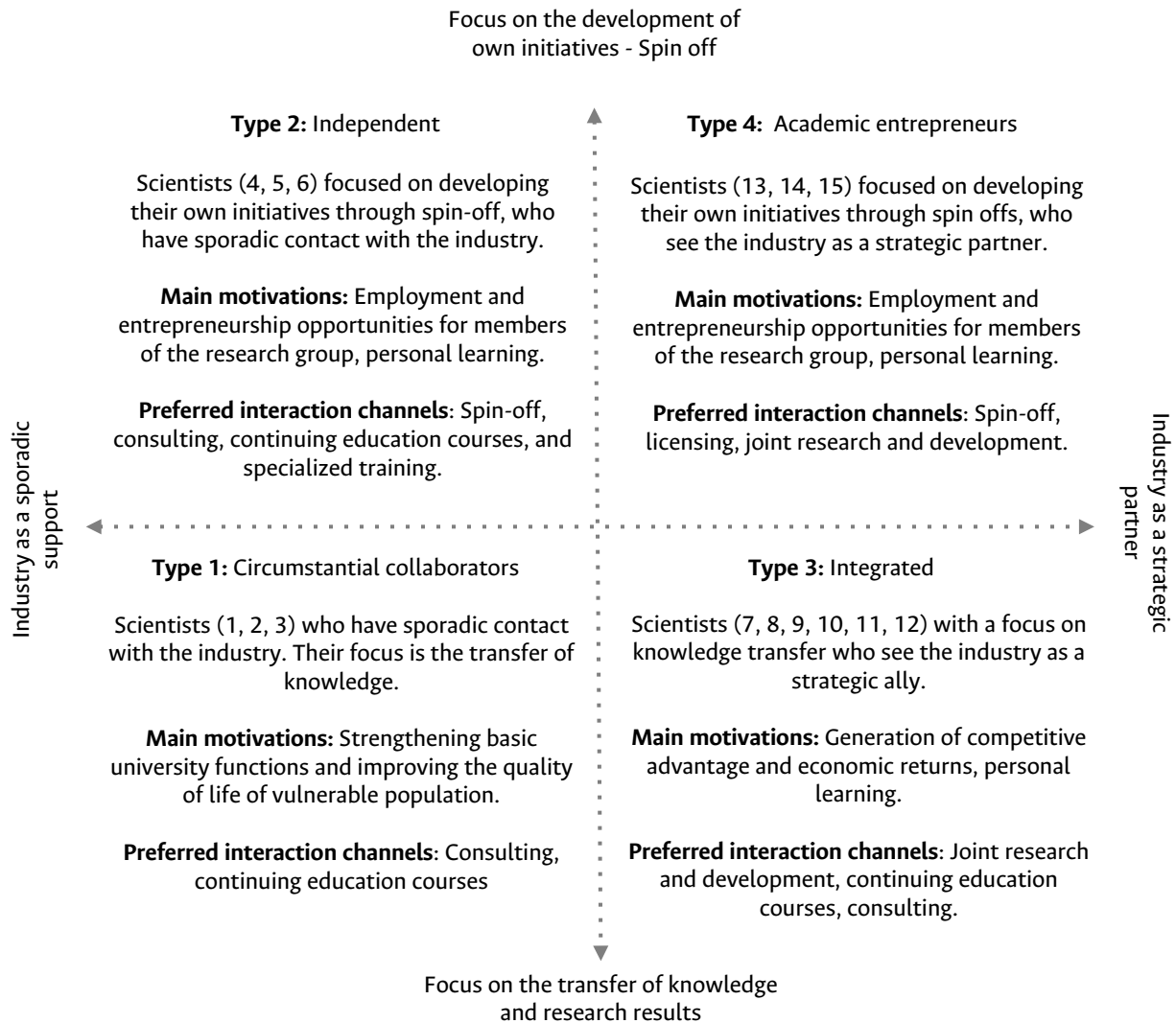
Although these academic scientists have participated in projects in which they have interacted with industry, unlike those on the right-hand side, interaction is not considered a strategic objective that they should systematically pursue. Hence, collaboration is circumstantial and implemented in some initiatives in which they realized that involving the productive sector generated specific advantages to be able to take “things into practice,” fulfill a social function or relate to some communities.

These scientists allocate greater relevance to the service-type interaction channels, especially continuing education courses aimed at company employees, which have been offered by five of the six academic scientists located on the left-hand side of figure 3. This phenomenon, as has been discussed, is probably related to the greater familiarity of academic scientists with the idea of the university as a producer of knowledge and the industries and employees as recipients of that knowledge.

Conversely, the vertical axis is related to academic scientists’ preferences in taking the results of their research and technological developments to society. At the top are located the scientists who prefer to promote their own initiatives, such as spin-offs, while at the bottom are those driven by transferring knowledge to other actors rather than creating a personal enterprise.

Academic scientists located at the top are characterized by preferring to “get their hands dirty” and leverage a spin-off to take their knowledge and technologies to society. In international literature, the possible economic gains have been pointed out as a fundamental motivation behind the scientists who create these companies (Lam, 2010). However, in the Colombian case, this statement needs to be nuanced, since other factors end up being more relevant.

It is striking that, to a certain extent, academic scientists are driven by the search for independence and the desire to have control over their own development. Most researchers were characterized by having already established professional trajectories. In this context, one reason for creating a spin-off was the desire to offer development opportunities to students and members of the research group. Additionally, given the low absorption capacity of the Colombian industry, spin-offs, rather than licensing, emerge as an alternative to effectively “put things into practice” and give back to society.



**Figure 3.** Typology of academic scientists who interact with industry. **Source:** authors.

For academic scientists at the bottom, the scenario is quite different. Generally, they prefer to keep some limits in relation to the business world, choosing to interact with or encourage third parties to bring the university developments to society. Based on their specialized knowledge and methodological rigor as academics, the focus of these scientists is on building capacities among NIS actors, training qualified personnel, and transferring knowledge and technology. Although these scientists recognize the importance of entrepreneurship and science and technology-intensive industry, they do not wish to lead or be part of an academic spin-off, they do not show the “entrepreneurial spirit.” For them, it is more rewarding to remain focused on their basic and applied research and let other actors, such as alumni or external companies, via licensing, take their developments and knowledge into practice. As a worker for the Directorate of Extension, Transfer, Intellectual Property, and Innovation states:

Not all scientists have to go out to manage companies. Some continue researching and can motivate alumni, graduate and undergraduate students or other people to take advantage of these developments (Expert 17).

Continuing the model, if we consider the vertical and horizontal axes, we have four quadrants that correspond to distinct types of researchers: circumstantial collaborators, independent, integrated, and academic entrepreneurs.

#### *Circumstantial collaborators*

Circumstantial collaborators are academic scientists who have sporadic contact with industry, and their focus is on the transfer of knowledge and research. They generally believe that the goals and logic of industry and university are different. Thus, they are only motivated to interact with the industry in narrowly specific circumstances, for example, when they consider that interaction is fundamental to strengthen the basic functions of the university and to help fulfill a social function.

These researchers are more familiar with service-type interaction channels, particularly with the offering of continuing education courses to employees in the productive sector. However, among the academic scientists in this profile, a unique initiative of brand registration and possible licensing of a health program designed by two nursing professors was evidenced. These two academic scientists decided to explore this interaction channel due to the opportunities it offered for strengthening the group's solidarity extension projects, i.e., to reinforce the basic missions of the university and its social role.

The three academic scientists classified in this profile are characterized by being highly active, interacting with government entities and working in the formulation of public policies, which could be related to the characteristics of their areas of expertise: social work and nursing.

#### *Independent researchers*

This category corresponds to academic scientists focused on the development of their own initiatives via spin-off, with sporadic contact with companies. These researchers highly value the fact that they directly transfer their knowledge and technological developments to society through spin-offs, which offer opportunities for personal and professional growth to the members of the research groups they lead. In this sense, they are also characterized by striving to consolidate interdisciplinary teams or by learning in other important areas such as management, finance, and marketing.

Compared with the integrated and academic entrepreneur profiles, independents exploit fewer channels of interaction, using mainly services. We highlight the apprehension of these researchers with possible commercial licensing to third parties, possibly related to their desire to keep track of their developments, and the low absorption capacity of science and technology of local companies.

The three academic scientists classified in this profile acted in areas typical of Pasteur's quadrant: biotechnology, which is supported by strong intellectual property through patents that guarantee the control of commercial exploitation, and computer science, whose developments are sustained in tacit knowledge that is difficult to copy and that generally requires low investments for scalability.

#### *Integrated researchers*

They are academic scientists focused on the transfer of knowledge and research, who see industry as a strategic partner. These researchers attach significant importance to the interaction with industry; they believe that both parties can benefit from the relationship. However, this interaction with the productive

sector does not mean that they are willing to undertake and create a spin-off, as they prefer to delegate this activity to their alumni, take licenses with third party companies or simply engage in knowledge transfer activities.

These researchers exploit an important variety of U-I interaction channels. In particular, the use of bidirectional channels stands out, which is related to the recognition of valuable skills and knowledge by the industry. This phenomenon could also be related to the fact that those academic scientists classified in this quadrant were characterized by acting in areas with a relevant applied component, such as engineering, economics and innovation management, agronomy, and biotechnology.

#### *Academic entrepreneurs*

These are academic scientists with a focus on developing their own initiatives via spin-off and who see the industry as a strategic partner. Similar to integrated scientists, academic entrepreneurs place significant importance on relationships with industry and exploit a wide variety of interaction channels. In contrast with their integrated peers, these scientists are eager to create their own spin-offs and have been working to consolidate interdisciplinary teams and learn about other areas such as management, finance, and marketing. The fact that researchers wish to become entrepreneurs does not mean that they are not open to licensing. For some of them, licensing is considered the first step towards getting to know the market and acquiring some competences that they will soon apply in their spin-offs.

It is important to note that the three academic scientists classified in this profile had enterprises focused on the agricultural sector, a situation that can be explained by the fact that this is one of the few economic sectors in Colombia that has a sectoral innovation system with a relevant trajectory (Velasco, 2015).

## DISCUSSION

The discussion section is developed into two sections. The first explores the theoretical implications of this study and the second discusses its practical implications.

### **Theoretical implications**

This article describes the motivations of academic scientists to interact with industry and the interaction channels they use in the context of a Latin American university. Reflecting on their motivations, it becomes clear that scientists recognize that, given certain conditions, interaction with the productive sector drives the creation of synergies with a positive impact on those involved. However, it was also clear that, for them, it is not just about interacting by interacting, but about how this interaction strengthens the teaching, research, and outreach missions of university institutions, opens possibilities for local socioeconomic development, and how it can offer opportunities for personal and professional development for them and for the members of the research groups they lead.

The interest of academic scientists in supporting social and economic development can be read within a long trajectory in Latin America that emphasizes the university's social function, which would reinforce the argument of some Latin American researchers about the broad role of this institution in solving national problems, helping social transformation, and improving the quality of life of the population (Gómez &

Figuerola, 2011; Ortiz-Riaga & Morales-Rubiano, 2011), so they recommend talking comprehensively about the university-society relationship (Malagón, 2006; Morales-Rubiano *et al.*, 2015a; Paranhos *et al.*, 2018).

As for the motivation to interact with the productive sector as a mechanism for professional growth, this is a phenomenon already raised by literature (Lam, 2011; Shane, 2004). However, this research unveils some previously unreported characteristics, such as a greater concern of academic scientists with the generation of job opportunities for their students and other members of their research groups, avoiding, among other issues, brain drain.

Our analysis showed that the channels for interaction most exploited by these academic scientists, in addition to traditional mechanisms, such as publications, were services mostly in the form of consulting or continuing education courses for employees in the productive sector. This finding can be understood within the characterization of “consulting university” made by Arocena and Sutz (2005) on higher education institutions in Latin America, which, inserted in fragile NIS and with industries that demand little science and technology, end up relating to the productive sector through service-type interaction channels. However, our research also suggests that this characteristic of the university and its scientists as “consultants” may, under certain circumstances, change over time. The gradual creation of long-term and trust relationships and the greater knowledge of the objectives and capacities of the actors involved are fundamental elements for the university to establish stronger and more systematic relationships with the productive sector.

Regarding bidirectional and commercial interaction channels, these were the least explored by academic scientists due to a series of difficulties, mainly the low demand for intensive activities in science and technology by companies, their short-term vision and their bureaucracy, in addition to researchers’ weaknesses in terms of technology transfer and intellectual property. Considering that researchers have repeatedly expressed difficulties in finding interlocutors in industry who understand the logic, time, and importance of academic research, it could be said that most companies have a low capacity for absorbing new technological developments from the university. From a macro perspective, legislative instruments to stimulate U-I interactions are too recent in Colombia to show results at this early stage.

Previous research had identified a series of characteristics of academic scientists and a set of conditions to strengthen the university-industry interaction in the Colombian context, highlighting the orientation of researchers to apply their knowledge and try to solve challenges in the productive sector, and the openness to collaborate in joint research and agreements (Morales-Rubiano, 2015b). Our research deepens into these insights, as we demonstrate an important variety of positions of academic scientists on university-industry interaction and propose a typology in four quadrants based on the diversity of motivations and interaction channels.

In this line, other typologies of scientists have appeared in the international literature, perhaps the most recognized being the one proposed by Lam (2010), in the United Kingdom, who, starting from two poles, “the traditional researchers in the ivory tower” and “entrepreneurial scientists,” gradually divides them into four groups: traditional, traditional hybrids, entrepreneurial hybrids, and entrepreneurial scientists.

We consider that Lam’s classification (2010) is based, mainly, on the apparent progression towards the preference for commercial interaction channels, not including other types of hues relevant in Latin America. The profiles that we call integrated and independent can hardly be explained under Lam’s model (2010):

integrated are characterized by recognizing in the industry a strategic partner, so that, according to Lam's typology, they could not be traditional nor traditional hybrids. On the other hand, our research indicates that most of these scientists also did not intend to explore commercial interaction channels such as spin-offs or licensing, so that they would neither fit in the classification of entrepreneurial hybrids nor entrepreneurial scientists.

As for independent researchers, we characterize them as academic scientists who collaborate only circumstantially with the industry, which would correspond to Lam's (2010) traditional or traditional hybrid profiles. However, these scientists have a desire to undertake and promote their own spin-offs, so they would also be researchers with an entrepreneurial profile.

In short, what our findings point out is that the typologies proposed in other countries do not necessarily fit Colombian reality nor probably the context of other Latin American countries with similar NIS. Morales-Rubiano (2015b) had identified, for example, different degrees of involvement of Colombian academic scientists with industry: some who preferred to do it through third parties, such as their students, and others more open to collaboration and the exploitation of gaps in the market. Likewise, their study identified that some professors had greater experience and recognition within the industry, while others favored academic recognition. These results of previous studies, which could even seem contradictory, make sense with the proposed typology, since we learned that some academic scientists prefer to do the transfer directly, others do not, and others see the industry as strategic allies, while others as sporadic collaborators.

The cases of integrated and independent scientists are emblematic due to their particularities. On the one hand, although integrated scientists value the interaction with the productive sector, they do not have the personal and professional objective to undertake and create a spin-off, they do not have this social expectation that seems to be stronger in other countries. In contrast, the independent ones, partly influenced by a business context with low absorption capacity, hardly interact with the productive sector, but find in the creation of spin-offs the possibility of putting their research into practice.

### Practical implications

The mapping of motivations and channels of interaction used by scientists, and the proposed typology, in addition to serving as an analytical tool, have implications for the formulation of public policies to foster innovation, university-industry interaction, and the performance of technology transfer offices at higher education institutions. Even considering that the results of this study should be revised according to the characteristics of each country and university, they can be guidance and reference in contexts with NIS similar to those in Colombia, as in the case of Latin American countries or other regions in the process of technological catch-up.

Historically, the Colombian NIS has been characterized by the limited interaction among its actors, particularly between universities and the productive sector (Monroy-Varela, 2006), a path-dependence similar to the rest of Latin American countries (Albuquerque *et al.*, 2015; Dutrénit & Arza, 2015). In this sense, recognizing the heterogeneity of academic scientists can be a good starting point for designing programs that adequately fit their characteristics and the contexts in which they develop, under the premise that a unique strategy within the innovation policies of universities is unlikely to be successful.



It is recommended that higher education institutions move forward in creating innovation and technology transfer programs that are more flexible and diversified, understanding that incentives and initiatives that are suitable for one type of academic scientist are not necessarily so for others. Now, analyzing the horizontal axis for scientists located on the right-hand side, academic and integrated entrepreneurs, it is relevant to establish flexible regulations in universities that facilitate the creation of partnerships with industry. As these researchers explore multiple and diverse channels of interaction, they need regulatory frameworks that are broad and adaptable to their needs. For scientists on the left-hand side, independent researchers and circumstantial collaborators, it is important to continue supporting their service delivery initiatives such as consulting, continuing education, or laboratory services. Eventually, these channels could become stronger and open spaces for the emergence of more systematic interactions with the productive sector.

Continuing with the vertical axis, academic entrepreneurs and independent scientists from the upper quadrants need programs that help them consolidate interdisciplinary teams, allowing them to acquire new skills in management, finance, and marketing, among other key areas in their journey as founders of spin-offs. Added to this, access to financing opportunities for the acceleration and scalability of their projects is also a key input. On the other hand, for academic scientists located at the bottom, especially those integrated who recognize the importance of interacting with the productive sector to transfer their developments to society, it is recommended to support the establishment of long-term two-way interaction channels, such as joint research and development, and the strengthening of licensing programs.

## FINAL CONSIDERATIONS

Throughout the article we have been discussing the relevance of the U-I interaction, focusing on the role of academic scientists in this collaboration. We begin with an understanding of the U-I interaction that in the case of Latin America is marked by a great fragility. We situate our problem in the context of UNAL, a university in the region, and analyze the motivations and channels of interaction used by academic scientists at this institution who interact effectively with industry. As a result, three large categories of motivations for interacting with industry were identified. The first category of motivations refers to the recognition that U-I interaction activities support the development of teaching, research, and outreach functions. The second group addresses the possibilities offered by the U-I interaction for strengthening the role of universities as an actor that contributes to local, economic, and social development. The third group is related to the opportunities offered by the U-I interaction for the personal development of researchers and the members of their research groups.

Likewise, the various traditional, service, bidirectional, and commercial interaction channels used by academic scientists are identified. In this sense, by combining motivations and interaction channels, we concluded that there is heterogeneity in the positions of academic scientists regarding U-I interaction, which is condensed into a four-quadrant typology: i) Circumstantial collaborators, who have sporadic contact with industry; ii) Independent, who develop their own initiatives through spin-offs with sporadic contacts with industry; iii) Integrated, who see industry as a strategic partner and do not wish to undertake

entrepreneurship; and iv) Academic entrepreneurs, who create spin-offs and see industry as a strategic partner.

Considering such a diversity, it is crucial that programs aimed at fostering innovation and strengthening interaction between universities and the productive sector become more flexible and resourceful. The analysis of scientists' location within the proposed quadrants' typology is a good starting point to guide what programs and incentives are most suitable for each type of academic scientist. From a micro and neo-institutional perspective, people's decisions and actions are influenced by the institutions in which they are embedded, so having customized strategies that recognize the diversity of these scientists can be an important external influence that drives U-I interaction and technology transfer.

Finally, we present appraisals about the limitations of this study and the opportunities it might open for new research works on the subject. As explained in the method, the academic scientists interviewed were chosen intentionally, having as inclusion criterion their participation in U-I interaction activity. Therefore, our conclusions do not fully cover all academic scientists, such as those who wish to interact with industry but have not yet succeeded in doing so. We must also consider that all participants belonged to the same public university based in Bogotá. Consequently, our results do not allow generalization about the specific characteristics of academic scientists from regional universities and private institutions. The extrapolation of our conclusions to other contexts must be performed with great care, understanding local-related particularities and conducting new studies.

Although participating scientists belonged to different disciplines, and we have brought this factor in certain moments of the analysis, we consider it is relevant to deepen into the knowledge about the possible differences and similarities in U-I interaction according to the area of expertise of these researchers. For example, based on our analysis, academic scientists categorized as circumstantial collaborators belonged to the departments of social work and nursing; the independents were in the area of biotechnology and computer science; while collaborators and academic entrepreneurs were mostly from other areas of Pasteur's Quadrant, such as engineering and agricultural sciences. Studies with expanded samples by area of activity can help to understand this phenomenon.

In addition, future research studies, preferably longitudinal, can pursue a broader understanding of the movement of scientists between quadrants and axes; in other words, they can broaden the understanding of the factors that influence an academic scientist to move between circumstantial collaborators, independents, integrated or academic entrepreneurs. In particular, we suggest deepening the knowledge about the possible influence of the absorptive capacity of the NIS and the scientist's trajectory on the interaction with industry.

## ACKNOWLEDGEMENTS

In memory of Alejandro Chaparro (R.I.P.) and his important inspiration and collaboration for conducting this research.

## DISCLOSURES

The authors declare no institutional or personal conflicts of interest.

## REFERENCES

- Albuquerque, E., Suzigan, W., Arza, V., & Dutrénit, G. (2015). Matrices of university-firm interactions in Latin America. In E. Albuquerque, W. Suzigan, G. Kruss, & K. Lee (Eds.). *Developing national systems of innovation university-industry: Interactions in the Global South* (pp. 194-218). Edward Elgar Publishing. <https://doi.org/10.4337/9781784711108.00016>
- Ankrah, S., & Al-Tabbaa, O. (2015) Universities-industry collaboration: A systematic review. *Scandinavian Journal of Management*, 31(3), 387-408. <https://doi.org/10.1016/j.scaman.2015.02.003>
- Arocena, R., & Sutz, J. (2005). Latin American universities: from an original revolution to an uncertain transition. *Higher Education*, 50, 573-592. <https://doi.org/10.1007/s10734-004-6367-8>
- Arocena, R., & Sutz, J. (2010). Weak knowledge demand in the South: Learning divides and innovation policies. *Science and Public Policy*, 37(8), 571-582. <https://doi.org/10.3152/030234210X12767691861137>
- Arocena, R., Göransson, B., & Sutz, J. (2018). *Developmental universities in inclusive innovation systems: Alternatives for Knowledge Democratization in the Global South*. Palgrave Macmillan. <https://doi.org/10.1007/978-3-319-64152-2>
- Bardin, L. (2011). *Análise de conteúdo* (2nd ed.). Edições 70.
- Chatterjee, D., Leisyte, L., Dasappa, D., & Sankaran, B. (2017). University research commercialization in emerging economies: A glimpse into the 'Black Box'. *Science and Public Policy*, 45(3), 361-372. <https://doi.org/10.1093/scipol/scx066>
- Congreso de la República de Colombia (2017). *Ley 1838 de 2017. Por la cual se Dictan Normas de Fomento a la Ciencia, Tecnología e Innovación Mediante la Creación de Empresas de Base Tecnológica (Spin Offs) y se Dictan Otras Disposiciones*. Diario Oficial No. 52.379. [http://www.secretariasenado.gov.co/senado/basedoc/ley\\_1838\\_2017.html](http://www.secretariasenado.gov.co/senado/basedoc/ley_1838_2017.html)
- Dutrénit, G., & Arza, V. (2015). Features of interactions between public research organizations and industry in Latin America: the perspective of researchers and firms. In E. Albuquerque, W. Suzigan, G. Kruss, & K. Lee (Eds.). *Developing national systems of innovation university-industry: Interactions in the Global South* (pp. 93-119). Edward Elgar Publishing. <https://doi.org/10.4337/9781784711108.00011>
- Fabiano, G., Marcellusi, A., & Favato, G. (2020). Channels and processes of knowledge transfer: How does knowledge move between university and industry? *Science and Public Policy*, 47(2), 256-270. <https://doi.org/10.1093/scipol/scaa002>
- Freeman, C. (1995). The 'national system of innovation' in historical perspective. *Cambridge Journal of Economics*, 19(1), 5-24. <https://doi.org/10.1093/oxfordjournals.cje.a035309>
- Fischer, B., Rücker, P., Vonortas, N. S., Queiroz, S. (2018). Quality comes first: University-industry collaboration as a source of academic entrepreneurship in a developing country. *Journal of Technology Transfer*, 43(2), 263-284. <https://doi.org/10.1007/s10961-017-9568-x>
- Fontanella, B. J. B., Luchesi, B., Saidel, M. G., Ricas, J., Turato, E., & Melo, D. (2011). Amostragem em pesquisas qualitativas: proposta de procedimentos para constatar saturação teórica. *Cadernos de Saúde*

- Pública, 27(2), 389-394. <https://doi.org/10.1590/S0102-311X2011000200020>
- Fosfuri, A., & Tribó, J. A. (2008). Exploring the antecedents of potential absorptive capacity and its impact on innovation performance. *Omega*, 36(2), 173-187. <https://doi.org/10.1016/j.omega.2006.06.012>
- Gómez, L. T., & Figueroa, S. (2011). Trayectos y trayectorias de la extensión universitaria: aproximación a una tipología de cinco universidades públicas latinoamericanas. *Ciencia Política*, 6(12), 109-146. <https://revistas.unal.edu.co/index.php/cienciapol/article/view/41508>
- Iorio, R., Labory, S., & Rentocchini, F. (2017). The importance of pro-social behaviour for the breadth and depth of knowledge transfer activities: An analysis of Italian academic scientists. *Research Policy*, 46(2), 497-509. <https://doi.org/10.1016/j.respol.2016.12.003>
- Jain, S., George, G., & Maltarich, M. (2009). Academics or entrepreneurs? Investigating role identity modification of university scientists involved in commercialization activity. *Research Policy*, 38(6), 922-935. <https://doi.org/10.1016/j.respol.2009.02.007>
- Jensen, M. B., Johnson, B., Lorenz, E., & Lundvall, B. A. (2007). Forms of knowledge and modes of innovation. *Research Policy*, 36(5), 680-693. <https://doi.org/10.1016/j.respol.2007.01.006>
- Lam, A. (2010). From 'ivory Tower Traditionalists' to 'Entrepreneurial Scientists'? Academic scientists in fuzzy university-industry boundaries. *Social Studies of Science*, 40(2), 307-40. <https://doi.org/10.1177%2F0306312709349963>
- Lam, A. (2011). What motivates academic scientists to engage in research commercialization: 'Gold', 'ribbon' or 'puzzle'? *Research Policy*, 40(10), 1354-1368. <https://doi.org/10.1016/j.respol.2011.09.002>
- Latham, G. P., & Pinder, C. C. (2005). Work motivation theory and research at the dawn of the twenty-first century. *Annual Review of Psychology*, 56, 485-516. <https://doi.org/10.1146/annurev.psych.55.090902.142105>
- Lundvall, B. Å. (1992). *National systems of innovation: Towards a theory of innovation and interactive learning*. Pinter publishers. <https://www.jstor.org/stable/j.ctt1gxp7cs>
- Lundvall, B. Å. (2006). *The university in the learning economy* (DRUID Working Paper 02-06). University of Aalborg. <https://wp.druid.dk/wp/20020006.pdf>
- Malagón, L. A. (2006). La vinculación universidad-sociedad desde una perspectiva social. *Educación y Educadores*, 9(2), 79-93. <https://educacionyeducadores.unisabana.edu.co/index.php/eye/article/view/664>
- Martínez, J. (2011). Métodos de investigación cualitativa. *Revista Silogismo*, 8(8), 1-33. <https://www.academia.edu/download/49747830/64-207-1-PB.pdf>
- Mascarenhas, C., Ferreira, J. J., & Marques, C. (2018). University-industry cooperation: A systematic literature review and research agenda. *Science and Public Policy*, 45(5), 708-718. <https://doi.org/10.1093/scipol/scy003>
- Misión de Sabios (2020). *Colombia hacia una Sociedad del Conocimiento: reflexiones y propuestas*. Ministerio de Ciencia, Tecnología e Innovación.
- Miller, K., Cunningham, J. A., & Albats, E. (2018). Entrepreneurial academics and academic entrepreneurs: A systematic literature review. *International Journal of Technology Management*, 77(3), 9-37. <https://doi.org/10.1504/IJTM.2018.091710>
- Monroy-Varela, S. (2006). Nuevas políticas y estrategias de articulación del sistema de ciencia, tecnología e innovación colombiano. *Innovar*, 16(28), 157-172. <https://revistas.unal.edu.co/index.php/innovar/article/view/19421>

- Morales-Rubiano, M. E., & Sanabria-Rangel, P. E., & Caballero-Martínez, D. (2015a). Características de la vinculación universidad-entorno en la Universidad Nacional de Colombia. *Revista Facultad de Ciencias Económicas*, 23(1), 189-208. <https://doi.org/10.18359/rfce.615>
- Morales-Rubiano, M. E., Sanabria-Rangel, P. E., Plata-Pacheco, P., Ninco-Hernández, F. (2015b). Research results transfer towards the productive sector via research: Collaboration in four Colombian public universities. *Journal of Technology Management & Innovation*, 10(2), 28-44. <https://doi.org/10.4067/S0718-27242015000400004>
- Nelson, R. (1993). *National innovation systems: A comparative analysis* (1st ed.). Oxford University Press.
- North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511808678>
- North, D. C. (1991). Institutions. *Journal of Economic Perspectives*, 5(1), 97-112. <https://doi.org/10.1257/jep.5.1.97>
- Organisation for Economic Co-operation and Development [OECD]. (2022). *Gross domestic spending on R&D*. OECD. <https://doi.org/10.1787/d8b068b4-en>
- Ortiz-Riaga, M. C., & Morales-Rubiano, M. E. (2011). La extensión universitaria en América Latina: concepciones y tendencias. *Educación y Educadores*, 14(2), 349-366. <https://doi.org/10.5294/edu.2011.14.2.6>
- Paranhos, J., Hasenclever, L., & Perin, F. S. (2018). Abordagens teóricas sobre o relacionamento entre empresas e universidades e o cenário brasileiro. *Revista Econômica*, 20(1), 9-29. <https://doi.org/10.22409/economica.20i1.p387>
- Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., & Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university-industry relations. *Research Policy*, 42(2), 423-42. <https://doi.org/10.1016/j.respol.2012.09.007>
- Red de Indicadores de Ciencia y Tecnología – Iberoamericana e Interamericana [RICYT]. (2020). *El estado de la ciencia: principales indicadores de ciencia y tecnología iberoamericanos / interamericanos 2020*. UNESCO & OEI.
- Salanova, M., Hontangas, P., & Peiró, J. M. (1996). Motivación laboral. In J. M. Peiró & F. Prieto (Eds.), *Tratado de psicología del trabajo* (pp. 215-249). Síntesis.
- Scott, W. R. (2001). *Institutions and organizations* (2nd ed.). Sage Publications.
- Shane, S. (2004). *Academic entrepreneurship: University spinoffs and wealth creation*. Edward Elgar Publishing. <https://doi.org/10.4337/9781843769828>
- Sun, P. Y. T., & Anderson, M. H. (2010). An examination of the relationship between absorptive capacity and organizational learning, and a proposed integration. *International Journal of Management Reviews*, 12(2), 130150. <https://doi.org/10.1111/j.1468-2370.2008.00256.x>
- Superintendencia de Industria y Comercio [sic]. (2016). *Estadísticas 2015. Nuevas creaciones*. sic. [https://www.sic.gov.co/sites/default/files/files/Estadisticas\\_Mensuales\\_Patentes\\_Disenos\\_2015\(1\).pdf](https://www.sic.gov.co/sites/default/files/files/Estadisticas_Mensuales_Patentes_Disenos_2015(1).pdf)
- Superintendencia de Industria y Comercio [sic]. (2017). *Estadísticas 2016 Nuevas Creaciones*. sic. <https://www.sic.gov.co/sites/default/files/files/Propiedad%20Industrial/Estadisticas/PATENTES-2016-Ver-2017-01-14.pdf>
- Superintendencia de Industria y Comercio [sic]. (2018). *Estadísticas 2017. Nuevas creaciones*. sic.

[https://www.sic.gov.co/sites/default/files/files/Propiedad%20Industrial/Estadisticas/Estadisticas\\_Mensuales\\_Patentes\\_2017\\_12-11.pdf](https://www.sic.gov.co/sites/default/files/files/Propiedad%20Industrial/Estadisticas/Estadisticas_Mensuales_Patentes_2017_12-11.pdf)

Tartari, V., Perkmann, M., & Salter, A. (2014). In good company: The influence of peers on industry engagement by academic scientists. *Research Policy*, 43(7), 1189-1203.

<https://doi.org/10.1016/j.respol.2014.02.003>

Universidad Nacional de Colombia. (2019). Balance social vigencia 2018. Unimedios.

[http://launalcuenta.unal.edu.co/fileadmin/user\\_upload/documentos/Informes/Nacional/2019/laUNAL\\_cuenta-2019\\_brochure.pdf](http://launalcuenta.unal.edu.co/fileadmin/user_upload/documentos/Informes/Nacional/2019/laUNAL_cuenta-2019_brochure.pdf)

Velasco, D. (2015). *Innovation systems in developing countries: A top-down and bottom-up approach to studying the Colombian National System of Innovation and the coffee, flower and sugarcane production chains* [Doctoral dissertation, University of Edinburgh]. Edinburgh Research Archive. <http://hdl.handle.net/1842/15813>

Würmseher, M. (2017). To each his own: Matching different entrepreneurial models to the academic scientist's individual needs. *Technovation*, 59, 1-17.

<https://doi.org/10.1016/j.technovation.2016.10.002>

Zahra, S. A., & George, G. (2002). Absorptive capacity: A review, reconceptualization, and extension. *Academy of Management Review*, 27(2), 185-203. <https://doi.org/10.2307/4134351>