Factors that Affect the Ability of Universities to Commercialize their Patents in a Latin American Country

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Abstract

The main purpose for this study was to find out which factors at the university level affect the ability to commercialize their invention patents in a Latin American country. Twenty-one Colombian universities participated in this study. The information was treated by the Partial Least Squares regression (PLS) path model. The primary information was obtained from the application of a survey to a random sample of 87 invention patents, whose holder is a Colombian university. Of the answers received, the one that generates the most concern is the fact that almost 80% of patents of invention have not been commercialized. This discovery is new for the Colombian case and it is something for which until now there was no scientific evidence. This not only questions the effectiveness of the country's Innovation System, but also forces to review the processes of scientific research and patenting carried out by universities. It demonstrates weaknesses in academic entrepreneurship to the extent that scientific research is not producing commercial applications capable of generating revenue and incomes for those universities. For its part, the determination level R^2 values of the endogenous constructs considered substantial the variable Closeness to the market (58.8%) which turns out to be the most determining factor in order to achieve an effective commercialization of patents in this country. This explains the poor ability of Colombian universities to commercialize their patents and it gives the management of innovation and university research the challenge of promoting the "exploitation of knowledge" through three strategies: 1) better market research; 2) strengthening relations with industry; and 3) the prior identification of the real possibilities of commercialization of its innovations.

Keywords: Innovation; patents commercialization; Colombian universities; Knowledge management; Latin American universities

Resumen Ejecutivo

El objetivo principal de este estudio fue descubrir qué factores a nivel universitario afectan la capacidad de comercializar sus patentes de invención en un país latinoamericano. 21 universidades colombianas participaron en este estudio. La información se trató mediante el modelo de regresión de mínimos cuadrados parciales (PLS). La información primaria se obtuvo de la aplicación de una encuesta a una muestra aleatoria de 87 patentes de invención, cuyo titular es alguna universidad colombiana. De las respuestas recibidas, la que genera mayor preocupación es el hecho de que casi el 80% de las patentes de invención no se han comercializado. Este descubrimiento es nuevo para el caso colombiano y es algo para lo que hasta ahora no había evidencia científica. Esto no solo cuestiona la efectividad del Sistema de Innovación del país, sino que también obliga a revisar los procesos de investigación científica y patentes llevados a cabo por las universidades. Ello demuestra debilidades en el espíritu empresarial académico en la medida en que la investigación científica no está produciendo aplicaciones comerciales capaces de generar ingresos para esas universidades. Por su parte, los valores del nivel de determinación R^2 de las construcciones endógenas considera sustancial la variable Cercanía al mercado (58.8%) que resulta ser un factor determinante para lograr una comercialización efectiva de patentes en este país. Esto explica la escasa habilidad de las universidades colombianas para comercializar sus patentes y entrega a la gerencia de la innovación e investigación universitaria el desafío de impulsar la "explotación del conocimiento" a través de tres estrategias: 1) una mejor investigación de mercado; 2) el fortalecimiento de las relaciones con la industria; y 3) la identificación previa de las posibilidades reales de comercialización de sus innovaciones.

Palabras clave: Innovación; comercialización de patentes; universidades colombianas; gerencia del conocimiento; universidades Latinoamericanas

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Introduction

As the specialized literature recognizes, there is a lack of empirical studies that address the analysis of how universities achieve an effective transfer of scientific knowledge to industry, and what are the factors that determine the choice of mechanisms for the commercialization of the university patents. This is evident at the level of international literature, is much more critical at the level of developing countries given its lower trajectory in terms of the use of the instruments of protection of inventions granted by Intellectual Property.

Given that, the chosen setting was the Colombian universities with the purpose of preparing a pioneering study in this field of knowledge. For this purpose, a survey was applied to the managers of technology transfer or research offices of 21 universities located in different parts of the country. The results show a low rate of use of the patents obtained and the need to promote a better relationship and closeness with the industry, given that it was found as the determining factor to achieve an effective commercialization of the innovations reached from university research.

Chapter 1 to 3: Research Proposal

University Patents and Technology Transfer in Latin America: Determinant Factors for Licensing and Creating Spin-Offs

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Chapter 1: Introduction

The present Research Proposal was elaborated in accordance with the Normative Guide of the Doctoral Program and contains in chapter one the academic formulation of the research topic, its argumentation regarding its academic relevance, the approach of the problem object of the research, the description of its scope and limitations as well as the theoretical framework that supports it; on the other hand, chapter two presents the review of the most recent literature related to the subject matter of this study; the chapter three contains the research methods and ends with the list of references that was used.

Background of the Problem

For almost 50 years, the universities have searched to find the most efficient way to achieve transfer processes of the results of their research to society and the productive sector, as one of the elements associated to its institutional mission. One important basis of this trend is the Bush Report published in 1945 by Vannevar Bush under the title: *Science, The Endless Frontier.*

The basic principle of the Bush Report (1945) indicates that discoveries resulting from research through technology transfer must be part of economic development and social welfare. Licensing, patents and publications in high-impact journals have played a key role in this.

On this respect, the linear model of innovation was the first framework developed to try understanding the relationship between science and technology and the economy. This model proposed that innovation begins with basic research, continuing with applied research and ending with production and transference. Some authors stated that this model comes from Vannevar Bush.

This linear model is related to the concept of the autonomy of science: It is independent of social processes and has no responsibility for the use and impacts that their results may have. These concepts became the basis of a social contract between the community and the State (Ronayne, 1984) and to inspire a normative-institutional model which oriented the policy of science and technology in developed countries, having as emblematic institution the National Science Foundation (NSF), created in 1950. "Little by little, this model was influencing the governments of most industrialized countries, establishing institutions with similar functions" (Salomon, 1977, p. 49).

This was the era of investment in basic scientific research and human capital as a locomotive of socio-economic development, mainly under the initiative of the state governments, following a linear model of the transfer of knowledge from the scientific sector towards industry and society in general.

In terms of economic policy, the empirical works initiated by Robert Solow (1956) searched to explain the growth of the North American economy as a result of the growth of production, finding that, in his opinion, “growth was mostly explained by what he called "technological progress" or "residue" (also called total factor productivity growth), which constitutes a first level of verification of the importance of technological progress” (Cervilla de Olivieri, 2011, p. 3).

A second phase, which began around the seventies, was characterized by state investment in strategic sectors, accompanied by private initiative in specific projects; according to Giachi (2017), following a vision of the transfer of knowledge as a process activated from the users under a contractual and mercantilist agreements.

Later, during the eighties, surged the idea that diffusion is the responsible for most of the economic benefits of the new technology; understanding that what give rise to the competitive advantage of a nation are not the techno-scientific leadership but the rate and

level of diffusion of technology in the economic environment (Rothwell & Zegfeld, 1985). Hence, the new theories of growth at that time assure that technological change is endogenous and that both positive externalities and increasing returns come from education and knowledge (Lucas, 1988; Romer, 1986).

Finally, between the eighties and the nineties, began what we could define as a "third phase", characterized by policies and innovation strategies aimed at promoting direct interaction between scientific agents and productive sector, vision that underlies a conception of the transfer of knowledge as an interactive process that follows an integrated model or in a network. “At this time, intermediation institutions between science, industry and governments arise, such as technological science parks, knowledge transfer offices, business incubators, or research centers with a mixed or collaborative nature” (Giachi, 2017, p.121).

However, from other perspective, Godin (2002) proposed that the linear model of innovation was developed in three stages corresponding with three different scientific communities. The first, “from the beginning of the twentieth century to circa 1945, was concerned with the first two terms, basic research and applied research” (p. 640). In this phase the scientists developed basic research as the source for applied research.

The second stage, from 1934 to 1960, was composed of “researchers from business schools, having been interested in science studies long before economists and studying the industrial management of research and the development of technologies” (Godin, 2002, p. 640). Finally, the third stage, starting in 1950’s to late 80’s, was formed by “economists from business schools, bringing forth the concept of innovation” (p. 640).

In a practical way, efforts to diffuse and commercialize innovation outcome from scientific research have been supported at the legislative level in countries such as the United States (Bradley, Hayter & Link, 2013). Key regulations that now facilitate technology transfer have been implemented around the world. A first example is the issuance of the Bayh-Dole

Act in 1980, which allows United States universities to retain intellectual property and to appropriate the proceeds of the licenses from those patents obtained from federal resources provided for research (Fish, Hassel, Sander & Block, 2015). The same has been emulated by domestic legislation in most European and Asian nations (Geuna & Rossi, 2011).

Hayter and Rooksby (2016) recently stated that research on technology transfer has now broadened its field of action generating links with the theory of economic development, providing a vision of growth and prosperity related to the creation, diffusion and marketing of new knowledge. The impact of this new knowledge depends on its ability to flow within society in order to be used for social and economic purposes.

There is no doubt that today there is a wide range of possibilities for interaction between the productive sector and the university, which contributes to its entrepreneurial activity, among others, recruitment of graduates, use of publications, specialized consulting, collaborative projects, sale of services, use of patents and licenses, and creation of Spin-Off companies resulting from the activity of university science and technology (Rodeiro, López, Otero & Sandías, 2010).

In this regard, the study on university technology transfer elaborated by Bradley, Hayter and Link (2013), found that the interest of universities in obtaining patents has grown rapidly in the last decade, with a significant increase in licensing activities as well as in the creation of university spin-off companies, both inside and outside the United States.

Statement of the Research Problem

The review of the recent literature (Pattnaik, & Pandey, 2016) allows identifying a void in the theoretical knowledge around technology transfer from university research. Due to the increasing number of patents granted to the universities around the world, it is necessary to identify the factors at the university level that determine the choice of licensing or the

creation of Spin-Offs as a mechanism for the transfer and commercialization of university patents. These are the two most used modalities for technology transfer to the productive sector, and now both record a significant increase from the recognition of patents.

Several authors (Czarnitzki, Doherr, Hussinger, Schliessler, & Toole, 2016; Grimaldi, Kenney, Siegel, & Wright, 2011; Wood, 2011) have stated that there is a lack of empirical studies based on representative samples that allow realizing useful statistical generalizations for those who are responsible for making these kind of decisions at university level.

Both the documented practice and the models proposed for the transfer of university technologies require an efficient marketing mechanism that delivers the highest benefit to society and allows universities and researchers to fulfill their institutional mission, which is to contribute with knowledge to the socio-economic development of the countries (Wood, 2011). Ultimately, this spirit stimulates this research proposal.

Purpose of the Study

The purpose of this research will be to find out which factors at the university level explain the choice of licensing and the creation of spin-offs as mechanisms for the transfer and commercialization of university patents in Latin American countries.

Significance of the Study

The setting of this doctoral research will be the Colombian universities, as a good example of the new dynamics in Research & Development (R&D) in Latin America. However, in order to achieve a better understanding of the dynamics of university patenting in Latin America today, a comparative analysis will initially be undertaken regarding the number of patents applied for and granted to universities located in Chile, Colombia, Mexico and Peru, for being the signatory countries of the Pacific Alliance (Alianza del Pacífico), regional integration initiative for the development of the people of Latin America.

According to Primi (2014), since the end of the 1990s, four different innovation policy models have emerged in this region: “competitiveness-based (e.g. Colombia), cluster-based (e.g. Chile), science-based (e.g. Argentina) and production development strategy (e.g. Brazil). These approaches have in common the recognition that innovation is shaped by the quality and density of the interactions in the national innovation system” (p. 212).

Consequently, since the beginning of the 2000s, innovation has become an important topic in this region. Most countries have started to construct national innovation plans including incentives related to intellectual property management. Even though they have low budgets, innovation policies have become priority of many countries in Latin America. In this sense, Primi (2014) stated: “an analysis of innovation policies in the region, shows that Latin American countries are recognizing the importance of innovation for development. Most countries have functioning institutions and, a more or less articulated policy mix” (p. 96).

In this sense, intellectual property rights have an important role in the innovation policy because they influence the quality and quantity of the knowledge base shaping the incentives to exploit the new technological opportunities to the universities, within the framework of innovation strategies according to the local, regional and global scientific challenges.

For these reasons, this study is relevant in order to analyze the principal factors that affect the decision at the University level by the moment to choose the best mechanism to commercialize the patents of invention. It could be useful for the Science and Technology Systems, the Higher Education Institutions, the Innovation Systems, the University managers and the Technology Transfer Offices (TTO), especially in developing countries.

In these countries, unlike the developed nations, the majority funds for research are placed by the universities (OECD, 2014). Consequently, it is necessary to find the most efficient way to select the mechanism to transfer the university knowledge to the society,

according to the context, the kind of patent of invention and the relationship with the market and the industry.

Nature of the Study

This research will use a quantitative approach. It will have an explanatory scope and a non-experimental design. Given the characteristics of the variables involved in the conceptual model, which combines information with metric and non-metric data and because it is the dependent dichotomy or binary variable, Partial Least Square (PLS) path modeling will be applied for the data analysis due to its capacity to simultaneously estimate dependencies and relationships between the variables and due to its robustness and ease for interpretation of results and diagnoses (Hair, Black, Babin & Anderson, 2010).

This study will use the official database upon University Patents granted to the Colombian universities. This is a public information and available through the Superintendence of Industry and Commerce of Colombia. From this universe, it is necessary to select the patents of invention and apply a computer random process to identify the sample of the research. The sample will include public and private universities patents and the size of the sample will be the necessary to assure a maximum 5% of statistical error with a confidence level of 90%.

Research Questions

¿Which factors at the university level determine the technology transfer of the university patents in Latin American countries?

¿Which factors explain the choice of licensing as a mechanism for the transfer and commercialization of university patents in Latin American countries?

¿Which factors explain the creation of spin-offs as a mechanism for the transfer and commercialization of university patents in Latin American countries?

Hypotheses

It is necessary to generate three groups of testable hypotheses depending on the most relevant factors that intervening at the university level: 1. Closeness to the market. 2. Innovation type. 3. Financial aspects.

H1: The closeness to the market determines the licensing as mechanism for the transfer and commercialization of university patents

H2: The closeness to the market determines the creation of a University Spin-Off as mechanism for the transfer and commercialization of university patents

H3: The innovation type determines the licensing as mechanism for the transfer and commercialization of university patents

H4: The innovation type determines the creation of a University Spin-Off as mechanism for the transfer and commercialization of university patents

H5: The financial aspects determine the licensing as mechanism for the transfer and commercialization of university patents

H6: The financial aspects determine the creation of a University Spin-Off as mechanism for the transfer and commercialization of university patents

Theoretical Framework

For the realization of this proposal, literature related to studies on different concepts and models associated with innovation was reviewed. From there, we conclude that the Innovation Economy, the National Innovation Systems, the Innovation Systems, the Triple Helix and the Academic Entrepreneurship provide us with the analytical framework that allows us to explain the relationships between university patents and the most commonly used mechanisms for their transfer and commercialization.

From the field of Economic Science, this research is framed within what is called the Innovation Economy, the concept of which was introduced by Schumpeter, 1934 (1978), in his book *The Theory of Economic Development. An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle*.

Following Mochón (1990), every market economy experiences fluctuations in the level of economic activity, which are often called cycles. The economic cycle consists of fluctuations in total production or gross domestic product (GDP) accompanied by fluctuations in most economic variables, including employment and inflation.

According to Schumpeter, the economic cycle has its origin in real factors, such as alterations in production costs, due to technological innovations or changes in the availability of resources (Schumpeter, 1978). He emphasizes the role of innovation as a dynamic force generating cycles and estimates that an expansion cycle ends when the investments associated with innovation cease, once this has become widespread.

In this context, innovation appears when new productive combinations arise that can originate in the following situations:

1. The introduction of a new product or a new quality of a product;

2. The introduction of a new method of production;

3. The opening of a new market;

4. The conquest of a new source of supply of raw materials;

5. The emergence of new sources of energy (Galindo & Malgesini, 1993, p.109).

According to the Oslo Manual, innovate is introducing a new or significantly improved product, service, or process, or a new marketing method or organization applied to business practices or successful work organization in the marketplace (OECD, 2005).

Undoubtedly, scientific research whose results lead to the obtaining of a university patent necessarily must be framed within the scope of innovation originally postulated by Schumpeter. On the other hand, both the licensing and the creation of University Spin-Off require a high dose of entrepreneurship. According to Schumpeter, companies are the areas in which new combinations are made and entrepreneurs are responsible for producing and implementing them (Galindo & Malgesini, 1994).

He believes that the extraordinary nature of entrepreneurs is based on that they are directed to do something different from the typical behaviors of society. In his view, an innovator is a "creative entrepreneur", who in the search for new fields of action drives the process of "creative destruction" (Schumpeter, 1978).

Notwithstanding the foregoing, it must be borne in mind that the only incentive that drives entrepreneurs to bear the great risks involved in introducing innovations is the benefits. Hence, it is necessary to create monopolistic conditions - via industrial protection, understood as the set of rights that a natural or legal person may possess over an invention - that allow in the short term to obtain profits given their status as a pioneer in the market.

In relation to national innovation systems (NIS), these emerged towards the end of 1980 (Edquist, 2005; Edquist & Hommen, 1999; Lundvall, 1992; Lundvall, Johnson, & Dalum, 2002; Nelson, 1993), whose precursors were Christopher Freeman, Bengt-Åke Lundvall, and Richard Nelson who introduced the concept was Freeman on the occasion of a study of Japan in 1987 (Freeman, 1987).

Although the approach to the concept of national innovation systems is not taken as a theory, it is useful as an analytical framework that allows us to understand the complexities of an innovation process within a country, based on the institutional arrangements. A national innovation system is understood as the flow of technology and information among the actors

of the system - companies, universities and government - that generates processes of innovation at national level.

According to these fundamentals, innovation and technological progress arise as a result of a complex set of relationships between the actors who produce, distribute, and apply different types of knowledge. Hence, the achievement of a country in this field depends then on how strong and dynamic are the relations between private companies, universities, and public research organizations, as belonging to a collective system of knowledge generation. Some definitions around this concept are as follows:

" .. the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." (Freeman, 1987, p. 23).

" .. the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state." (Lundvall, 1992, p. 79).

"... a set of institutions whose interactions determine the innovative performance ... of national firms." (Nelson, 1993, p. 58).

Based on these foundations, the Organization for Economic Cooperation and Development (OECD) published in 1997 a document on national innovation systems in order that "an understanding of these systems can help policy makers develop approaches for enhancing innovative performance in the knowledge-based economies of today" (OECD, 1997, p.3), stating that the good performance of an innovation system is related to the way knowledge flows between companies, universities and public research institutions.

In the case of Latin American countries, this concept has been used to design policies and instruments, to establish an organizational infrastructure to facilitate the connections between the different actors, trying to promote knowledge networks to generate innovation at

the level of companies. National innovation systems, therefore, define basic conditions for this research, such as mechanisms for the protection of inventions, incentives for the promotion of scientific research, mechanisms for financing projects, conditions for the licensing of patents, and the promotion of university-business alliances for innovation.

However, other innovation scholars have identified different contexts to conceptualize the innovation systems (Russo-Spena, Tregua & Bifulco, 2017). Specifically, they have referred to clusters, regions and technologies, rather than a national-system level. For example: "Carlsson and Stankiewitz (1991) developed the concept of technological innovation systems to identify more specific networks of organizations and individual agents interacting in a particular technology area and supported by institutional infrastructure (Berger and Diez, 2006)" (p. 990).

Additionally, "Since the mid-1990s, the 'regional system of innovation' has grown rapidly in the literature (Cooke et al., 1997; Maskell & Malmberg, 1997) to stress the relationship between technology, innovation and industrial location" (Russo-Spena et al., 2017, p. 991). More recently, 'innovation ecosystems' came into use in the early 2000s as a new concept in the literature. According to Russo-Spena et al. (2017), "The ecosystem has an internal, hierarchical organization with interacting parts depending on each other for access to resources on which the whole community depends" (p. 999).

Clearly, different authors have considered knowledge spillovers as one of the most important sources for the economic growth of the countries (Romer, 1986; 1990). In this sense, Gibbons et al. (1994) indicated that there are two modes of knowledge generation. In the "Mode 1", there is no interaction between academy and industry. The knowledge is produced by autonomous universities according to their motivation and disciplines. In the "Mode 2", "knowledge production which relies on interdisciplinary teams collaborating together for short periods to work on specific problems in the real world" (Hsu, Shen, Yuan &

Chou, 2015, p. 25). This “Mode 2” of knowledge production was conceptualized as the Triple Helix model in terms of university-industry-government relations (Etzkowitz & Leydesdorff, 2000).

The model of the Triple Helix of relations between university, industry and government (Etzkowitz & Leydesdorff, 2000; Leydesdorff, 1998; Leydesdorff, 2000; Leydesdorff & Meyer, 2003) widely used in innovation studies, arises of the premise that the movement of people around different fields improves creativity and expertise. Under this approach, universities as traditional suppliers of human resources and knowledge, become critical actors of socio-economic development (Dzisah & Etzkowitz, 2010).

According to Chang (2010), this model emerges as a response to the growing need to relate scientific, technological and productive activities in order to meet market demand. González (2009) refers to the Triple Helix as based on analyzing the relationships between university scientific communities as the first helix, companies as a second helix and the government as third helix.

The focal point of the Triple Helix model is the interactions between the actors where the fundamental scope is the circulation of people, ideas, and innovations. For the purposes of the present study, it is important to bear in mind that a substantial difference between the national innovation systems and the Triple Helix model is that the former places companies as a center of innovation, while the latter considers universities as axes of knowledge generation and innovation. In the words of Etzkowitz and Leydesdorff, "The Triple Helix thesis states that the university can play an enhanced role in innovation in increasingly knowledge-based societies. The NIS approach considers the firm as having the leading role in innovation" (Etzkowitz & Leydesdorff, 2000, p. 109).

According to Halilem (2010), in the Triple Helix the academic researcher has a predominant role within the processes which generates opportunities for innovation; in

teaching, forming highly qualified personnel and in entrepreneurship from transforming the new knowledge into applied forms, as additional spaces for innovation. Of course, the concept has evolved over time, adapting to a context of global economic change.

On this, Lawton and Leydesdorff (2014) affirmed that the globalization has meant a transformation in the configuration of the model of the Triple Helix to varying degrees according with the opening of the countries. Networks of knowledge as well as the circulation of ideas go from having only a local or regional configuration to articulate with other similar actors but in different latitudes.

Another important evolution of the model refers to the networks of relationships and the position each helix occupies in that relationship. In this sense, as Lawton and Leydesdorff (2014) put it, an action-oriented Triple Helix model puts its emphasis on the structural conditions for innovation. For the case of patents, this is of particular importance insofar as: "patents can be considered as positioned in terms of the three social coordination mechanisms of (1) wealth generation in the market by industry; (2) legislative control by government; and (3) novelty production in academia" (Lawton & Leydesdorff, 2014, p.323).

In other words, the relationships in a knowledge-based economy are dimensioned in three spatial positions: industry, government, and universities. And since patents can circulate between the three helixes, three ways of interaction can be expected. Finally, given the trends of the global economy the geographical level in which the synergies of the Triple Helix are presented shows wide variations between nations and regions.

As a particular development of the one of the helixes, Etzkowitz (1998) launched the idea that knowledge generated from university research programs can be used for commercial applications and income generation, what he called the entrepreneurial university to describe the role that universities have come to play in modern process of economic development. "The university's contribution to innovation in economic and social development is the heart

of the entrepreneurial university concept. Academic entrepreneurship transcends simple knowledge capitalization as the university interacts with innovative actors from other institutional spheres to promote regional growth" (Etzkowitz & Zhou, 2008, p. 629).

Etzkowitz, Webster, Gebhardt and Cantilano (2000) affirmed that these developments have allowed the role of universities today is not only limited to teaching and research; its field of action has expanded to the productive sector and to economic development through different extension actions, all of which configure the entrepreneurial university. Universities have become entrepreneurs because of their internal dynamics have created commercial firms for research and technology transfer contracts, generating a strong link with knowledge users, which have turned the University into an economic actor (Etzkowitz, 2004).

The entrepreneurial university contributes to industry in different ways, among others, education, consulting, technology patent, licensing, and Spin-Offs´ formation. In practice, entrepreneurial university integrates teaching, research, and community service. This concept over time has evolved in what is now called academic entrepreneurship as a way of referring to all the efforts and activities that universities and their associated industries carry out in the expectation of commercializing the results of university research (Wood, 2011).

There is no doubt that today there is a wide range of possibilities for interaction between the productive sector and the university which contribute to its entrepreneurial activity. Among others, we can mention: recruitment of graduates, use of publications, specialized consulting, collaborative projects, sale of services, use of patents and licenses, and creation of companies resulting from the activity of university science and technology (Spin-Off) (Rodeiro, López, Otero & Sandías, 2010).

In this regard, a recent study on university technology transfer elaborated by Bradley, Hayter and Link (2013) found that the interest of universities in obtaining patents has grown

rapidly in the last decade, with a significant increase in licensing activities as well as in the creation of university spin-off companies, both inside and outside the United States.

Definitions of terms

The following concepts are going to be the most used for this research. The definitions come from different studies and publications made by some of the most relevant authors in this topic.

Academic Entrepreneurship: All the efforts and activities that university and their associated industries carry out in the expectation of commercializing the results of university research (Wood, 2011).

University Patents: Knowledge protection system for innovative results as an output of academic research that allow it to be transferred to the marketplace (Grimaldi, Kenney, Siegel, & Wright, 2011).

Technology Transfer: Critical mechanism for the dissemination and commercialization of new technology stemming from academic research (Hayter & Rooksby, 2016).

Licensing: Contract between the owner of Intellectual Property Rights (university) and licensee (firm), under which the firm is given a right to use, reproduce, and commercialize the invention developed by the university under specified conditions in the contract (Özel, & Pénin, 2016).

University Spin-Off: New firms created to exploit commercially some knowledge, technology or research results developed within a university (Pirnay, Surlemont, & Nlemvo, 2003).

Assumptions

The first assumption of this research is that all the university patents of the sample will have these two characteristics: applicability and marketability. Applicability refers to what extent university research produces technology that can be used for product development. Marketability represents the degree to which the inventions are recognized by industry as important input that can be sold in the innovation market. Other assumption is that all the universities of the sample have the intention to commercialize their patents through licensing or creation of a university spin-off.

Limitations

It is not possible in this research for economic, logistic, and time resources to analyze all the university patents granted for the universities in Latin America countries during the period of the study. For that reason, a random sample will be used to choose a representative number of patents of invention that have been commercialized by Colombian universities in recent years. Based on that sample through a form, a survey will be applied in order to get the main information about the dominant factors that affect the commercialization decision at the university level.

Delimitations

The principal delimitation is that this study will take a sample of the recognized patents of invention whose holders are Colombian universities located in different cities of the country. Besides, only three factors will be analyzed according to the purpose of the study – Closeness to the market, Innovation type and financial aspects – which are commonly used in the specialized literature. In addition, the historical period will be the years run from 2008 until 2017.

Summary

This chapter presents the main background of the subject of the study, while formulating the problem of doctoral research adding its purpose and significance. In the same way, the research questions are formulated, which corresponds to the title of the work. From there emerges a set of six hypotheses which are considered to allow the problem of investigation to be testable and verifiable.

As for the theoretical framework, the main theories, models and approaches that have surrounded the concept of innovation are presented historically. Starting from the field of Economic Science and continuing with the national innovation systems (NIS), which derive in the formulation of the Model of The Triple Helix fundamental when studying the phenomena associated with innovation and university technology transfer.

Finally, the concept of academic entrepreneurship that will serve as a basis for analysis for this doctoral thesis is presented. This is a concept that integrates all the efforts and activities that universities and associated industries perform looking for the commercialization of innovations as a result of the faculty research (O´Shea, Allen, O´Gorman, & Roche, 2004). The basic idea is that a "wide range of scientific research takes place within universities, and some of the results may have commercial applications capable of generating revenue and incomes for those universities" (Wood, 2011, p. 157).

For the universities, a process model of academic entrepreneurship is useful because it delivers wide opportunities for the institution, the research faculties, the entrepreneurs and business sector. It is like to lead the research to a host of financial, reputational and societal benefits (Wood, 2011). "Universities that understand industrial demand and technological trends possess enhanced strategies to find the right actors and then established a close business partnership or alliance" (Ho, Liu, Lu, & Huang, 2014, p. 255).

The Economy of Innovation, the National Innovation Systems, the Innovation Systems, the Triple Helix and the Academic Entrepreneurship models will provide us with the analytical and normative frameworks to explain the relationship between the University Patents and the Transfer and Commercialization Mechanisms. These bases allow us to construct the following figure that resume the theoretical framework of this doctoral research.

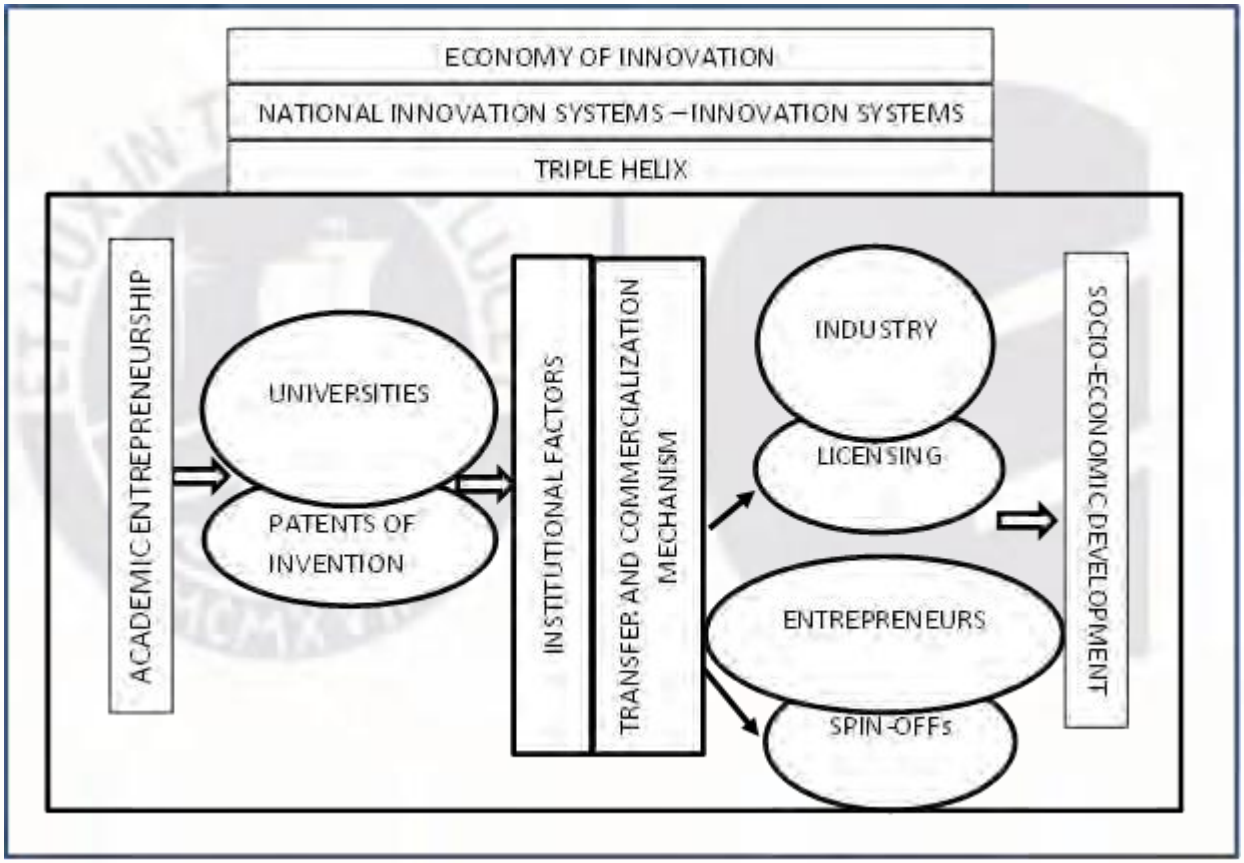

Figure 1. Theoretical Framework

Chapter 2: Review of the Literature

The review of the literature allows delimiting with more clarity the problem object of the investigation, to identify, and to analyze the current state of the knowledge regarding the subject that occupies this research. At the same time, this exercise makes it possible to gather the factors that must be taken into account throughout the investigation, to establish the degree of relevance that the problem has had for the National and International Scientific Community and to recognize the evolution that this thematic has presented over time.

Documentation

The strategy that was used for the review of the literature is showing in the next chart. Closest keywords were selected according to the different concepts related with the variables of this research. Mainly Academic Entrepreneurship, Industrial Property, University Patents, Technology Transfer, University Patents Licensing and University Spin-Off. These keywords were searched in the principal international scientific database looking for peer-reviewed articles in different journals like EBSCO, Jstor, Scientific Direct, Springer and Web of Science.

Additionally, the Mendeley web program was useful in order to manage and discover research papers. Then, were selected the closest and the most recent literature with the topic of this study according to the main variables trying to find theories, concepts, models and the principal methods has been used for research in this field of knowledge. All the references are 100% reliable and contain the source of the information.

All the literature, current findings and studies are presented with appropriate citations. Each research variable is discussed according to the different perspectives and trying to identify the latest academic development related with the research question. Finally, the gap

of the knowledge and the suggestions for addressing the study proposed by this doctoral thesis, are highlighted according to the corresponding journal paper.

Map of the review of the literature

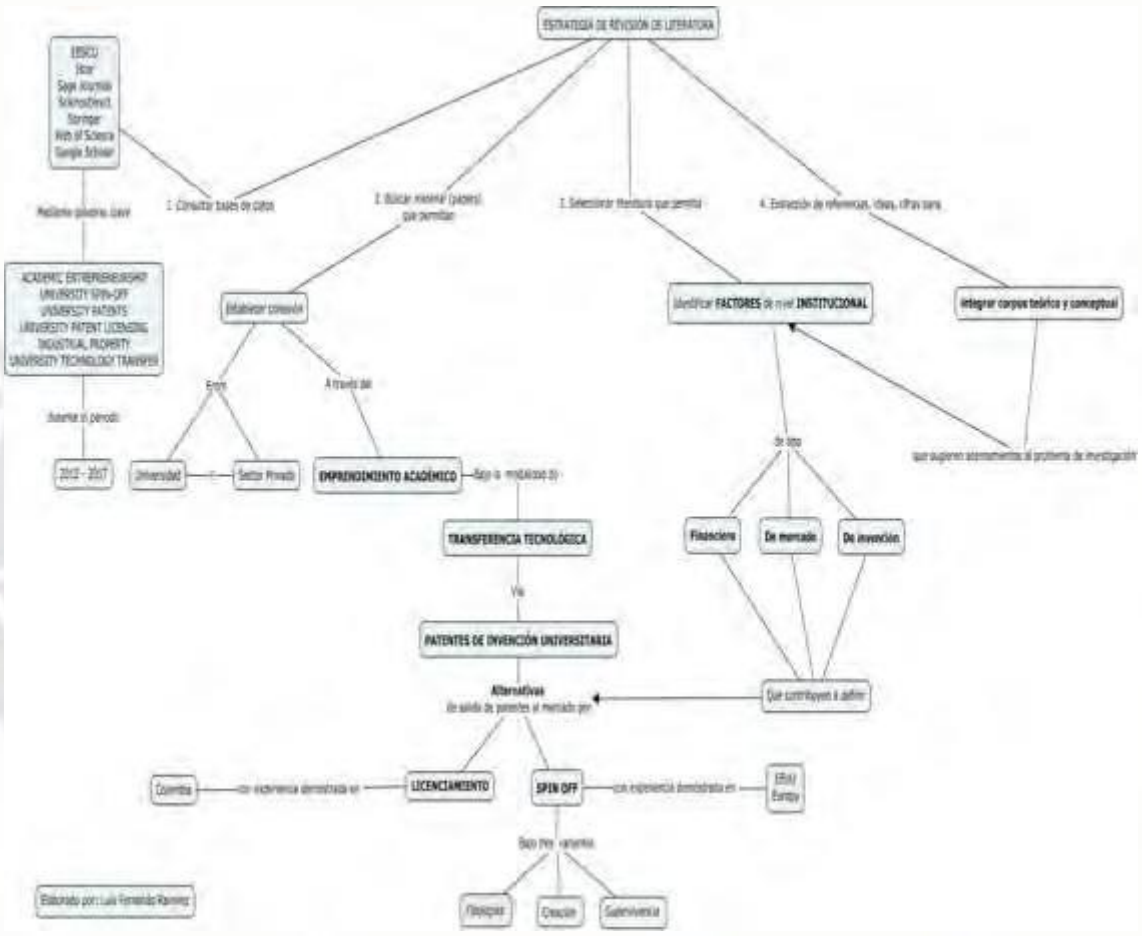

Figure 2. Map of the Review

Headings of the review

The generation of scientific knowledge is the tool that through history has allowed societies to modernize and advance in solving problems in the economic and social spheres. Universities, as institutions designed for the dissemination and production of scientific knowledge, are today requested to carry out processes of technological transfer of their discoveries and innovations towards the productive sector.

In this sense, the acquisition of patents, its licensing and the creation of Spin-Off University companies are currently mechanisms commonly used in developed countries through which technological transfer and commercial exploitation of the knowledge generated within a university is achieved. The process of the review of the recent literature was made following the strategy previously described, focusing in the keywords related with the main subject of this research, and delivered the next headings about this important topic.

Academic entrepreneurship

From the theoretical perspective, Audretsch (2014) presents an interesting review of how and why the role of the university in society has evolved over time, arguing that the forces shaping economic growth have also influenced the correspondent role for the university. He stated that "As the economy has evolved from being driven by physical capital to knowledge, and then again, to being driven by entrepreneurship, the role of the university has evolved over time" (p. 313).

In this sense, he made a comparison between the influences of he called Solow economy (Robert Solow) in relation with the Romer economy (Paul Romer). In the Solow model, "the emphasis on physical capital and unskilled labor as the twin factors shaping economic performance. Despite the preeminent contributions to social and political values, the economic contribution of universities was modest" (Audretsch, 2014, p. 315). Meanwhile, in the Romer economy knowledge was considered particularly potent as a driver of economic growth. Finally, "As the Romer economy replaced the Solow economy, a new role for the university emerged, as an important source of economic knowledge" (p. 316).

Following this theoretical discussion, Osiri, Miller, Clark, and Jessup (2014) presented a framework for academic entrepreneurship through an extensive review of scientific articles published in leading entrepreneurship journals. They defined entrepreneurship "as the act of exploiting opportunities and transforming innovations into social or economic value" (p. 41),

and concluded that “The outcomes in Academic Entrepreneurship are varied and include IP disclosures, patents, licenses, cash, deals (e.g. equity), spin-offs, partnerships, revenue, returns-on-investment, and so on” (p. 42). They believed that academic entrepreneurship is a complex process that contains a variety of input (or independent) and moderating variables.

For its part Guerrero, Urbano, Fayolle, Klofsten, and Mian (2016) made a theoretical framework analysis trying to improve our understanding of the political implications of emerging models of entrepreneurial universities in the new social and economic landscape. They argued that “The emerging role of a modern entrepreneurial university is dichotomous, focusing both innovation and entrepreneurship that contributes to innovation, competiveness, and economic growth” (p. 552). They concluded, “As universities are located on the intersection of education, research, and transfer of knowledge, they are considered a key access agent in any entrepreneurship and innovation ecosystems” (p. 556).

These three theoretical approximations present the development of the universities as a source of economic growth, offering new technologies for the market and basic support of the innovation systems. In sum, a role that goes beyond teaching and involve now transference of his research to the society.

In a more practical way, Wood (2011) developed a multi-stage process model of academic entrepreneurship. His model “intended to guide potential stakeholders through the application of academic entrepreneurship, with a focus on improving the odds of success. They define success to be sustainable and ongoing revenue generation for both the university and its industry partners” (p. 153).

In relation with the topic of this doctoral research, Wood (2011) affirmed that “the stakeholders–faculty, TTO, industry partners–must decide whether a technology licensing agreement or a spin-off is the most appropriate avenue for commercialization, and this is not easy because the various stakeholders impose their view of the right mechanism” (p. 158). He

concluded that the process of academic entrepreneurship is not as efficient or as effective as it could be.

Based on the model of Knowledge-Based Entrepreneurship (KBE), Moutinho, Au-Yong-Oliveira, Coelho, and Manso (2016) conducted a research related to the factors that determine successful entrepreneurial endeavors by academic researchers. With base in a sample of 1.401 researchers from Portuguese universities, they found that "when the institutional strategy is to increase patenting and spin-off activities, the university should begin investing in creating a networking environment capable of reinforcing the researchers' Social Capital" (p. 171). Their study concluded that "The KBE ecosystem in which researchers work and have access to is perceived to be very important, for the patenting and licensing process, and ultimately for spin-off creation to be executed successfully, and more research is warranted in this area" (p. 189).

Using and external change in German Federal law Czarnitzki, Doherr, Hussinger, Schliessler, and Toole (2016) examined how entrepreneurial support and the ownership of patent rights influence academic entrepreneurship. They carried out a study on the impact of the Federal Government regulations in Germany since 2002, following the objectives of the Bayh-Dole Act of the United States. It is the reform called Knowledge Creates Markets, aimed at generating a series of subsidies, supports for technology transfer, and changes the patent rights resulting from university inventions of researchers at individual level towards universities. The empirical analysis showed a strong relation between patents and the creation of university companies.

The evidence then suggests the existence of a high dependence on academic entrepreneurship regarding industrial protection granted by patents. Since the study was based on a single mode of transfer, which is the creation of Spin-Off companies, they suggest that future research should be more far-reaching and include other transfer modalities such as the

licensing of inventions to the productive sector (Czarnitzki et al., 2016). That is one of the purposes of this doctoral research.

From other context Eesley, Bai Li, and Yang (2016) conducted a research trying to identify how the China's Project 985 influences new ventures in an institutional environment. They found that Project 985 was successes in two ways: "did successfully instill a belief in the importance of innovation among students. When these students started ventures, their altered beliefs did lead to an increased likelihood to engage in technologically intensive activities" (p. 446), and "likely to positively influence students' beliefs regarding the importance of intellectual property" (p. 449).

Using a longitudinal approach Rasmussen, Mosey, and Wright (2014) followed eight university spin-off venturing processes and compared the development paths of ventures. They found that "Evidence appears to suggest that there is a positive relationship between the research quality of a department and commercialization activities (but not engagement with industry) by academics and whether colleagues of the same rank are entrepreneurial" (p. 95). Their conclusions are highly related with this doctoral research: "The opportunity identification and development competency may therefore need to be developed to enable recognition of whether the best route to commercializing technology may be through licensing rather than a spin-off" (p. 104). In addition, they suggested that an interesting extension of their study "would be to explore whether the department level mechanisms conducive to (restrictive of) spin-offs also promote (constrain) other forms of university technology transfer like licensing" (p.105).

From the Latin America context Cantu-Ortiz, Galeano, Mora-Castro, and Fangmeyer (2017) presented REPITA (Research-Ecosystem-People-Intellectual Property-Transfer-Alignment), "a prescriptive and repeatable model for successful technology-based academic entrepreneurship, synthesized from research of academic entrepreneurship in developing

economy conditions" (p. 541). Using the resource-based theory and the capability-based framework, they concluded, "resources and capabilities are two different ways of framing academic entrepreneurship. The resource-based view emphasizes supply and access to resources. The capability-based framework focuses on competency and agency" (p. 543).

They assured that "The REPITA model is deployed as a coherent set of actions that a university may take to establish successful academic entrepreneurship. Critically, these actions are feasible for universities without a history of entrepreneurship or an internationally recognized brand" (Cantu-Ortiz et al., 2017, p. 547). The study concluded assuring that if a university take these steps could position it among the leaders in the spreading global phenomenon of academic entrepreneurship.

For its part, Binkauskas (2012) looked to identify the main reasons that determine why universities as organized institutions are passive in commercializing research findings. Through intervening heads of research and innovation departments of the universities, he found that there are three principal external factors associated with the third mission of the universities: "The first one included the decreasing public funding of universities……. The second is related to the fact that industry is no longer an institution separated from universities… ....The third factor is the outcome of an increasingly stronger local or regional cooperation" (p. 234). In general, the universities have difficulties regulating their relationships with the academic entrepreneurs in terms of publishing research, the time for business and academy, the use of university resources and the intellectual property rights, among others (Binkauskas, 2012).

Finally, Siegel, and Wright (2015) argued that we have reached a juncture that requires rethinking academic entrepreneurship, due the changing role and purpose of the universities. They found that "More stakeholders have become involved in academic entrepreneurship, including students, a younger generation of faculty and post-doctoral

fellows who are more comfortable working with industry than the previous generation and alumni" (p. 583).

In this sense, they concluded, "the debate regarding universities and academic entrepreneurship has relied too much on the research–third mission nexus and insufficient focus on the teaching/education–third mission nexus informed by research" (Siegel & Wright, 2015, p. 593). For that reason, it is necessary to generate a greater variety regarding the scope and nature of academic entrepreneurship according to the changing role and purpose of universities. They suggested for future research questions: "How do universities organize 'multidextrous' (i.e. social and commercial start-ups, licensing, etc.) academic entrepreneurship activities?" (p. 587). Precisely this kind of analysis is one of the purposes of this doctoral research.

As we can see, the academic entrepreneurship is a concept that integrates all the efforts that universities and associated industries perform trying to commercialize the innovations resulting of the faculty research (O´Shea, Allen, O´Gorman, & Roche, 2004). The basic idea is that a "wide range of scientific research takes place within universities, and some of the results may have commercial applications capable of generating revenue and incomes for those universities" (Wood, 2011, p. 157).

For the universities, a process model of academic entrepreneurship is useful because it provides opportunities for the institution, the research faculties, the entrepreneurs and business sectors. It is like to lead the research to a host of financial, reputational and societal benefits (Wood, 2011). Universities that manage to understand industrial dynamics and technological trends can more easily reach strategic alliances and to identify the right partnership for development of innovations.

Industrial property

The industrial property is the legal framework that protects the interests of innovators giving them rights over their creation. This legislation is part of the wider body of law known as intellectual property (IP) (WIPO, 2016). These rights conferring to the inventor(s) an exclusive monopoly on exploitation, after completing some formalities. In this category, fall the patents of invention intended to protect innovations of a technical nature.

At this respect, Kesan (2015) examined several theories that explain and justify the role of patents in today's knowledge-based, technology-intensive economy, stating that: "Patents reduce transaction costs, help convert inventions into transferable assets, promote disclosure, provide a system of certification and standardization, and allow greater divisibility of technology" (p. 903). In relation with the market of innovations additionally he assured: "All of these functions make transactions in the marketplace for inventions more efficient, to the benefit of both inventors and consumers" (p. 903).

His study concluded, "Governments issue patent rights to secure the possibility of monopoly power, and thereby reduce competition based on imitation, but not competition based on innovation. Patents are necessary for other reasons such as increasing economic efficiency" (Kesan, 2015, p. 899). In this context patenting help the university bring in revenue and allows the technology transfer offices and corporate firms interested in commercializing innovations be connected to the universities through industrial property.

In this sense, Savescu (2017) presented that "The industrial property rights are outlined in Article 27 of the Universal Declaration of Human Rights, which states that everyone should enjoy the protection of moral and material interests resulted from any scientific, literary or artistic production of which is the author" (p. 136). Also considered that an efficient patent system contributes to the stimulation of innovation, because, "Innovative ideas should be part of an organization's heritage, which is possible only through their legal

protection. It can be considered that stimulating innovation and intellectual property protection is a prerequisite for economic growth, design, implementation of competitive products" (p. 140).

From the European perspective, Geuna and Rossi (2011) developed a general framework to describe the changes in university Intellectual Property Rights (IPR) regulations in Europe, and their effects on the patenting activities of universities on knowledge transfer processes assuring, "despite the general trend towards institutional ownership, university IPR regulations in Europe remain extremely differentiated and there is no one-to-one mapping to the US system" (p. 1068). In addition, they concluded, "It was not so much the change in IPR ownership regulations that led to an increase in university patenting, but that this change motivated universities that previously had not patented, to establish a technology transfer infrastructure" (p. 1074).

In relation with the Trans-Pacific Partnership (TPP), Rogowsky (2016) made a review of the Intellectual Property (IP) Chapter of this agreement, affirming that "Developing economies tend to benefit more from the diffusion of IP than from protection of indigenous IP, at least until they begin producing a sufficient amount of their own IP to change that balance" (p. 127). He concluded, "IP protection is a policy intended to promote economic growth through innovation and designed to balance the incentive to innovate. The TPP moves further pushing an ambitious agenda to create a global trading environment, more secure for high-technology exports" (p. 130).

For developing countries, Kanwar (2012) conducted a study related with the influence of stronger patent protection on technology licensing. Using a panel data for the period of 1995–2005, he found that "stronger protection is associated with increased royalty and license fee payments by developing countries, which implies greater technology transfer into these countries. This result is robust to the inclusion of country fixed effects, and alternative

specifications of the model estimated" (p. 539). His study concluded, "The predominant proportion of technology has come to be concentrated in the hands of multinational corporations, rather than individuals (Scherer and Ross 1990), and the licensing of technology has become an important vehicle of technology transfer between nations" (p. 540).

Finally, Zekos (2016) made a legal and economic investigation to illustrate the developments regarding patents, copyrights and trademarks due to globalization and cyberspace. He found that "Strong IPR convinces holders of intellectual property to invest, as adequate protection of IPR guarantee foreign investors that their knowledge will not be unveiled to competitors. As a result, the smaller risk of replication allows larger require for protected goods" (p. 65).

However, he considered that "The current legal environment does not tender sufficient protection in the changing technological environment but there is need to go on with supporting technological advancement while protecting users' data and interests" (Zekos, 2016, p. 70). The technology is changing faster than the development of law that means that this failure could be transplanted into IPRs regulation.

In sum, industrial property brings to the universities the legal protection for their inventions as a result of the academic research. These national and international rights allow that their knowledge will not be unveiled to competitors, conferring to the inventor(s) an exclusive monopoly on exploitation.

University patents

On the 30th anniversary of enactment of the Bayh–Dole Act in the U.S., Grimaldi, Kenney, Siegel, and Wright (2011), considered the rationale for academic entrepreneurship and described the evolving role of universities in the commercialization of research. They considered that this Act "was both an outcome of and response to the changing climate, by

enhancing incentives for firms and universities to commercialize university-based technologies. Specifically, the legislation instituted a uniform patent policy across federal agencies and removed many restrictions on licensing" (p. 1046).

Additionally, "Bayh–Dole also stipulated that researchers working on a federal research grant are required to disclose their inventions to the technology licensing office. Several European (Wright et al., 2008 a, b) and Asian (Kodama, 2008) countries adopted similar legislation" (Grimaldi et al., 2011, p. 1046). They concluded, "University patents represent only one mechanism by which academic research results can be transferred to the marketplace. Other mechanisms include licensing, the generation of academic spin-offs, collaborative research, contract research and consulting" (p. 1047).

In relation with this doctoral research this paper presented a wide number of themes for a future research agenda, among them, "How do universities trade-off choice between licensing and spin-offs?" (Grimaldi et al., 2011, p. 1053). That is precisely the principal research question of this proposal.

As complement of this topic, Guerzoni, Aldridge, Audretsch, and Desai (2014) made a research looking what conditions, drive patents originality in the process of knowledge creation within the university finding that "when universities scientists are partly founded by their own university, they have a higher propensity to generate original patents. By contrast, university scientists funded either by industry or other non-university organizations have a lower propensity to generate more original patents" (Guerzoni et al., 2014, p. 1697). They found that the source of funding is important, so the funding context is a condition which could affect patent originality.

For its part, Drivas, Economidou, Karamanis, and Zank (2016) conducted a study trying to determine whether university patents are licensed over their enforceable lifecycle and at what point in time the licensing occurs. Based in an analysis of over 20,000 university

patents granted between 1990 and 2000, they stated that since the Bayh-Dole Act "most research universities have established their own Offices of Technology Transfer (OTT) to undertake these commercialization and patent monetization activities. These academic technology transfer entities use a wide range of exclusive and non-exclusive licensing agreements to monetize the intellectual property they own." (p. 46).

They concluded that "while the funding source of patented inventions makes no difference to the propensity of an academic patent being licensed, federally sponsored patents are less likely to be licensed early compared to their non-federally funded counterparts" (Drivas, et al., 2016, p. 45). Their data shows that "both types of sponsored patents, federal and non-federal, are equally likely to be licensed. The differences in timing of licensing are most likely attributed to the nature of the technologies rather than management" (p. 57).

Additionally, the study of Chang (2017) employed a two-mode network analysis (countries and technology fields) method to highlight the pivotal role of various countries in technology networks. He found that "The key technologies in the more recent UIC (University-Industry collaboration) technology network were largely in the fields of measurement and chemistry, which are characterized as basic sciences with cross-disciplinary traits" (p. 107).

This paper concluded, "Patents directly reflect innovative output. Therefore, they can serve as an indicator for measuring national technology output. The country-technology network analysis results revealed that Japan and the United Stated played crucial roles in the UIC technology network" (Chang, 2017, p. 107).

From other perspective, Aldridge and Audretsch (2011) treated to identify which factors are conducive to scientist entrepreneurship and which factors inhibit scientist entrepreneurship. They stated that "Five types of factors have been found to shape the individual decision to become an entrepreneur – characteristics specific to the individual,

human capital, social capital, the institutional context, and access to financial capital" (p. 1060). They concluded that "Neither personal characteristics nor human capital seem to play an important role in the decision of a scientist to become an entrepreneur, as they do for the broader population. Rather, it is the levels of social capital, as measured by linkages to private industry that increase the propensity of a scientist to become an entrepreneur" (p. 1066).

Finally, Fisch, Hassel, Sandner, and Block (2015) conducted a research from an international perspective, examining patents at the top 300 universities worldwide from 32 different countries, showing a predominance of US universities. They found that "18 of the top 25 universities are located in the US, with the Massachusetts Institute of Technology ranked as first" (p. 318). They concluded that the propensity to apply for patents are very high among US and Asian universities, while is lower in European universities. Their international comparison shows profound differences between countries, which equally affect licensing, the creation of university spin-offs and other technology transfer mechanisms.

As we can see the emergence of the Bayh–Dole Act in the U.S, marks a milestone in relation to university patents. This Act generates an environment conducive to research and the commercialization of the results. The legal protection of the innovations encourages university research and its transfer to society.

Technology transfer

In the academic sector, the process of disseminate new technologies to the marketplace is known as "technology transfer". In this sense, Hayter and Rooksby (2016) reviewed the extant legal scholarship and provide examples of how the legal structures and the character of intellectual property law, affects technology transfer. They stated that research on technology transfer has now broadened its field of action generating links with the theory of economic development, providing a vision of growth and prosperity related with the

creation, diffusion and transference of new knowledge. The impact of this new knowledge depends on its ability to flow within society to be used for social and economic purposes.

Additionally they found that: “the university technology transfer literature (Bradley et al. 2013) find that university interest in patenting has grown rapidly in recent years, with high growth in university patenting and licensing activities, as well as the creation of university spinoff companies” (Hayter & Rooksby, 2016, p. 271).

For its part, Bodas and Verspagen (2017) made a study focusing on university-industry collaborations examining “how different axes of alignment of university and industry motivations are integrated in projects with specific technological objectives and organizational structures, benefitting from the presence of specific institutions designed to facilitate collaboration” (p. 379). They identified “two trade-offs axes. One trade-off we labelled academic goals vs. advance industry research agenda…. The second trade-off concerns finance knowledge development vs. access technical support and results mainly from conflictual interests and goals of the industry” (p. 405).

Finally, they suggested four main spaces “of alignment of university and industry motivations (advance industry research agenda, finance knowledge development, access technical support and applied R&D) and two trade-off axes (academic goals vs. advance industry research agenda, and finance knowledge development vs. access technical support)” (Bodas & Verspagen, 2017, p. 407).

In this sense, Kirchberger and Pohl (2016) conducted a systematic review of the current literature on technology transfer, focuses on the different interaction channels through which technology commercialization occur. They defined technology commercialization “as the process of transferring a technology-based innovation from the developer of the technology to an organization utilizing and applying the technology for marketable products” (p. 1081). This review found that “The motivation for academics to engage in spin-off

formation is similar to those of academics involved in licensing activities, i.e., it is rather about contributions that might advance their research, than financial returns" (p. 1095).

Looking to explore the efficiencies in different stages of technology transfer, Ho, Liu, Lu, and Huang (2014) applied a 2-stage process DEA method trying to identify the required capabilities for universities to be efficient in technology transfer process. They found that "Possessing technology rights gives universities a relatively good position to negotiate with external actors, including other research laboratories or commercial firms" (p. 251), for that reason according to previous studies, both the number of patent applications and the number of patents approved are good indicators of university-innovation output.

Additionally, they concluded, "large-scale funding resources are important for universities to pursue efficiencies in different stages of the overall technology transfer process. Without a strong resource support, a university might be unable to accumulate different capabilities required in both stages" (Ho et al., 2014, p. 268).

Due the academic engagement represents an important way in which academic knowledge is disseminate into the industrial field, Perkmanna, et al. (2013), focused on "academic engagement" that they define as knowledge-related collaboration by academic researchers with non-academic organizations. They made a systematic review of the literature, finding that "many companies consider it significantly more valuable than licensing university patents" (p. 424). However, "Academic engagement is empirically more difficult to detect because it includes collaboration instances that may not be documented by generally accessible records" (p. 430).

Following this topic Lee (2012) explored the role of tacit, uncodified knowledge in effectively exploiting patented academic inventions. He stated, "Only about 50 percent of all patented inventions (including those arising from university research) ultimately achieve commercialization" (p. 1507). In addition, "Approximately 12 percent of university-owned

inventions are transferred to the private sector by establishing start-ups, and universities' support for such arrangements is rising" (p. 1553).

He concluded, "Tacit knowledge may be very helpful in extending, adapting, or refining a technology above and beyond the core invention disclosed in a patent. The inventor's knowledge is helpful in accelerating adoption of a basic patented invention" (Lee, 2012, p. 1529). For that reason, "Relationships and organizational integration can serve as important vehicles for transferring tacit knowledge and realizing the promise of university-based innovation" (p. 1572).

From other perspective Chang, Cheng, and Fong (2016), built a mathematic model for transferring technology from faculty to firm based in two types of main decisions: patent disclosure and commercialization mode selection. This topic is highly related with this doctoral research and they considered that there are two commercialization modes, classified by the licensee (i.e. established firm or spin-off). Their analysis found "patent disclosure is negatively related to licensing price but positively related to faculty share rate. The personal demographics of an academic, including the possession of a professorship and age also play a crucial role in patent assignment" (p. 86).

They assured that faculty has to make decisions about invention disclosure and commercialization mode selection having two opportunities to select between the TTE (Licensing) and TTS (Spin-Off) mode before and after disclosing their inventions (Chang, Cheng and Fong, 2016). Finally this study concluded that "In the TTE (Licensing) mode, the optimal royalty fee per unit mainly depends on faculty's effort and the firm's investment, while in the TTS (Spin-Off) mode, it only relates to the faculty's share of licensing revenue" (p. 96).

As complement, Hsu, Shen, Yuan, and Chou (2015), tried to identify the critical drivers affecting the performance of university technology transfer. They stated, "To

understand the critical performance drivers of university technology transfer, it is necessary to depict the process of technology transfer from a university to a firm or entrepreneur through a licensing agreement or a spin-off activity" (p. 27). In addition, concluded, "The human capital of a university is the key to the performance of university technology transfer. Strengthening the university network with industry and the government might be a feasible approach for university administrators to directly or indirectly draw industry and government funding" (p. 37). For that reason, they recommended to the universities to establish attractive incentives in order to encourage faculty members to get involved in technology development for industrial exploitation.

In other study Hsu and Ken (2014), used AUTM (The Association of University Technology Managers) licensing survey to figure out the relationship between issued patents, published articles, and technology commercialization. Their regression analysis found "Expenditures are important inputs of production. If without considering efficiency, more inputs bring more outputs" (p. 27). In this sense, "The outcome demonstrates that research expenditure and the scale of schools have positive relationship to the results of published articles, issued patent number and invention disclosure number" (p. 27).

A recent study made by Mazurkiewicz and Poteralska (2017), presented a classification of barriers in the field of innovation activity, proposing the following: "(1) technical barriers, (2) organizational-economic barriers, and (3) system barriers to technology transfer" (p. 457). They concluded, "The processes of technology development and transfer conducted by R&D organizations are hampered by various barriers hindering the practical application of innovative technologies and products in the economy" (p. 462). For that reason, each situation must be analyzed individually depending of the type of the barriers, the infrastructural and human potential, and the kind of collaborative institutions.

From a regional perspective, Fernández-Esquinas, Pinto, Pérez, and Santos (2016), explored the combination of mechanisms used by firms in the region of Andalusia in Spain and Europe, when interacting with universities. They found that "university–industry links can be grouped into five latent dimensions (knowledge generation and adaptation, involvement in new organizations, training and exchange of human resources, intellectual property rights, and facilities and equipment) which are mainly based on exploitation or exploration activities" (p. 266).

This study concluded, "The most frequent relationships are those related to the training and exchange of human resources, as well as consultancy work. The least frequent activities include the exploitation of patents, the creation of spin-offs and participation in joint ventures" (Fernandez-Esquinas, et al., 2016, p. 277). It could be clear that the absorptive capacity determines the particular mode of technology transfer.

The process of commercialization academic research in emerging economies was analyzed by Chatterjee and Sankaran (2015), using Indian universities involved in the research and commercialization of biomedical innovations. They found "some evidence for a co-variation between the output of research commercialization activities and the respective organizational identities" (p. 608). This study concluded, "the organizational identities of universities appear to matter in important ways by being associated with the quantity and quality of products commercialized, as well as the nature of such commercialization contracts" (p. 611).

For Latin America countries Sargent and Matthews (2014), examined the efforts of elite universities in Chile, Mexico, and Brazil to transfer faculty inventions to the marketplace. Based on statistical information about patents filling, they found for this sample that a "significant percentage of the new knowledge produced by researchers employed at universities has commercial value. Universities can take this knowledge, file for patents or

other forms of intellectual property (IP) protection, and then license the IP to existing or spinout companies" (p. 169). In this sense, "Policymakers in the developing world are aggressively pursuing strategies designed to create their own knowledge-intensive clusters. Key components of this strategy include upgrading research universities, improving commercialization infrastructure, and promoting technology entrepreneurship" (p. 169).

These authors recognized that there are clearly weaknesses in Latin American National System of Innovation. However, "In cities such as Sao Paulo, Campinas, Santiago, and Monterrey, elite universities have established well designed systems to both create and commercialize knowledge in S&T fields. In general, these initiatives have significant financial support from state and federal governments" (Sargent and Matthews, 2014, p. 184). They recommended to explore how the legal barriers in Latin America determine the evolution of licensing efforts and university spin-offs, and to analyze the support received by the industry to the success or failure of university commercialization systems.

Finally, Morales, Sanabria, Plata, and Ninco (2015), made an exploratory and qualitative research trying to show the determining factors in the research results transfer towards the productive sector via research collaboration in four Colombian public universities. They found "Research Collaboration (RC) and Research Result Transfer via Research Collaboration (RTCR) processes start by creating a trust relationship (informal) between the two parts and then formalizing it by a strict planning process that generates total clarity according to project expectations" (p. 43). Due some barriers present in the transfer process; the research results not always have been transferred in its totality regardless of the interest of the industry.

In sum, technology transfer can take different ways depending of the quality of the research, the relationship between the institutions and the academic engagement of the actors. However, in all the cases the main motivation of the universities when make links with the

productive sector is to achieve the contribution of the new knowledge to the reality of the countries and the generation of prosperity to the society.

University patents licensing

The universities around the world have an important mechanism to contribute to economic development, which is by converting the research inventions to innovation through patenting and licensing of scientific outputs. At this respect, Wu, Welch and Huang (2015) made a national survey of academic scientists in the United States questioning about 2006 patents for which they were listed as inventors. The main issue was to determine how individual and institutional factors affect the likelihood that a patent will be licensed. They found that "the likelihood of licensing is significantly determined by individual factors including inventors' attitude towards commercialization of research, additional research conducted during patent review, and collaboration with industry scientists on the underlying research" (p.12).

This study concluded, "Individual factors play a more important role in university licensing than institutional factors. Specifically, university scientists' attitudes towards research commercialization and their engagement in post-disclosure activity are much more influential than the assistance provided by university TTOs" (Wu et al., 2015, p. 12). In addition, they suggested that the licenses outcomes must be determined by two main concepts: applicability and marketability of the underlying technology.

Following with this topic, Walter, Schmidt, and Walter (2016), made an investigation exploring "why academic entrepreneurs seek patents for spin-off technology in weak organizational regimes (the employee owns her inventions) and strong organizational regimes (the employer, i.e. the university or research organization, owns these inventions)" (p. 533). At this respect they stated that at the moment to decide "whether to patent or not, academic entrepreneurs have to weigh several benefits and risks of patenting. Patents can safeguard

their spin-off's knowledge-base by defining property rights, attract venture capital, support inter-firm partnering, and, if effective, yield substantial competitive advantage" (p. 534).

However, at the same time "patents require the disclosure of critical information is considerably time-consuming and expensive and can be a suboptimal strategy for spin-offs lacking the resources to effectively litigate and enforce their rights in cases of infringement" (Walter et al., p. 534). For that reason, they concluded, "In strong organizational regimes, social norms seem to be a main driving force behind patenting by academic entrepreneurs. In weak organizational regimes, academic entrepreneurs higher in expert knowledge and entrepreneurial orientation seek patents more extensively" (p. 542).

For its part, Öcalan-Özen and Pénin (2016) made an economic analysis of university patenting and licensing strategies, focusing on technology transfer through publication versus formal licensing contracts. They found "the strategy of the transfer will be chosen according to the nature of the invention and, in particular, to two important variables: whether or not the invention is embryonic or mature; and whether or not it is generic or specific" (p. 135).

In this sense, "An exclusive license is therefore very similar to a sale of the patent. An important consequence of exclusive license is that, since the university grants a license to only one firm, this firm will enjoy a monopoly position over the use and commercialization of the invention" (Öcalan & Pénin, 2016, p. 136). They concluded, "There is no systematic licensing scheme that guarantees successful technology transfer. The success of a given strategy depends largely on the context and, in particular, on the nature of the invention" (p. 140).

Following with this topic, Drivas, Leib and Wright (2017), conducted an empirically research address the effects of exclusive licensing of university inventions on subsequent patented innovation by non-licensees. They found that "exclusive licensing of a UC/NL patent is followed by a statistically significant increase in non-licensee patent citations. The information role of exclusive licensing, as a signpost pointing to promising follow-on

research paths, increases forward citations by non-licensees" (p. 291). For this reason, "Exclusive licensing of university patents and related technology transfer activities generates information externalities that increase innovation by non-licensees. They offer support for claims that university patenting and technology transfer generates social benefits in addition to licensing royalties" (p. 300).

From other perspective, Mowery and Ziedonis (2015) made a comparison among the localization of knowledge flows from university inventions through market contracts (licenses) and nonmarket "spillovers" exemplified by patent citations, finding "knowledge flows through market transactions to be more geographically localized than those operating through nonmarket spillovers. Moreover, the differential effects of distance on licenses and citations are most pronounced for exclusively licensed university patents" (p. 50).

They concluded "a consistent tendency for knowledge flows through market transactions (in the narrow sense defined above) to be more geographically localized than those operating through nonmarket spillovers" (Mowery and Ziedonis, 2015, p. 50). For that reason, the study recommended additional research on how firms manage the acquisition of these technologies through contractual agreements and through spillovers.

As complement, Crespi, D´Este, Fontana, and Geuna (2011), discussed on the impact of academic patenting on publishing and knowledge transfer using two separate surveys of academics, and their CV information based in a longitudinal database. Their findings indicated, "patenting potentially can act as another way to transfer knowledge from universities to the rest of society. However, beyond a certain threshold, a continuing focus on patenting can result in a negative effect on other channels of knowledge diffusion. As in the case of publishing" (p. 65).

In this sense, Thompson, Ziedonis and Mowery (2016), examined the effect that the licensing of academic patents has on journal citations to academic publications covering the

same scientific research. They found that “for patented academic discoveries in general, licensing appears to have little effect on journal citations to related scientific publications” (p. 1). The study also affirmed, “Licensing of IP related to research tools thus may have negative consequences for follow–on scientific research and therefore may have a negative effect on citation rates for publications related to such IP” (p. 7). They concluded, “academic licensing of intellectual property may be associated with restrictions on research inputs that are important for follow–on research” (p. 22).

The last paper made by Quintás, Caballero, Arévalo, and Piñeiro (2012), studied the patents that have applied, across the European route, the Japanese, American and European universities, in order to establish a comparative analysis among them. They found “1. Las solicitudes de patentes por parte de las universidades se incrementan año a año. 2. Es más acentuada en el área químico-farmacéutica y en el área de instrumentación. 3. Las empresas que más colaboran con las universidades pertenecen al sector químico-farmacéutico” (p. 33). They concluded that exist important differences between universities at the time to apply for a patent due to historical, cultural and institutional contexts.

As can be seen in the literature, the licensing of university patents is a widely used way to achieve technology transfer to companies. However, its use depends on factors related to the type of innovation, the degree of commitment of the inventor and the ability to generate resources for the University. The degree of exclusivity of the licenses and their impacts on the indexes of the scientific publication must also be taken into account.

University Spin-Off

The literature on University Spin-Off has been quite prolific at the level of scientific publications both in Europe and in the United States. On the other hand, the treatment that different authors have given to the subject can be grouped in three great tendencies: a. Approaches regarding the definition and / or typologies of University Spin-Off; b. Analysis

on the process of creation of University Spin-Offs, and c. Studies on the organizational and institutional factors that favor the creation and development of University Spin-Off.

In order to introduce this topic, Seguí-Mas, Sarrión-Viñes, Tormo-Carbó, and Oltra (2016) made a literature review of existing academic spin-offs in order to present the current situation at the international level, through a bibliometric analysis of the literature (1990-2014) on academic spin-off (224 articles). They found three main reasons for the high volume of scientific articles in this topic:

"• la promulgació de la Llei Bayh-Dole als EUA al 1980, diverses lleis europees, però a diferent ritme

• l'augment de l'emprendiment en les universitats

• l'aparició de revistes que realitzen edicions centrades en emprendiment universitari" (p. 252)

They concluded that "Les paraules clau "Technology Transfer", "Academic entrepreneurship", "University Spin-offs" i "Spin-offs", en la literatura bàsica SOA, convertintse en els nexes essencials en la literatura d'aquest camp" (p. 259).

The definition is perhaps one of the topics of greater debate when the conceptual analysis regarding University Spin-Off is addressed. The characterization of this type of company changes substantially depending on the factors that configure it denominating like Spin-Off any type of enterprise that fulfills three conditions:

1. That arises within an existing organization, which in Anglo-Saxon literature is called as "parent organization", and here we will call it the parent company.

2. Involves one or more individuals regardless of their function and hierarchical level within the parent company.

3. These individuals leave the parent company to create a new organization (Pirnay, Surlemont & Nlembo, 2003).

In this context, a University Spin-Off arises from a particular "parent organization" that is called University. After compiling a series of definitions found since 1982, they conclude that a University Spin-Off is "a new company created to commercially exploit some knowledge, technology or research results developed within a University" (Pirnay et al., 2003, p.356), a concept that we will welcome for the execution of this Doctoral Thesis.

For its part Beraza and Rodriguez (2012, January) tried to identify the different realities that it includes organizing the University Spin-Off by means of typologies. They proposed a classification that distinguishes four Spin-offs types: independent, linked, joint venture and subsidiary. “The three key approaches used to distinguish these four types of university spin-offs are: the implication or not of the investigator as entrepreneur, the nature of the transferred knowledge and the participation of external partners in the new company” (p. 39)

Following this topic Pattnaik and Pandey (2014) made a review of available literature on university Spin-offs and presented a comprehensive overview of what university Spin-offs are. They found that “University spinoffs are not very common, but they are important for economic development (Lowe, 2002), for commercializing university technologies (Etzkowitz, 2003), and for helping universities with their major missions of research and teaching (Jones & Gold, 2001)” (p. 45).

This study concluded proposing a multistage holistic model of university Spin-offs that can be used by scholars in the area of academic entrepreneurship to build case studies. In addition, “Statistical generalizations can be possible in future studies that take into account causal relationships between identified competencies, attempts to patent the invention or

innovation, spinoffs created, and economic value generated in large-scale survey-based studies" (Pattnaik and Pandey, 2014, p. 49).

Fryges and Wright (2014) provided a typology of corporate and academic spin-off types, distinguishing Spin-offs involving new ventures from those that concern existing activities. They found that "Corporate spin-offs tend to be based on narrow technology while spin-offs from universities are more likely based on broader platform technologies" (p. 256). Additionally, the paper presented a Table of Typology Spin-Off depending of the environmental context (University and Commercial). For that reason, they recommended, "The mobility of industry researchers into spin-off firms may create opportunities to recruit new expertise, such as newly qualified graduates from universities or from other countries" (p. 257).

From other perspective Wennberg, Wiklund, and Wright (2011) studied the flow to entrepreneurship by individuals with a university education background who become involved in new venture creation by means of corporate spinoffs (CSO), finding two paths to knowledge-intensive entrepreneurship based on university knowledge. "The first is the direct path where individuals first study, then work at universities and subsequently spin off their business directly from the university. We refer to spinoffs taking this direct path as university spinoffs (USOs)" (p. 1129).

The other path is "represented by university graduates who pursue careers in private industry and spin off their companies from that context (Parhankangas & Arenius, 2003). We refer to those as corporate spinoffs (CSOs)" (Wennberg, et al. 2011, p. 1129). At this respect, they found that "The direct path to knowledge-intensive entrepreneurship via university spinoffs seems to represent only a small minority of cases. The indirect path via corporate spinoffs is much more common" (p. 1137).

From Latin America context Castillo-Vergara and Alvarez-Marin (2015, September) made an analysis about the current situation regarding the concept of Spin-Off in Chile as a mechanism that universities can use to transfer results of public research into the economic system. They focused “on contextualizing the development of Spin-Off in countries in North America and Europe and emphasize the factors that have allowed its birth, growth and key results in those nations” (p. 1). They concluded that “business models are important for the commercialization of the research results, as is the role that the research team plays, and should consider strategies to encourage the team's own skills in addition to the technical profile” (p. 1).

For its part, Zúñiga (2013) made a bibliographical revision trying to analyze the spin-offs within the university context. She stated “Para ser clasificada como una spin-off, debe cumplir que su fundador o sus fundadores provengan de una universidad, y la actividad de la empresa debe estar basada en ideas técnicas generadas en el entorno universitario” (p. 85). Additionally, the paper included a Table with different typologies of Spin-Off. She concluded that “Es necesario que las universidades tomen conciencia de que crear una empresa a partir de resultados de investigación supone un excelente análisis de la tecnología, el equipo emprendedor, las posibilidades de financiación y las implicaciones de la creación de esta” (p. 93).

Another of the topics that recurrently addresses the literature has reference to the organizational environment and the conditions of the environment in the midst of which the processes that allow the creation of Spin-Offs in the Universities are developed. Institutional support, promotion of entrepreneurship, human capital characteristics, adequate legal protection of innovations, financing capacity, among others, are essential factors that give impetus to these initiatives.

At this respect Senelwa, Mukulu, and Kihoro (2016) examined the extent to which academic entrepreneurial intentions influences the creation of University Spin-offs firms from various significant viewpoints. They found “For effective conversion of research findings into new business venture, a close collaboration of the government –university – industry must be active, the connection of individual academic and prevailing university environment forms the requisite solid foundation of academic entrepreneurship” (p. 532).

With respect to this doctoral research, they concluded that Academic Entrepreneurial Intentions (AEI) is the independent variable that influences creation of University spin-off firms. In addition, “With reference to the reviewed literature, it is assumed that university context moderates the relationship between AEI and creation of university spin-off firms, hence it is the moderating variable that has a strong contingent effect on the independent-dependent variable relationship” (Senelwa, et al., 2016, p. 537).

As complement, there is the study made by Roseli da Luz and Sanches da Silva (2013). They looked the critical factors that influence the creation of Academic Spin-Offs, finding that it is a process comprises four stages: “(1) geração de ideias a partir de resultados de pesquisa; (2) finalização de projetos do novo negócio a partir das ideias; (3), lançamento do spin-off e (4) fortalecimento da nova empresa (Ndonzuau, 2002)” (p. 195).

According to this authors the principal factors that influence the creation of Spin-Offs are: “Grau de suporte oferecido pela organização-mãe (instituição de pesquisa); Disponibilidade de recursos; Posse dos direitos de propriedade intelectual pelos centros de transferência tecnológica; Escassez de talentos; Potencial mercadológico; Localização e dificuldade de gerenciamento” (Roseli da Luz and Sanches da Silva, 2016, p. 196). They concluded that this kind of enterprises require business incubators and technological parks in order to promote their creation.

Another study developed by Fernandez-Alles, Camelo-Ordaz and Franco-Leal (2015) identify theoretically the resources and competences critical for Academic Spin-Offs (ASO) development, and determine empirically the actors from the academic and market contexts who supply them at two stages of development: creation and initial development and consolidation stages. They found that "government institutions and Science Park are very relevant actors that assume a key role for future ASOs consolidation. In both stages, venture capital firms are relevant market actors that provide not only financial resources, but also market credibility" (p. 976).

From other perspective, Pattnaik and Pandey (2016) reviewed the scholarly literature on university spin-off and present a comprehensive overview of what is a university spin-off, why it is important, what makes it significant and how university spin-offs are created. They concluded something relevant for this doctoral research "application to file a patent is forwarded to technology licensing officer, upon finding the research result appropriate decision to lease or to spin-off is made which further leads to economic and social value generation" (p. 9). They considered the Spinoffs as one of the significant engines of direct commercialization of university intellectual property.

In their seminal paper Ndonzuau, Pirnay, and Surlemont (2002) made a study trying to identify, understand, and distinguish the major issues raised by the creation of academic spin-offs from the point of view of both public and academic authorities. Based in semi-structured interviews their found that "four stages emerged as relevant in explaining the transformation of academic research results into economic value" (p. 282). This four stages are "Stage 1: to generate business ideas from research; Stage 2: to finalize new venture projects out of ideas; Stage 3: to launch spin-off firms from projects; Stage 4: to strengthen the creation of economic value by spin-off firms" (p. 282). Each stage has a specific function in the process

to identify the various changes of status that research results have to undergo to generate economic value.

For its part, Rasmussen (2011) suggested, “that the different theories or motors play roles of varying importance at different times in the spin-off venture formation process. Moreover, it has been suggested that the stage, teleological and dialectical processes provide input to the evolutionary motor” (p. 465). He recommended, “Adding teleological, dialectical and evolutionary theories, this study provides a more comprehensive framework for spin-off processes that takes into account how the process moves from one stage of development to the next” (p. 466).

His analyzes suggested that each of the four theories of processes used: "Life cycle, Teleological, Dialectic and Evolutionary, provides an additional look at the process of forming a Spin-Off, in particular, regarding its progress through time" (Rasmussen, 2011, p.462). Based on the above, it suggests that universities should pay special attention to the role of key people in the initial stages of entrepreneurship and to the process of transition from a research project to the formation of a commercial enterprise.

Following with this topic Huynh, Patton, Arias-Aranda, and Molina-Fernandez (2017) made an analysis about the influence that the capabilities and networks of a founding team, at incorporation, have upon the future performance of the spin-off. Based in a survey with 181 Spanish university spin-offs they found “The entrepreneurial capabilities of a founding team, augmented during the ‘creation’ phase, have a positive influence on the performance of a spin-off during the ‘growth’ phase” (p. 10).

Additionally, “the networks of a founding team indirectly affect a spin-off's performance through the enhancement of a team's entrepreneurial capabilities” (Huynh et al. 2017, p. 10). They recommended paying more attention to the founding team and the process by which they build capabilities and networks in the ‘creation’ phase.

Another study made by De Cleyn, Braet, and Klofsten (2015) focuses on venture team characteristics with respect to human capital dimensions in early stage ventures emerging from academic research (institutions). Their interviews with 185 product-oriented academic spin-offs in nine European countries shows “a significant positive—but diminishing—impact of team heterogeneity on venture success, as well as a positive impact from legal expertise within the board of directors” (p. 599). The results indicated that larger management team is better equipped to face the challenges in academic spin-offs.

For that reasons they concluded for new venture’s early development, “the characteristics of key persons (in the form of human capital) play a crucial role by providing a source of legitimization and credibility. The results have pointed to the important role of heterogeneity, both at TMTand BoD levels” (De Cleyn et al, 2015, p. 600).

Continuing with this theme is the work done by Gilsing, Burg and Romme (2010), who address the analysis of those principles that serve to create Spin-Offs differentiating them from those who focus on their subsequent probability of success. Following the model adopted by Beckkers, Gilsing and Van der Steen (2006), based on the notion that there are institutional levels within a national innovation system each of which determines the enabling environment for the creation and success of companies Spin Offs, present four levels as follows: "Norms and National Policies; Sectorial Characteristics / Technological Development; Home / University; and Regional Policy” (Gilsing et al., 2010, p.14).

They emphasize that the existence of an "entrepreneurial environment" in universities is something that encourages the development of this type of initiatives. In this sense, "business incubator programs, entrepreneurial culture, the existence of offices for the transfer of technology and, at a regional level, Spin-Off networks and the existence of technology parks, are factors that drive their creation and future growth" (Gilsing et al., 2010, p.16).

The last set of analyzes that we present is related to the institutional factors within universities that allow the formal creation of a Spin-Off and what are the factors that guarantee its growth and durability over time. At this respect, Rasmussen and Wright (2015) explored how universities can promote new research-based businesses by suggesting that the nature of the support supplied depends on the demands of the spin-off firms. They found that the university context "plays an important role, both in relation to the individuals starting university spin-offs and their ventures. Some university characteristics associated with spin-off firm formation are well established in the literature, such as intellectual eminence, faculty quality, or scientific productivity" (p. 3).

This study concluded identifying three-core process necessary to develop a new venture: opportunity development competency, championing competency and resource acquisition competency. Meanwhile in the development of all three entrepreneurial competences the individual academic plays a key role, "other levels may play more or less important roles depending on the competency considered. The central university management and students seems to play a more indirect role in spin-off support" (Rasmussen and Wright, 2015, p. 23).

Meanwhile a review of tracking the advancements in academic entrepreneurship Osiri (2013) stated, "University-based spin-off companies tend to be making important economic contributions in their home-states; however, when a cumulative effect of all these spin-offs is considered, a national economic contribution due to their business activities emerges" (p. 134). By using multiplexed approach, he concluded, "Apparently, universities that have a culture that promotes entrepreneurship would have greater number start-up companies formed compared to their counter-parts that do not share similar values" (p. 137).

For its part, Sternberg (2014) analyzed the factors that lead to the success of University Spin-Off from a regional approach. His study was based on empirically comparing

the impact of two federal programs of support for university entrepreneurship in regions of Germany in relation to the regional environment in which Spin-Off is created. With information spanning a period of 11 years through ordinal regressions, he concludes that the regional context in which a company starts has a greater impact on its performance and is more important than having received some government support for its constitution.

From other perspective Fini, Grimaldi, Santoni, and Sobrero (2011) made a study analyzing the extent to which University-Level Support Mechanisms (ULSMs) and Local-Context Support Mechanisms (LCSMs) complement or substitute for each other in fostering the creation of academic spin-offs. They found "The ULSMs' marginal effect on universities' spin-off productivity may be positive or negative depending on the contribution offered by different LCSMs" (p. 1113). Additionally, "ULSMs complement the legislative support offered to high-tech entrepreneurship whereas they have a substitution effect with regard to the amount of regional social capital, regional financial development, the presence of a regional business incubator, regional public R&D expenses" (p. 1113). For that reason, they recommended, "universities have to invest in both ad-hoc mechanisms and policies, including TTOs and spin-off regulations, and other related activities that might complement them, such as external collaboration regulations and patent regulations" (p. 1125)

Beraza and Rodriguez (2011, may) analyzed the characteristics of the programs that are implanting in the Spanish universities to foment the spin-offs creation, by means of a comparison with the existent in the European universities. They found "La Administración Pública participa habitualmente en la financiación de las spinoffs, mientras que la presencia del capital riesgo y los business angels está poco extendida. Normalmente, la universidad no participa ni en el capital ni en la gestión de sus spin-offs" (p. 112).

Using a cluster analysis Iglesias, Jambrino, and Peñafiel (2012) focused on defining and characterizing the typology of the University Spin-Off in order to provide a framework

and to establish a useful basis for designing support policies for entrepreneurship in universities. They confirmed “la existencia de categorías de Spin-Off universitarias cuyas diferencias de comportamiento dependen de la capacidad de inversión en I+D, de la productividad de resultados de investigación y de la capacidad de generación de ingresos derivados” (p. 253). For that reason they recommended for the universities “concentrar sus esfuerzos en propiciar un escenario de apoyo a la creación de Spin-Off, pero… programas que favorezcan el paso de la etapa start-up a la de crecimiento, y de esta última a la de consolidación” (p. 253)

Freitas, Goncalves, Cheng and Muñiz (2013), when referring to the factors that structure a University Spin-Off considered that these could be differentiated in relation to three main dimensions: a. the institutional link; b. the business model; and c. type of resources. The latter identify four main categories of resources: technical, social, human and financial. For the business model, it allows identifying the market segment, the value chain of the company, its cost structure and the marginal benefits. Finally, the institutional links shape the relationship of the Spin-Off with its Head Office and what the influence of its business strategy.

From another perspective, the work published by Rasmussen, Mosey and Wright (2014) addressed the impact of the institutional context on the development of University Spin-Off companies. In particular, how the existence of departments responsible for promoting entrepreneurial skills influences the emergence of Spin-Off in universities. Through the application of the case study method, the authors conducted a longitudinal study of eight companies from their inception to their early development. Four of them from two universities in the United Kingdom and the other four from two universities in Norway, related to the areas of Biotechnology and Engineering.

Their conclusions suggested that the existence of a department in charge of supporting entrepreneurship exerts a high influence on the initial development of University Spin-Offs. In particular, "these areas provide support in terms of time and tangible resources, coupled with adequate commercial capacity and a group of top-tier researchers represents a powerful combination of factors that ensure the success of these endeavors." (Rasmussen et al., 2014, p.103).

Without a doubt, the transition from a teaching and research university to an entrepreneur implies substantial changes in institutional policies. The creation of an environment that promotes academic entrepreneurship, strong relationships with industry, the promotion of applied research projects and the capacity of taking risks, all of which is shown as necessary to achieve the goal of creating university Spin-Off with vocation of permanence in the market.

Summary

The Academic Entrepreneurship gives to the universities the opportunity to enhance the economic development of the countries and regions. The legal process to obtain patents and their commercialization through licensing (exclusive and non-exclusive form) or through the creation of Universities Spin-Off (Academic or Corporate), are the most formal way to achieve the effective technological transfer of the knowledge created by the universities research.

The review of the literature was carried out using a strategy that allowed its focus on those sources that would contribute to define more clearly each of the topics associated with this research. Therefore, the most recent documents related to the main concepts and variables that derive from the object of the study were reviewed, namely: Academic Entrepreneurship, Industrial Property, University Patents, Technology Transfer, University Patent Licensing and University Spin-Off.

The international literature on these topics is abundant and with an increasing tendency. This input allows us to appreciate the topicality and relevance of the subject matter of this research. Likewise, there are multiple references to the importance of the university patents dynamics and technology transfer within knowledge-based economies today, not only as a reflection of the countries' national innovation systems but also as a support to the regional development.

Conclusions

Regarding the unresolved issues that the specialized literature suggests to address, there is a lack of empirical studies that allow identifying the factors that at the university level determine the choice between licensing or the creation of Spin-Offs as a mechanism for the transfer and commercialization of university patents. (Czarnitzki et al., 2016; Wood, 2011)

In the same sense other authors suggest analyzing how universities organize the multiple activities that arise from academic entrepreneurship, among others licensing and the creation of Spin-Offs (Pattnaik & Pandey, 2016; Siegel & Wright, 2015). Similarly, it is suggested as a future research agenda how universities perform the option of exchange between licensing and Spin-Offs (Grimaldi et al., 2011). All these are topics highly related to the research question and the hypotheses formulated for this doctoral thesis. Its development will fill these gaps in related knowledge and justify the development of this work.

Chapter 3: Methods

This is a quantitative, cross-sectional and descriptive research focused on find out the relationship between the factors at the university level that explain the choice of licensing and the creation of spin-offs as a mechanism for the transfer and commercialization of university patents in Latin American countries. This research will have an explanatory scope and a non-experimental design. This chapter defines the research design criteria, the instruments to be applied, the procedures for data collection, the confidentiality conditions, the sample size criteria, the survey features and the validity and reliability issues forecast that may affect research.

Research Design

According to the Literature Review, previous researches based on the concept of technology transfer were elaborated using quantitative methods. Its authors suggest maintaining this methodology and the use of instruments already developed and tested empirically for future studies. To advance this study, we will take as a basis of analysis the following conceptual model (Figure 3), built from the literature review and the consulting with some directors of Technology Transfer Offices (TTO) in several universities, which presents the different factors as well as their characteristics and indicators.

As independent variable, we will take the university patents, from which a random sample will be taken from the patents of invention recognized according to a data base supplied by the Superintendence of Industry and Commerce of Colombia and processed by the Observatorio Colombiano de Ciencia y Tecnologia (OCyT) (www.ocyt.org.co). Each invention patent contains associated control variables such as: area of knowledge to which it

belongs, year of grant, type of university that owns the rights, university size and city of origin.

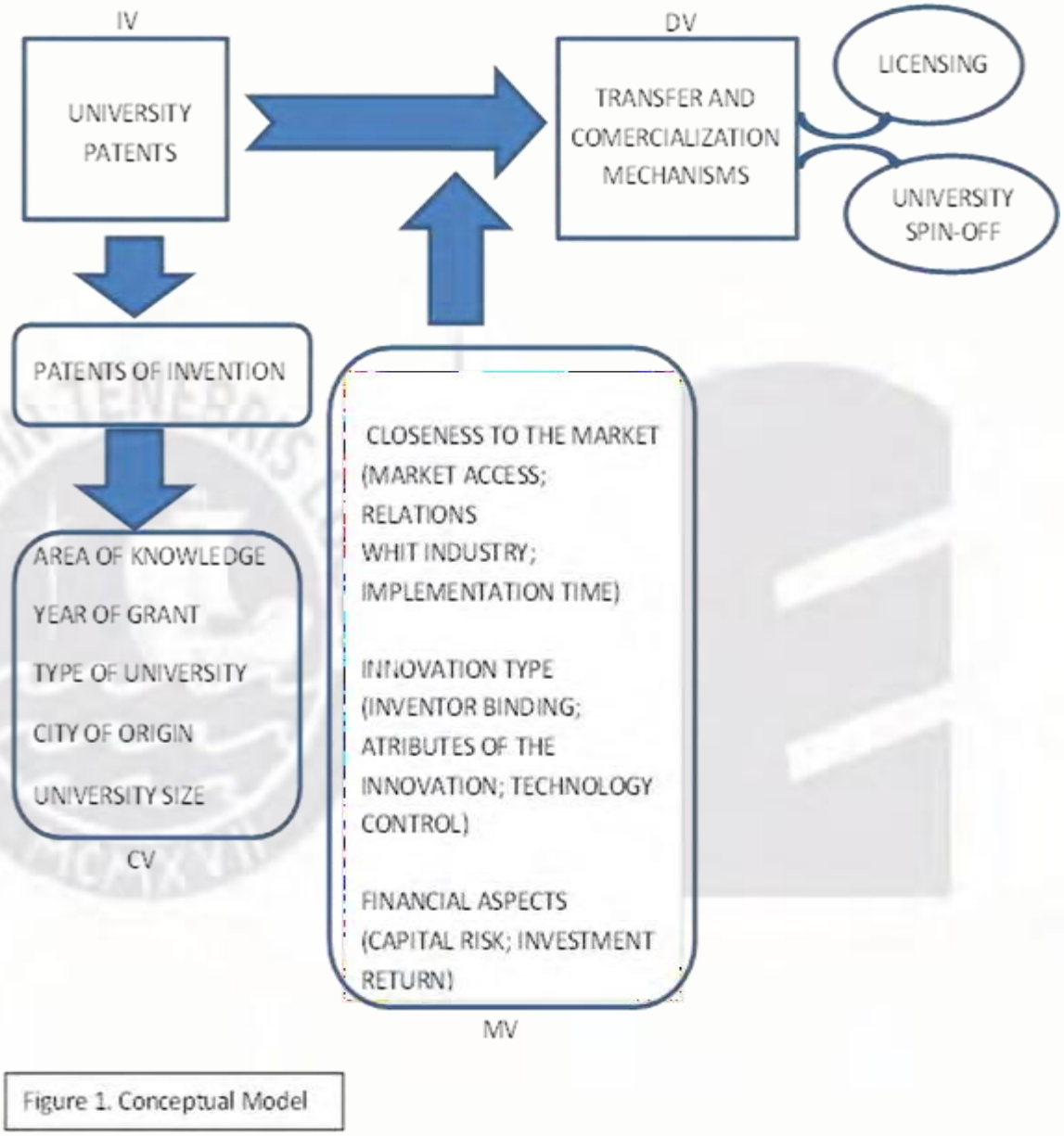

Figure 3. Conceptual Model

For its part the dependent variable, transfer and commercialization mechanisms, in this model present two options of result: Licensing or creation of University Spin-Off. Likewise, a series of moderating variables will be tested which this proposal considers are the main factors that determine the choice of one or another transfer and commercialization

mechanism. For this study, the following will be taken: Closeness to the market; innovation type and financial aspects. Each one of these factors has several indicators and the information will be obtained from a survey that will be carried out among the university institutions that hold the patents according to the sample.

Appropriateness of the Design

This design makes it possible to establish the relationships between university patents and the mechanisms commonly used for their transfer and commercialization, by identifying the main factors that at the institutional level determine the choice between licensing or the creation of university spin-offs. Based on the process diagram of Figure 3 and according to the application of the alpha-beta method (Figueroa, 2012), the University Patents as independent variable have a cause-effect relationship with Technology Transfer Mechanisms (dependent variable).

Based on Figueroa (2012), Karl Popper's epistemology will be apply with the alpha-beta method that states that scientific knowledge is achieved through a deductive logic process with the collection and processing of information from a conceptual framework, which allowed the confirmation of the model. For this purpose, illustrated in Figure 4 is the process diagram that related the exogenous variables with the endogenous variables (Wang et al., 2012).

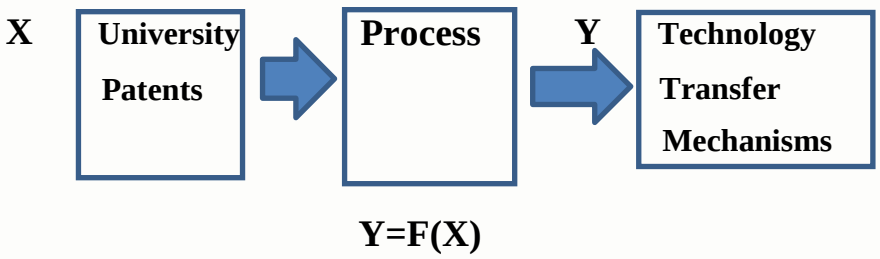

Figure 4. Research process diagram alpha-beta method (Figueroa, 2012)

Given the characteristics of the variables involved in the conceptual model, which combines information with metric and non-metric data and because it is the dependent dichotomy or binary variable, Partial Least Square (PLS) path modeling will be applied for the data analysis due to its capacity to simultaneously estimate dependencies and relationships between the variables and due to its robustness and ease for interpretation of results and diagnoses (Hair, Black, Babin & Anderson, 2010).

Research Questions

The following are the research questions incorporated in the study and associated to relationships between the variables, according with the research framework:

¿Which factors at the university level determine the technology transfer of the university patents in Latin American countries?

¿Which factors explain the choice of licensing as a mechanism for the transfer and commercialization of university patents in Latin American countries?

¿Which factors explain the creation of spin-offs as a mechanism for the transfer and commercialization of university patents in Latin American countries?

Hypothesis

It is necessary to generate three groups of testable hypotheses depending of the most relevant factors that intervening at the university level: 1. Closeness to the market. 2. Innovation type. 3. Financial aspects.

H1: The closeness to the market determines the licensing as mechanism for the transfer and commercialization of university patents

H2: The closeness to the market determines the creation of a University Spin-Off as mechanism for the transfer and commercialization of university patents

H3: The innovation type determines the licensing as mechanism for the transfer and commercialization of university patents

H4: The innovation type determines the creation of a University Spin-Off as mechanism for the transfer and commercialization of university patents

H5: The financial aspects determine the licensing as mechanism for the transfer and commercialization of university patents

H6: The financial aspects determine the creation of a University Spin-Off as mechanism for the transfer and commercialization of university patents

Population

The population of this study is grouped into two levels. On a first level, in order to achieve a better understanding of the dynamics of university patenting in Latin America today, a comparative analysis will initially be undertaken regarding the number of patents applied for and granted to universities located in Chile, Colombia, Mexico and Peru, for being the signatory countries of the Pacific Alliance (Alianza del Pacífico), regional integration initiative for the development of the people of Latin America.

In this case, the information will be obtained from secondary sources through consultation in the electronic databases held by the agencies in charge of issuing patents of invention in each national jurisdiction. These are the following: Instituto Nacional de Propiedad Industrial de Chile (INAPI) (www.inapi.cl); the Superintendencia de Industria y Comercio de Colombia (SIC)(www.sic.gov.co); the Instituto Mexicano de Propiedad Industrial (IMPI)(www.impi.gob.mx); and the Instituto Nacional de Defensa de la Competencia y de La Protección de la Propiedad Intelectual de Perú (INDECOPI) (www.indecopi.gob.pe). For each one of them, the information will be collected regarding

invention patents requested and granted to national universities, during the period from 2008 to 2017.

At a second level, in order to study the relationships between university patents and the main factors that affect the decision at the University level at the moment to choose the best mechanism to commercialize the patents of invention, the primary information will be obtained through a survey applied among the managers of the Technological Transfer Offices of a group of Colombian universities. From the universe of the 200 patents of invention granted in the last ten years, it is necessary to apply a computer random process to identify the sample of the research. The sample it will include public and private universities patents and the size of the sample will be the necessary to assure a maximum 5% of statistical error with a confidence level of 90%.

Informed Consent

Surveys will be answered by directors with responsibilities in the Technology Transfer Offices in different Colombian universities. It will be explained that their participation will contribute with the enhancement of the development of the assessed institutions, since the structured information will allow design new strategies that promote the academic knowledge to the society. The format of the survey will have the research objectives, the respondent's profile, the information confidentiality agreement, the informed consent and the voluntary expression to answer the survey.

Sampling Frame

One key function of statistics is to use the information collected to make informed conjectures about larger questions for which we do not have full information. Researches use data from the "known world" to make informed inferences about the "unknown world". But data deserve respect, in order to get the best "picture" of the reality.

In this sense, due to several theoretical and practical reasons such as ethical, budgetary, logistics and time limitations, most of the studies are performed using samples. “We define sample as a finite part or subset of participants drawn from the target population. In turn, the target population corresponds to the entire set of subjects whose characteristics are of interest to the research team” (Martinez-Mesa, González-Chica, Pereira, Rangel, & Luiz, 2016, p. 326)

According to Kvanli, Pavur and Keeling (2003), when for a researcher it is time to obtain a sample data or primary data, an important decision is whether to gather data in a random process or will get it using a deliberate selection procedure. In the first case, we are in front of probabilistic or random sampling. In the second case, they are often referred to as non-probabilistic or nonrandom sampling.

In this study, we are going to use the random sampling because it assures that every sample of size n has the same chance of being selected. A computer program will be used to generate random numbers. The main advantage of random sampling is that it can generalize the results beyond the sample itself.

In probability sampling, randomness is the element of control, while in non-probability sampling it depends on the personal research judgment. But randomness or not randomness is necessarily connected with the sample size. And the sample size, at the same time, depends of the nature of the study, the research method and the field of knowledge.

In the first place, different authors agree that the sample size definition is not only to be considered a means to an end in obtaining accurate results. It is an integral part of research planning, which will shape the eventual study design and data collection processes (Pye, Taylor, Williams & Braithwaite, 2016; Boddy, 2016). In addition, the size of the sample is contextual and partially dependent upon the scientific paradigm under which investigation is taking place (Boddy, 2016).

For this particular research, we will use an extended formula that guides on the calculation of the sample size for global data is the following:

$$n = \frac{k^{2} * p * q * N}{(e^{2} * (N-1)) + k^{2} * p * q}$$

Where:

N is the size of the population or universe (total number of possible respondents).

K is a constant that depends on the level of confidence that we assign. In our case it will be 90%

e is the desired sampling error. The sampling error is the difference that can exist between the result that we obtain by asking a sample of the population and the one that we would obtain if we asked the total of it. We will apply 5%.

p is the proportion of individuals who possess the characteristic of study in the population. This data is usually assumed that p = q = 0.5, which is the safest option.

q is the proportion of individuals who do not possess this characteristic, that is, it is 1-p.

n is the size of the sample (number of surveys that must be done).

Once this formula is applied, based on the previously defined parameters, on a universe of 200 patents granted to Colombian universities, the sample size is 115 patents (Feedback Network Technologies, 2013).

The sampling method will have the following characteristics: 1. A true representation of the population of the study; 2. Free from error due to bias; 3. Size adequate for being

reliable; 4. Free from random sampling error; 5. All the units of the sample should be independent and relevant (Ullah, 2016).

Confidentiality

In general, all information will be treated as confidential, principally the respondent's identities and their correspondent institutions. In order to ensure the confidentiality, raw data will be saved in places with adequate security, data files will have security code and the respondent names will not be recorded on any of the instruments administered. For the data processing purposes, each survey will be allocated with a numeric code to keep the identity.

Location

For the first level of analysis, this study will be located geographically in Chile, Colombia, Mexico and Peru, particularly in the university systems of each country and their regulatory entities in matters of Intellectual Property. For the second level of analysis, through the application of online surveys, data from the Technology Transfer Offices of Colombian universities located in different cities of the country will be collected, as long as they have invention patents according to the random sample obtained.

For the purposes of this study, Colombia is considered an appropriate setting to carry out these analyzes, given the advances it has made in terms of its innovation system, which is recognized by international organizations. In this sense, the evaluation carried out by the Organisation for Economic Co-operation and Development (OECD, 2014) on the innovation policies of Colombia, previous its acceptance as a member of this Organization concluded the following:

> Significant alterations to the political framework and institutional system in recent years have indicated an increasing commitment to boost innovation:

• The potential significance of innovation for Colombia's socioeconomic transition has been acknowledged and given prominence in the National Development Plan (NDP).

• A noteworthy increase in resources for science, technology and innovation (STI) was built into the restructured regime for distributing the royalties from mineral exploitation (the General Royalties System, set up in 2011).

• This new funding regime was designed to ensure that participation in and the benefits of STI activities would be more widely distributed across all regions of the country.

• In order to advance these plans, new governance structures were developed and new methods and mechanisms were established to manage resource allocation and programme implementation in these areas, not only at the national but also at the regional level, such as the "Ruta N" initiative in the city of Medellin. (p. 14)

In addition to the above, the evaluation recognizes that the conditions for innovation have improved considerably, and now the country has greater openness internationally. From this integration of Colombia in global networks of knowledge, innovation and value chains, new opportunities are expected to emerge.

Finally, this international report emphasized that the increase of external financing and the governmental impulse to research and innovation has not only increased the number of doctors at the national level but has also strengthened the management of research in universities. The country has a "modern legislation on Intellectual Property (IP), in line with the Bayh-Dole Act in the United States, which has further encouraged the creation of technology transfer offices (OTT) in a high number of universities" (OECD, 2014, p. 16).

Instrumentation

Research data will be first-hand with a Likert survey (1 to 5), developed by Wang et al. (2012), which will be peer reviewed. It will be applied adjusting in order to adapt to

Colombian context and research focus. The survey is originally written in English, but it will be translated into Spanish but maintaining the academic translation standards (Usunier, 2011).

Survey will provide respondents' traits, which will be included as moderator factor. Survey will have a pilot test aimed at guaranteeing the respondents' comprehension regarding what is established by Hair et al. (2010). For the purposes of this research, it will be supposed that the measurement instruments were suitable, and that the surveys' information corresponded to the best options, taking into account the respondents' knowledge and experience.

Data Collection

The data collection process will be developed as follows:

1. For the first level of analysis, the information of the patents requested and granted to universities in Chile, Colombia, Mexico and Peru during the period 2008-2017 will be obtained from the consultation and systematization of public data that are available in the databases that are administered by the respective official organisms in charge of administering the Intellectual Property regime in each territorial jurisdiction. These will be global data without going to discriminate by type of university or class of patent recognized.

2. For the second level of analysis, the information corresponding to Colombian universities on patents recognized to potential respondents - according to the sample that is determined - will be sent an invitation to voluntarily respond to an electronic survey that guarantees the confidentiality described above. At this time, control questions will be made to establish the consistency of the profile of the respondent.

3. Respondent's data will be included in the research until the required numbers are completed in accordance with the sample size. Each survey will be allocated with a numeric code to keep the identity.

4. Complete data will be processed according to the statistical methodology premises.

5. Finally, results analysis and interpretation will be performed, and conclusions will be redacted.

Data Analysis

According to the study's instrumentation, data mining will be done in Excel sheets in accordance with Wahba (2013). In order to achieve a better understanding of the dynamics of university patenting in Latin America today, a comparative analysis will initially be undertaken regarding the number of patents applied for and granted to universities located in Chile, Colombia, Mexico and Peru. Based on the information obtained from official agencies in each country, a series of linear regressions will be carried out in order to establish comparisons between the independent variable university patents recognized annually, in relation to: Population; GDP per capita; Number of recognized researchers; Foreign direct investment; and Gross Expenditure on Research and Development as a percentage of GDP (GERD) for each of the countries. This information will be obtained through the consultation of the Global Innovation Index (www.globalinnovationindex.org)

The purpose of this analysis is to predict the value of the independent variable according with the value of the other variables. This part of the study will use SPSS Statistics, as a good tool to interpret and report the results from the different tests. Of course, this regression analysis method requires a reliability data generation process, and casual relationships consistent with the reality of the different countries.

The other purpose of this study will establish what kind of relationships exist between the independent variable university patents, versus the dependent variable transfer and commercialization mechanisms with two possible outcomes: Licensing or Creation of a Spin-

Off. As moderating variables, it will have a set of factors that affect the decision process within the universities.

The selection of the variables for this study was based on the review of the literature of those journal papers that in the last five years presented the greatest relevance and citation according to the purpose of this research. The first thing that was found is that the theoretical approaches that have been used to analyze the mechanisms for the transfer and commercialization of university patents are heterogeneous.

Among these are the Knowledge-based entrepreneurship (Kesan, 2015; Moutinho et al., 2016), the Capability-based framework (Cantu-Ortiz et al., 2017; Rasmussen & Wright, 2015), the Academic engagement (Hsu et al., 2015; Perkmanna, et al., 2013), the Absorptive capacities (Fernández-Esquinas et al., 2016), the Research collaboration (Morales et al., 2015), the Entrepreneurial capabilities (Huynh et al., 2017; Senelwa, 2016), among others. However, all of them were applied in qualitative research that is not the methodological approach of this research.

On the other hand, a large part of the quantitative work was based on the theoretical approach of Academic entrepreneurship (Wood, 2011), which is the same used in this research. From the most recent empirical studies carried out by different authors, it was then proceeded to identify which variables were the most used to analyze the mechanisms of technological transfer applied by universities for marketing their patents.

Six studies emphasized market-related variables, such as links to industry or institutional openness towards university-industry collaboration (Bodas & Verspagen, 2017; Dahlborg et al., 2017; Fernández-Esquinas et al., 2016; Fischer et al., 2018; Lee, 2012; Wu et al., 2015), four other papers focused on analyze the entrepreneurial attitude of the inventor and the technical characteristics of the patents (Hsu et al., 2015; Marzurkiewiz & Poteralska, 2017; Öcalan-Özel & Pénin, 2016; Sargent & Matthews, 2014), and finally four

investigations focused on the financial topic such as sources of resources for the research and financing for the creation of Spin-Offs (Drivas et al., 2016; Gubbitta et al., 2016; Guerzoni et al., 2014; Hsu & Ken, 2014).

Based on the above, in this research what is sought is to group these previously proposed variables with their corresponding indicators in an instrument, that allows not only a more comprehensive analysis of the factors that determine the choice of mechanisms for technology transfer of the invention patents at the university level, but also as a contribution to the existing knowledge gap on this subject. In consequence, the items which measures the constructs in the model proposed are the following:

Closeness to the market

1. Market access
2. Links with industry
3. Industry collaboration

Innovation type

1. Inventor binding
2. Attributes of the technology
3. Field of knowledge

Financial aspects

1. Funding sources
2. Research funding

In order to establish the different relationships between the independent, the dependent, the control and the moderating variables of the model, this study will use the Partial Least Squares regression (PLS) statistical method that allows finding a linear

regression model by projecting the predicted variables and the observable variables to a new space (Wold, 1985). The model of analysis under this method is shown in Figure 5.

For the analysis of the information that will be collected from the surveys, in this research it has been decided to use the Partial Least Squares regression (PLS) as a statistical method and not the Structural Equation Modeling (SEM), considering it the most appropriate to the objectives of the study, previous the following considerations. The SEM method is oriented towards the theory, emphasizing the transition from the exploratory to the confirmatory, while the PLS is oriented to the causal-predictive analysis in situations of high complexity, as are the variables of this research, but with scarce theoretical information (Jöreskog & Wold, 1982).

Additionally, the SEM requires large samples and a small number of variables, while the PLS algorithm allows to manage a reduced number of observations and a large number of variables. Finally, and given that this research does not seek to confirm a theory based on reality, which is typical of the SEM analysis, but to explore the reality given a prior ignorance is that the PLS method is considered the most appropriate given the predictive approach of the hypotheses formulated.

However, it must be recognized that although there are differences between both techniques and that the SEM and PLS models pursue different objectives, they should be considered as complementary and not as excluding depending on the focus and scope of each investigation.

A functional PLS model is a method to avoid the multicollinearity problem based on covariance. It is recommended in studies whit high number of explanatory correlated variables. Studies have shown “that the method also avoids the problem of high dimensionality that precludes the logit model” (Escabias, Aguilera & Valderrama, 2007, p. 4901).

Validity and Reliability

Validity is related with the analysis specifically that you are looking to infer from the research. With the measurement model specified and the process of information gathering the internal validity depends on establishing acceptable levels of authenticity, goodness and credibility, as an accurate reflection of the phenomena under study. For its part the external validity will permit the generalization of the results according to the empirical findings and the theoretical approximation of the research. The reliability is related with the replication and transparency. At this respect, a Cronbach´s alpha value is going to be applied in order to estimate the reliability of the test scores and to establish the internal consistency. Absence of random error and careful documentation will assure the replication and transparency of this study.

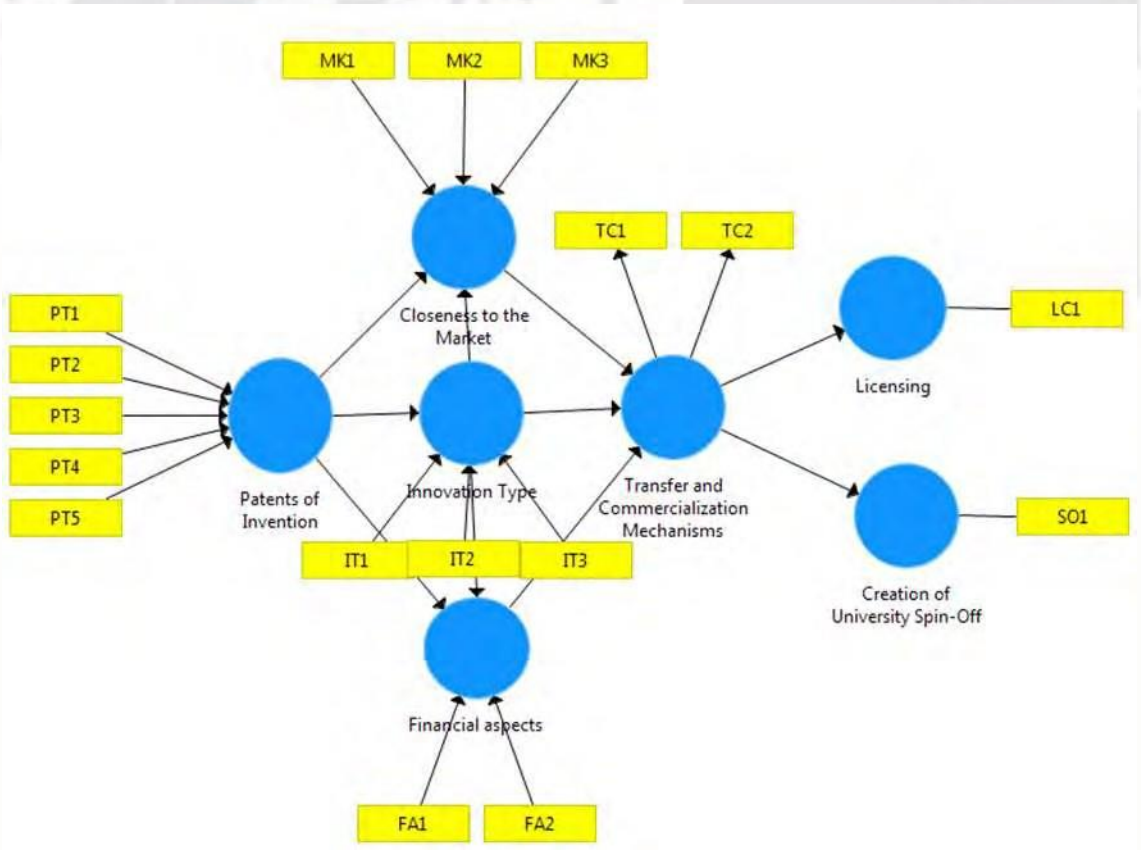

Figure 5. Proposed PLS

Summary

In this chapter we presented the conceptual model and the design that will guide the research, as well as the description about the variables that are the object of the study. Again, the questions and hypotheses formulated in Chapter 1 are presented in order to verify their methodological consistency with the proposal model. In a detailed way, we analyze what is related to the population and how to select the representative sample that guarantees randomness and an adequate degree of statistical confidence. Finally, aspects related to the instrumentation, the form of data collection and the way in which the information object of the study will be analyzed were presented.

References

Aldridge, T.T. & Audretsch, D. (2011). The Bayh-Dole Act and scientist entrepreneurship. *Research Policy, 40*, 1058-1067

Audretsch, D.B. (2014). From the entrepreneurial university to the university for the entrepreneurial society. *Journal of Technology Transfer, 39*, 313-321

Beraza, J.M. & Rodríguez, A. (2011, May). Los programas de apoyo a la creación de spin-offs en las universidades españolas: una comparación internacional. *Investigaciones Europeas, Vol. 17(2)*, 89-117

Beraza, J.M. & Rodriguez, A. (2012, January). Tipología de las spin-offs en un contexto universitario: una propuesta de clasificación. *Cuadernos de Gestión, Vol. I2 (1),* 39-57

Binkauskas, G. (2012). Academic entrepreneurship: Barriers and fears versus wishes and opportunities. *International Journal of Technology Management & Sustainable Development, 11: 3,* 231–244, doi: 10.1386/tmsd.11.3.231_1

Bodas, I. & Verspagen, B. (2017). The motivations, institutions and organization of university-industry collaborations in the Netherlands. *Journal of Evolution Economics, 2,* 379–412 DOI 10.1007/s00191-017-0495-7

Boddy, C.R. (2016). Sample size for qualitative research. *Qualitative Market Research: An International Journal, Vol. 19(4),* 426-432

Bradley, S., Hayter, C. S., & Link, A. N. (2013). Models and methods of university technology transfer. *Foundations and trends in Entrepreneurship, 9 (6),* 571 - 650.

Bush, V. (1945). *Science, the Endless Frontier: a Report to the President*. Washington, D.C.: U.S. Government Printing Office.

Cantu-Ortiz, F., Galeano, N., Mora-Castro, P., & Fangmeyer Jr., J. (2017). Spreading academic entrepreneurship: Made in Mexico. *Business Horizons, 60,* 541-550

Castillo-Vergara, M. & Alvarez-Marin, A. (2015, septiembre). La transferencia de investigación en Instituciones de Educación Superior mediante Spin-Off. *Revista Actualidades Investigativas en Educación, Volúmen 15(3),* 1-23

Cervilla de Olivieri, M. A. (2001). *La innovación como un proceso económico y social: Algunas implicaciones para el diseño de una estrategia de desarrollo*. Caracas, Venezuela: Cendes

Chang, H. (2010, January). El Modelo de la Triple Hélice como un medio para la vinculación entre la Universidad y la Empresa. *Revista Nacional de Administración, Vol. 1(10),* 85-94

Chang, X., Chen, Q., & Fong, P. (2016). Scientific disclosure and commercialization mode selection for university technology transfer. *Science and Public Policy, 43,* 85-101

Chang, S. (2017). The technology networks and development trends of university-industry collaborative patents. *Technological Forecasting & Social Change, 118,* 107-113

Chatterjee, D., & Sankaran, B. (2015). Commercializing academic research in emerging economies: Do organizational identities matter? *Science and Public Policy, 42,* 599-613

Crespi, G., D'Este, P., Fontana, R., & Geuna, A. (2011). The impact of academic patenting on university research and its transfer. *Research Policy, 40,* 55–68

Czarnitzki, D., Doherr, T., Hussinger, K., Schliessler, P., & Toole, A. (2016). Knowledge Creates Markets: The influence of entrepreneurial support and patent rights on academic entrepreneurship. *European Economic Review, 86,* 131 - 146

Dahlborg, CH., Lewensohn, D., Danell, R., & Sundberg, C. J. (2017). To invent and let others innovate: a framework of academic patent transfer modes. *Journal of Technology Transfer, 42,* 538-563

De Cleyn, S.H., Braet, J., & Klofsten, M. (2015). How human capital interacts with the early development of academic spin-offs. *International Entrepreneurship Management Journal, 11,* 599 - 621

Drivas, K., Economidou, C., Karamanis, D., & Zank, A. (2016). Academic patents and technology transfer. *Journal of Engineering and Technology Management, 40,* 45-63

Drivas, K., Leib, Z., & Wright, B.D. (2017). Academic patent licenses: Roadblocks or signposts for non-licensee cumulative innovation? *Journal of Economic Behavior & Organization, 137,* 282–303

Dzisah, J., & Etzkowitz, H. (2010). Triple helix circulation: the heart of innovation and development. *International Journal of Technology Management and Sustainable Development, Volume 7(2),* 101-115

Edquist, C. (2005). Systems of innovation: Perspectives and challenges. In J. Fagerberg, D. Mowery & R. Nelson (Eds.), *The Oxford handbook of innovation*. New York: Oxford University Press.

Edquist, C., & Hommen, L. (1999). Systems of innovation: theory and policy for the demand side. *Technology in Society, 21(1),* 63-79.

Eesley, C., Bai Li, J., & Yang, D. (2016). ¿Does Institutional Change in Universities Influence High-Tech Entrepreneurship? Evidence from China's Project 985. *Organization Science, Vol. 27 (2),* 446-461

Escabias, M., Aguilera, A.M., & Valderrama, M.J. (2007). Functional PLS logit regression model. *Computational Statistics & Data Analysis, 51,* 4891-4902

Etzkowitz, H. (1998). The norms of entrepreneurial science: Cognitive effects of the new university-industry linkage. *Research Policy, 27(8),* 823 - 833.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry government relations. *Research Policy, 29(2),* 109-123

Etzkowitz, H., Webster, A., Gebhardt, C., & Cantisano, B. (2000). The Future of the University and the University of the Future: Evolution of Ivory Tower to Entrepreneurial Paradigm. *Research Policy, 29(2),* 313 - 330.

Etzkowitz, H. (2004). The evolution of the entrepreneurial university. *International Journal of Technology and Globalization, 1(1),* 64 - 77 doi: http://dx.doi.org/10.1504/IJTG.2004.004551

Etzkowitz, H. & Zhou, Ch. (2008). Building the entrepreneurial university: a global perspective. *Science and Public Policy, 35(9),* 627-635

Fernandez-Alles, M., Camelo-Ordaz, C., & Franco-Leal, N. (2015). Key resources and actors for the evolution of academic spin-offs. *Journal of Technology Transfer, 40,* 976–1002

Fernández-Esquinas, M., Pinto, H., Pérez, M. & Santos, T. (2016). Tracing the flows of knowledge transfer: Latent dimensions and determinants of university–industry interactions in peripheral innovation systems. *Technological Forecasting & Social Change, 113,* 266-279

Figueroa, A. (2012). *A unified theory of capitalist development (Rev. Ed.).* Retrieved from http://freescience.info/AF_UT_Revised_Version.pdf

Fini, R., Grimaldi, R., Santoni, S., & Sobrero, M. (2011). Complements or substitutes? The role of universities and local context in supporting the creation of academic spin-offs. *Research Policy, 40,* 1113-1127

Fish, C., Hassel, T., Sandner, P., & Block, J. (2015). University patenting: a comparison of 300 leading universities worldwide. *Journal of Technology Transfer, 40(2),* 318 - 345. doi:10.1007/s10961-014-9355-x

Fischer, B., Schaeffer, P., Vonortas, N., & 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

Freitas, J. S., Goncalves, C.A., Cheng, L.C., & Muñiz, R.M. (2013). Structuration aspects in academic spin-off emergence: A roadmap-based analysis. *Technological Forecasting & Social Change, 80,* 1162–1178

Freeman, C. (1987). *Technology and Economic Performance: Lessons from Japan.* London, UK: Pinter

Fryges, H., & Wright, M. (2014). The origin of spin-offs: a typology of corporate and academic spin-offs. *Small Business Economics, 43,* 245-259

Galindo, M. A., & Malgesini, G. (1994). *Crecimiento Económico: Principales teorías desde Keynes*. Madrid: McGraw-Hill

Geuna, A., & Rossi, F. (2011). Changes to university IPR regulations in Europe and the impact on academic patenting. *Research Policy, 40,* 1068 - 1076.

Giachi, S. (2017, January). La evolución de la gobernanza de las políticas de innovación en España: el caso de la colaboración entre ciencia e industria. *Política y Gobernanza. Revista de Investigaciones y Análisis Político, 1,* 109-132

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. London, UK: SAGE

Gilsing, V., Burg, E., & Romme, G. (2010). Policy principles for the creation and success of corporate and academic spin-offs. *Technovation, 30,* 12–23

Godin, B. (2006). The Linear Model of Innovation: The Historical Construction of an Analytical Framework. *Science, Technology, & Human Values, 31 (6),* 639 – 667

González, T. (2009). El modelo de la triple hélice de relaciones universidad, industria y gobierno: Un análisis crítico. *Ciencia, Pensamiento y Cultura, Vol. 185 (738),* 739-755.

Grimaldi, R., Kenney, M., Siegel, D., & Wright, M. (2011). 30 years after Bayh-Dole: Reassessing academic entrepreneurship. *Research Policy, 40,* 1045 – 1057

Gubitta, P., Tognazzo, A., & Destro, F. (2016). Signaling in academic ventures: the role of technology transfer offices and university funds. *Journal of Technology Transfer, 41,* 368–393

Guerrero, M., Urbano, D., Fayolle, A., Klofsten, M., & Mian, S. (2016). Entrepreneurial universities: emerging models in the new social and economic landscape. *Small Business Economics, 47,* 551-563

Guerzoni, M., Aldridge, T., Audretsch, D., & Desai, S. (2014). A new industry creation and originality: Insight from the founding source of university patents. *Research Policy, 43,* 1697-1706

Hair, J., Black, W., Babin, B., & Anderson, R. (2010). *Multivariate data analysis: A global perspective (7 Ed.).* Upper Saddle River, NJ: Prentice Hall.

Halilem, N. (2010). Inside the Triple Helix: An Integrative Conceptual Framework of the Academic Researcher's Activities, a Systematic Review. *Journal of Research Administration, Volume XLI (3),* 23-50

Hayter, C., & Rooksby, J. (2016). A legal perspective on university technology transfer. *Journal of Technology Transfer, 43(8),* 270 - 289. doi:10.1007/s10961-015-9436-5

Ho, M., Liu, J., Lu, W., & Hang, C. (2014). A new perspective to explore the technology transfer efficiencies in US universities. *Journal of Technology Transfer, 39,* 247 – 275

Hsu, W., & Ken, Y. (2014). License income of technology commercialization: The case of U.S. universities. *The International Journal of Organizational Innovation, Vol 6, Num. 3,* 21-30

Hsu, D., Shen, Y., Yuan, B., & Chou, C.J. (2015). Toward successful commercialization of university technology: Performance drivers of university technology transfer in Taiwan. *Technological Forecasting & Social Change*, 92, 25-39

https://www.feedbacknetworks.com/cas/experiencia/sol-preguntar-calcular.html

Huynh, T., Patton, D., Arias-Aranda, D. & Molina-Fernández, L.M. (2017). University spin-off's performance: Capabilities and networks of founding teams at creation phase. *Journal of Business Research, 78,* 10-22

Iglesias, P.P., Jambrino, C., & Peñafiel, A. (2012). Caracterización de las Spin-Off universitarias como mecanismo de transferencia de tecnología a través de un análisis clúster. *Revista Europea de Dirección y Economía de la Empresa, 21,* 240-254

Jöreskog, K. G., & Wold, H. (1982). *Systems under indirect observation: causality, structure, prediction.* Amsterdam: North-Holland

Kanwar, S. (2012). Intellectual Property Protection and Technology Licensing: The Case of Developing Countries. *Journal of Law and Economics, Vol. 55, No. 3,* 539-564

Kesan, J. P. (2015). Economic rationales for the Patent System in current context. *George Mason Law Review, Vol 22:4,* 897-924

Kirchberger, M.A., & Pohl, L. (2016). Technology commercialization: a literature review of success factors and antecedents across different contexts. *Journal of Technology Transfer, 41*, 1077–1112

Kvanli, A.H., Pavur, R.J., & Keeling, K.R. (2003). *Introduction to business statistics: A Microsoft Excel, integrated approach (6th Ed.).* Mason, OH: Southwestern.

Lawton, H., & Leydesdorff, L. (2014). The Triple Helix in the context of global change: dynamics and challenges. *Prometheus, Vol. 32 (4),* 321–336

Lee, P. (2012). Transcending the Tacit Dimension: Patents, Relationships, and Organizational Integration in Technology Transfer. *California Law Review, Vol. 100,* 1503-1572

Leydesdorff, L. (1998). Triple Helix of innovation: Introduction. *Science and Public Policy, 25(6),* 280-296

Leydesdorff, L. (2000). The Triple Helix: An evolutionary model of innovations. *Research Policy, 29(2),* 243-255.

Leydesdorff, L., & Meyer, M. (2003). The Triple Helix of university-industry-government relations. *Scientometrics, 58(2),* 191-203

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics, 22,* 421-446

Lundvall, B.-A. (Ed.). (1992). *National innovation systems: Towards a theory of innovation and interactive learning*. London, UK: Pinter

Lundvall, B.-A., Johnson, B., Anderson, E. S., & Dalum, B. (2002). National systems of production, innovation and competence-building. *Research Policy, 31(2),* 213-231

Martínez-Mesa, J., González-Chica, D., Pereira, R., Rangel R., & Luiz, J. (2016). Sampling: how to select participants in my research study? *Anais Brasileiros de Dermatologia, 91(3),* 326-330

Mazurkiewicz, A., & Poteralska, B. (2017). Technology Transfer Barriers and Challenges Faced by R&D Organizations. *Procedia Engineering, 182,* 457-465

Mochón, F. (1990). *Economía: Teoría y Política*. Madrid, España: McGraw-Hill

Morales, M.E., Sanabria, P.E., Plata, P.A., & Ninco, F.A. (2015). Research Results Transfer towards the Productive Sector via Research Collaboration in Four Colombian Public Universities. *Journal of Technology Management & Innovation, Volume 10,* Issue 4, 28-44

Moutinho, R., Au-Yong-Oliveira, M., Coelho, A., & Manso, J.P. (2016). Determinants of knowledge-based entrepreneurship: an exploratory approach. *International Entrepreneurship Management Journal, 12,* 171-197

Mowery, D.C., & Ziedonis, A.A. (2015). Markets versus spillovers in outflows of university research. *Research Policy, 44,* 50–66

Nelson, R. (Ed.). (1993). *National innovation systems: A comparative analysis*. New York, NY: Oxford University Press

Ndonzuau, F., Pirnay, F., & Surlemont, B. (2002). A stage model of academic spin-off creation. *Technovation, 22,* 281–289

Organisation for Economic Co-operation and Development (1997). *National Innovation Systems*. Paris, France: OECD Publications

Organización para la Cooperación y el Desarrollo Económico (2005). *Medición de las Actividades Científicas y Tecnológicas. Directrices propuestas para recabar e*

interpretar datos de la innovación tecnológica: Manual Oslo. Tercera Edición, OECD/EU/Eurostat

OECD (2014). *Gross domestic spending on R&D* (indicator). http://dx.doi.org/10.1787/d8b068b4-en (Accessed on 10 September 2017)

OECD (2014). *Reviews of Innovation Policy: Colombia 2014*. Paris, France: OECD Publishing

Osiri, J.K. (2013). How do financial, institutional, and human capital factors affect university start-ups? *Journal of Entrepreneurship Education, Volume 16*, 133 - 143

Osiri, J. K., Miller, D., Clarke, L., & Jessup, L. (2014). Academic Entrepreneurship: Technology Transfer in Higher Education. *Journal of Entrepreneurship Education, Volume 17,* Number 1, 39-61

O'Shea, R., Allen, T., O'Gorman, C., & Roche, F. (2004). Universities and Technology Transfer: A review of academic entrepreneurship literature. *Irish Journal of Management, 25 (2)*, 11-29.

Öcalan-Özel, S., & Pénin, J. (2016). Exclusive or open? An economic analysis of university intellectual property patenting and licensing strategies. *Journal of Innovation Economics & Management, 21(3),* 133-153. DOI 10.3917/jie.021.0133

Pattnaik, P.N., & Pandey, S.C. (2014). University Spinoffs: What, Why, and How? *Technology Innovation Management Review, 82,* 44-50

Pattnaik, P., & Pandey, S. (2016). Revisiting University Spinoffs: Conceptual Advancements and Theoretical Underpinnings. *International Journal of Innovation and Technology Management, 13(1),* 1 - 13. doi: http://dx.doi.org/10.1142/S021987701650005X

Perkmanna, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P.,… Sobrero, M. (2013). Academic engagement and commercialization: A review of the literature on university–industry relations. *Research Policy, 42*, 423-442

Pirnay, F., Surlemont, B., & Nlemvo, F. (2003). Toward a Typology of University Spin-Offs. *Small Business Economics, Vol. 21 (4)*, 355-369

Primi, A. (2014). *Promoting Innovation in Latin America: What Countries Have Learned (and What They Have Not) in Designing and Implementing Innovation and Intellectual Property Polices* (Doctoral Thesis, Maastricht University, Maastricht, The Netherlands).

Pye, V., Taylor, N., Clay‐Williams, R., & Braithwaite, J. (2016). When is enough, enough? Understanding and solving your sample size problems in health services research. *BMC Research Notes, 9:90*, 1-7

Quintas, M., Caballero, G., Arévalo, R., & Pineiro, P. (2012, January). La protección de las invenciones mediante patentes en las universidades europeas, japonesas y estadounidenses. *Cuadernos de Gestión, Vol. 12 (1)*, 15-38

Rasmussen, E. (2011). Understanding academic entrepreneurship: Exploring the emergence of university spin-off ventures using process theories. *International Small Business Journal, 29(5)*, 448–471

Rasmussen, E., Mosey, S., & Wright, M. (2014). The influence of university departments on the evolution of entrepreneurial competencies in spin-off ventures. *Research Policy, 43*, 92– 106

Rasmussen, E. & Wright, M. (2015). How can universities facilitate academic spin-offs? An entrepreneurial competency perspective. *Journal of Technology Transfer, 40(5),* 782-799.

Rodeiro, D., López, F., Otero, L., & Sandías, R. (2010). Factores determinantes de la creación de spin-offs universitarias. *Revista Europea de Dirección y Economía de la Empresa, 19(1),* 47 – 68.

Rogowsky, R. (2016). Intellectual Property in the Trans-Pacific Partnership. *The Brown Journal of World Affairs, Volume XXII, Issue II,* 123-136

Romer, P.M., (1986). Increasing returns and long-run growth. *Journal of Political Economy, 94 (5),* 1002–1037.

Romer, P.M., (1990). Endogenous technological change. *Journal of Political Economy, 98 (5),* S71–S102

Ronayne, J. (1984). *Science in government*. London, UK: Edward Arnold

Roseli da Luz, M. & Sanches da Silva, C.E. (2013). Fatores críticos para a criação de spin-offs acadêmicos: Um estudo exploratório. *Iberoamerican Journal of Industrial Engineering, Vol. 5(9),* 186-202

Rothwell, R. & Zegfeld, W. (1985). *Reindustrialisation and Technology*. Essex, UK: Longman

Russo-Spena, T.,Tregua, M., & Bifulco, F. (2017). Searching through the jungle of innovation conceptualizations: System, network and ecosystem perspectives. *Journal of Service Theory and Practice, Vol. 27 (5),* p.977-1005

Salomon, J. J. (1977). Science policy studies and the development of science policy. In: Spiegelrösing, I. & Price, D. S. (Orgs.). *Science, technology and society: a cross-disciplinary perspective* (pp. 43-70). London, UK: SAGE

Sargent, J., & Matthews, L. (2014). Latin American Universities and Technology Commercialization. *Latin American Business Review, 15,* 167–190

Savescu, D. (2017, January). The importance of Intellectual Property Protection in Technological Transfer. Some aspects. *Fiability & Durability, No. 1*, 135-141

Schumpeter, J. A. (1978). *Teoría del desenvolvimiento económico. Una investigación sobre ganancias, capital, crédito, interés y ciclos económicos*. México, D.F.: Fondo de Cultura Económica

Seguí-Mas, E., Sarrión-Viñes, F., Tormo-Carbó, G., & Oltra, V. (2016). Producció científica en el camp de les spin-off acadèmiques: Una anàlisi bibliomètrica. *Intangible Capital, 12(1),* 246-267

Senelwa, W., Mukulu, E., & Kihoro, J. (2016). Academic Entrepreneurial Intentions and the Creation of University Spin-Off Firms: Critical Review. *International Journal of Management, Accounting and Economics, Vol. 3(9),* 532-544

Siegel, D.S., & Wright, M. (2015). Academic Entrepreneurship: Time for a Rethink? *British Journal of Management, Vol. 2*, 582-595

Solow, R. (1956). A contribution to the Theory of Economic Growth. *Quarterly Journal of Economics, vol. 70*, 665-694.

Sternberg, R. (2014). Success factors of university-spinoffs: Regional government support programs versus regional environment. *Technovation, 34*,137–148

Thompson, N.C., Ziedonis, A.A., & Mowery, D.C. (2016). University Licensing and the Flow of Scientific Knowledge. *MIT Sloan School Working Paper, 5189-16,* 1-33 Retrieved from https://ssrn.com/abstract=2899547

Ullah, R. (2016). *Non-Probability Sampling*. Retrieved from https://es.slideshare.net/.../nonprobability-sampling-61733634

Usunier, J.C. (2011). Language as a resource to assess cross-cultural equivalence in quantitative management research. *Journal of World Business, 46 (3),* 314-319.

Wahba, K. (2016). *Working paper quantitative research methods*. Bogotá, Col: Centrum

Walter, S.G., Schmidt, A, & Walter, A. (2016). Patenting rationales of academic entrepreneurs in weak and strong organizational regimes. *Research Policy, vol. 45, issue 2,* 533-545

Wang, N., Liang, H., Zhong, W., Xue, Y., & Xiao, J. (2012). Resource Structuring or Capability Building? An Empirical Study of the Business Value of Information Technology. *Journal of Management Information System, 29(2),* 325–367

Wennberg, K., Wiklund, J., & Wright, M. (2011). The effectiveness of university knowledge spillovers: Performance differences between university spinoffs and corporate spinoffs. *Research Policy, 40,* 1128-1143

WIPO (2016). *Understanding Industrial Property.* Genève, Switzerland: WIPO Publications

Wold, H. (1985). Partial least squares. In Kotz, S. & Johnson, N. L. *Encyclopedia of statistical sciences.* 6. New York, NY: Wiley

Wood, M. (2011). A process model of academic entrepreneurship. *Business Horizons, 54,* 153-161

Wu, Y., Welch, E.W., & Huang, W. (2015). Commercialization of university inventions: Individual and institutional factors affecting licensing of university patents. *Technovation, 36-37,* 12-25

Zekos, G. (2016). Intellectual Property Rights: A Legal and Economic Investigation. *The IUP Journal of Knowledge Management, Vol. XIV, No. 3,* 28-71

Zúñiga, A. C. (2013). Las spin-off en el contexto universitario colombiano: consideraciones generales. *Journal of Engineering and Technology, Vol. 2(2),* 82-95

Chapter 4: Results

The purpose of this chapter is to present the principal results according with the research questions and the methodological design of the study. As was mentioned before, initially with the purpose of expanding the field of analysis of this subject a meso vision was added by selecting four Latin American countries to give it a regional context.

Much of the literature has emphasized the transfer of innovation and technology gained from the university sector to the rest of the economy in the industrialized world. This topic has received less attention regarding developing countries, particularly in Latin America. As a contribution to the study of this dynamic at the regional level, we set out to investigate the following relationships. First, to what extent the amount of resources invested in research and development by the innovation systems at the national level be associated to technology transfer activity as measured by the number of patents granted to universities? Second, what is the relationship between the technology transfer from universities to society in terms of granted patents to both their enrolment size and their scientific publications?

In this way to achieve a better understanding of the dynamics of university patenting in Latin America today, a comparative analysis was undertaken regarding the number of patents applied for and granted to universities located in Chile, Colombia, Mexico and Peru, in relation with certain institutional characteristics.

After this regional context, the results obtained from studying the relationships between university patents and the main factors that affect their effective technology transfer

and decision at the University level when choosing the mechanism to commercialize the patents of invention, based on a survey applied to a sample of Colombian universities.

Research Paper

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When size matters: trends in innovation and patents in Latin American universities

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Abstract
This paper characterizes the trends in technological innovation and intellectual property in four Latin American countries (Chile, Colombia, Mexico, and Peru). Toward this aim, we collected a database of patents granted at the national and university levels in combination with information from a variety of sources to construct a set of plausible explanatory variables. Based on panel data at the national level, we verify that the number of patents granted to universities is strongly associated with the share of resources, as a percentage of GDP, invested in science and technology. At the university level, we find that institutions with more scientific publications and larger enrolment size tend to be granted more innovation patents. To some extent, the evidence presented in this paper indicates that both the absolute and relative sizes of resources invested in scientific and technological research at the university level are subject to economies of scale: a greater amount of resources invested in technological research is associated with increasing levels of innovation and patenting activity.
KEY WORDS: innovation, patents, R&D policy, universities, Latin America

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1. Introduction

A political concern in the agenda for governments and universities alike has been the relationship between science and technology and the corresponding link between universities and industries. Globally, as a key element of their institutional missions, universities search to find the most efficient way to transfer the outcomes of their research to society and to industries. One important basis of this concern is the 1945 Bush Report called: *Science, The Endless Frontier*. The basic principle of the report is that discoveries resulting from research through technology transfer must support economic development and social welfare. Technology licensing, patents, and publications in high-impact journals are materialization of such transfer.

The linear model of innovation was the first analytical framework to explain the relationship between science and technology (Godin, 2006). This model proposes that innovation begins with basic research, continues with applied research, and ends with production and transference. To support the final stage at the policy level, efforts to diffuse and commercialize the innovation outcomes of scientific research have been supported at the legislative level in many countries (Bradley, Hayter & Link, 2013). In the United States, the Bayh–Dole Act of 1980 allowed universities to retain intellectual property and to appropriate the proceeds of licenses from patents obtained through federal research funding (Fish, Hassel, Sander & Block, 2015). European and East Asian nations have emulated

the US by enacting domestic legislation specifying that intellectual property be privileged at the institutional level; this is evident in Finland, Germany, Spain, the UK, Korea, and Singapore, among others (Geuna & Rossi, 2011). Hayter and Rooksby (2016) recently stated that research on technology transfer has now broadened its field of action generating links to the theory of economic development and providing a vision of growth and prosperity related to the creation, diffusion, and marketing of new knowledge. The impact of this new knowledge depends on its ability to flow within societies, fostering social and economic development.

According to Rodeiro, Lopez, Otero and Sandias (2010), there is a wide range of possibilities for interaction between universities' science and technology output and industries, including entrepreneurship, recruitment of graduates, technology diffusion and transfer, specialized consulting, collaborative projects, the use of patents and licenses, and the creation of spin-off companies. In this regard, the study on university technology transfer elaborated by Bradley et al. (2013) found universities' interest in obtaining patents has grown rapidly in the last decade; there has been a significant increase in licensing activities and the creation of university spin-off companies, both inside and outside the United States.

Much of the literature has emphasized the transfer of innovation and technology from the university sector to the rest of the economy in the industrialized world. This topic has received less attention regarding developing countries, particularly in Latin America. Consequently, the purpose of this paper is to answer two questions. First, to what extent can the amount of resources invested in research and development by the innovation systems at the national level be associated to technology transfer activity as measured by the number of patents granted to universities? Second, what is the relationship between the technology transfer from universities to society in terms of granted patents to both their enrolment size and their scientific publications? We aim to answer these questions with an empirical application based on quantitative data from four Latin American countries: Chile, Colombia, Mexico, and Peru. For this aim, we assembled a database of granted patents at the national and university levels in combination with information from a variety of sources to construct a set of plausible explanatory variables. Based on panel data at the national level, we verify that the number of patents granted to universities is strongly associated with the share of resources as a percentage of GDP invested in science and technology. At the university level, we find that those universities with more scientific publications and higher enrolment size tend to obtain more granted innovation patents. To some extent, the evidence presented in this paper indicates that both the absolute and relative size of the resources invested in scientific and technological research are subject to scale economies whereby a larger size of resources invested in technological research is associated with an increasingly larger innovation and patenting.

The rest of this paper is organized as follows. Section II presents a literature review, which includes a theoretical framework for the study, a review of the innovation systems in Latin America, and a review of previous research in the field of patents and innovation. The third section explains the data sources for the data presented in this paper. Section IV displays the statistical and econometric results and discusses them in the light of the existing literature. Finally, the fifth section makes a summary of the findings and puts forward some limitations and considerations for further research.

2. Literature Review

2.1 Theoretical Framework of the Study

From a theoretical perspective, Audretsch (2014) presents an interesting review of how and why the role of the university in society has evolved over time, arguing that the forces shaping economic growth have influenced the corresponding role of the university. He stated, "As the economy has evolved from being driven by physical capital to knowledge, and then again, to being driven by entrepreneurship, the role of the university has evolved over time" (p. 313).

In this sense, he makes a comparison between the influences of the so-called Solow economy (popularized by Robert Solow) and the Romer economy (introduced by Paul Romer). The Solow model puts "emphasis on physical capital and unskilled labor as the twin factors shaping economic performance. Despite the preeminent contributions to social and political values, the economic contribution of universities [is] modest" (Audretsch, 2014, p. 315). Meanwhile, in the Romer economy, knowledge is considered particularly potent as a driver of economic growth. Audretsch states, "As the Romer economy replaced the Solow economy, a new role for the university emerged, as an important source of economic knowledge" (Audretsch, 2014, p. 316).

In a related stream of research, Kesan (2015) examined several theories that explain and justify the role of patents in today's knowledge-based, technology-intensive economy, stating, "patents reduce transaction costs, help convert inventions into transferable assets, promote disclosure, provide a system of certification and standardization, and allow greater divisibility of technology" (p. 903). In relation to the marketing of innovations, Kesan (2015) assured, "All of these functions make transactions in the marketplace for inventions more efficient, to the benefit of both inventors and consumers" (p. 903). In this context, acquiring patents helps a university bring

in revenue, and allows for technology transfer offices and corporate firms interested in commercializing innovations to be connected to the universities through industrial property.
These theoretical approximations indicate that universities' scientific and technological development is a source of economic growth through offering new technologies to the market and providing basic support to nations' innovation systems. In sum, the university today has a role that goes beyond teaching and involves the transference of research knowledge to society.

2.2 Innovation Systems in Latin America

In the last decade, innovation has gained increasing importance in Latin America. Most of the countries in the region now have national strategies for innovation and have created governing institutions for this purpose. While these countries have accumulated experience in designing innovation policies, they still sometimes struggle to articulate industrial policies and domestic production from the generation of scientific knowledge and technological capabilities (Primi, 2014).
When the concept of National Systems of Innovation (NIS) gained importance in the region in the mid-1990s, the main concern was how to articulate cooperation between the public sector and the private sector to boost efforts of science and technology (Edquist & Hommen, 1999; Lundvall, 1992; Nelson, 1993). At the time, most countries suffered from a lack of industrial transformation and limited development of technological capabilities. This was due to the growing specialization that guided nations' development models according to the comparative advantages they exhibited for international trade.
A national innovation system can be described as the flow of technology and information among the actors of the system—companies, universities, and government—that generates processes of innovation at national level (Russo-Spena, Tregua & Bifulco, 2017). In the case of Latin American countries, this concept has been used to design policies and instruments to establish organizational infrastructures to facilitate the connections between the different actors, to promote knowledge networks that generate innovation at the firm level. National innovation systems, therefore, define the basic conditions for this research, like mechanisms for protecting inventions, incentives for promoting scientific research, mechanisms for financing projects, conditions for licensing of patents, and aligning universities and businesses for innovation.
However, other innovation scholars have identified different contexts to conceptualize national innovation systems. Specifically, they refer innovation by clusters, regions, and within technological areas, rather than by a national system (Russo-Spena, *et al.*, 2017).
Later, toward the middle of the 2000s, along with an increase in the prices of commodities worldwide, new financial opportunities emerged for countries in Latin America, sparking a relaunch in public policies for innovation. At that time, innovation policies redirected emphasis on (i) sectorial differentiation, (ii) the generation of incentives for science and technology, and (iii) the definition of new priorities for social and territorial inclusion and environmental sustainability (Primi, 2014).
Latin American institutions have different policies in relation to the governance of innovation policies. Developments in the four countries in this study are as follows. In Chile, the Ministry of Science, Technology, Knowledge and Innovation was created in 2018; it reports directly to the Presidency of the Republic. In Colombia, the agency responsible for innovation is Colciencias, which in 2009 was declared an autonomous department and was recently elevated to the Ministry of Science, Technology and Innovation, which begin operation in 2020. In Mexico, the agency in charge is the CONACYT, which reports to the Ministry of Economy. In Peru there are two entities, CONCYTEC, which depends on the Ministry of Education, and the National Council for Competitiveness, which reports to the Ministry of Economy and Finance.
Each country differs in the magnitude of resources applied to the promotion of innovation and in the way that the resources are assigned. However, for all Latin American countries, progress has been made in at least three areas: (i) institutional strengthening, with the creation of bodies charged with guiding the innovation policy with sufficient autonomy and capabilities, (ii) new funding sources for innovation programs through the collection of royalties for the production of commodities and through the establishment of sectorial funds for technological development, and (iii) improvements in the legal framework for innovation, through the establishment of clear policies on industrial property, and the simplification of procedures for access to resources and the promotion of technology-based companies (OECD, 2016)
Finally, from an analysis of the innovation systems in Latin America, it can be concluded that they have the following features in common:
- Almost all of them have an overarching plan for science, technology, and innovation that identifies the challenges and goals, establishes programs, and defines the plans of action.
- The programs tend to be similar in terms of priority areas (nanotechnology, biotechnology, alternative energies, health, and agricultural production).
- Most countries today have a territorial perspective in their national innovation strategies. In the case of Chile, Colombia, and Peru, this perspective is closely related to the funding structures from taxes associated with the

exploitation of natural resources, where territorial authorities have great influence on the allocation of resources for science, technology, and innovation.

It is undeniable that the governments of the region have improved policies for innovation, especially in the last decade. Today, institutions are empowered, available budgets have been increased to finance programs for innovation, and regulatory frameworks support industrial property and encourage the creation of companies based on innovation. An adequate alignment of innovation policies with efforts for productive transformation will generate new development opportunities for these countries in the immediate future.

2.3. Previous Research

An industrial property is the legal framework that protects the interests of innovators, giving them rights over their creations. This legislation is part of the wider body of law known as intellectual property (IP) (WIPO, 2016). These rights confer to the inventor(s) an exclusive monopoly on exploitation, after completing some formalities. Patents of invention intended to protect innovations of a technical nature fit in this category.

In this sense, Savescu (2017) stated, "Industrial property rights are outlined in Article 27 of the Universal Declaration of Human Rights, which states that everyone should enjoy the protection of moral and material interests resulted from any scientific, literary or artistic production of which is the author" (p. 136). An efficient patent system contributes to the stimulation of innovation, because is a condition for economic growth, through the design and implementation of new products.

On the 30th anniversary of the enactment of the Bayh–Dole Act in the US, Grimaldi, Kenney, Siegel, and Wright (2011), considered the rationale for academic entrepreneurship and described the evolving role of universities in the commercialization of research. They considered that the Act "was both an outcome of and response to the changing climate, by enhancing incentives for firms and universities to commercialize university-based technologies. Specifically, the legislation instituted a uniform patent policy across federal agencies and removed many restrictions on licensing" (p. 1046). Several European (Wright et al., 2008) and Asian (Kodama, 2008) countries adopted similar legislation (Grimaldi et al., 2011).

In a similar vein, Drivas, Economidou, Karamanis, and Zank (2016) conducted a study to determine whether university patents are licensed over their enforceable lifecycle and at what point in time the licensing occurs. Based on an analysis of over 20,000 university patents granted between 1990 and 2000, they stated that since the Bayh–Dole Act was enacted, "most research universities have established their own Offices of Technology Transfer to undertake these commercialization and patent monetization activities. These academic technology transfer entities use a wide range of exclusive and non-exclusive licensing agreements to monetize the IP they own." (p. 46).

Using an external change in German Federal law Czarnitzki, Doherr, Hussinger, Schliessler, and Toole (2016) examined how entrepreneurial support and the ownership of patent rights influence academic entrepreneurship. They carried out a study on the impact of the Federal Government regulations in Germany since 2002, following the objectives of the US Bayh–Dole Act. The German reform called Knowledge Creates Markets generates subsidies, supports technology transfer, and assigns patent rights that result from university inventions from the individual level to the university level. An empirical analysis showed a strong relationship between patents and the creation of university companies. The evidence then suggests the existence of a high dependence on academic entrepreneurship regarding industrial protection granted by patents.

Fisch, Hassel, Sandner, and Block (2015) conducted a research from an international perspective, examining patents at the top 300 universities worldwide from 32 different countries, indicating a predominance of US universities. They found that "18 of the top 25 universities are located in the US, with the Massachusetts Institute of Technology ranked as first" (p. 318). They concluded that the propensity to apply for patents is very high in universities in the US and Asia; comparatively, it is lower in European universities. Their international comparison shows profound differences between countries that equally affect licensing, the creation of university spin-offs and other technology transfer mechanisms.

Additionally, Chang (2017) employed a two-mode network analysis method (using countries and fields of technology) to highlight the pivotal role of various countries in technology networks. He found that "the key technologies in the more recent UIC (University-Industry collaboration) technology network were largely in the fields of measurement and chemistry, which are characterized as basic sciences with cross-disciplinary traits" (p. 107).

Chang concluded, "Patents directly reflect innovative output. Therefore, they can serve as an indicator for measuring national technology output. The country-technology network analysis results revealed that Japan and the United Stated played crucial roles in the UIC technology network" (Chang, 2017, p. 107).

As demonstrated, the emergence of the Bayh–Dole Act in the U.S marked a milestone in the granting of university patents. This act generates an environment conducive to research and the commercialization of the results. The legal protection offered to the innovations encourages more university research and the transfer of the results to society.

For Latin America countries, Sargent and Matthews (2014) examined the efforts of elite universities in Chile, Mexico, and Brazil to transfer faculty inventions to the marketplace. Based on statistical information about patents

filing, they found, for this sample, that a "significant percentage of the new knowledge produced by researchers employed at universities has commercial value. Universities can take this knowledge, file for patents or other forms of IP protection, and then license the IP to existing or spinout companies" (p. 169).

These authors recognized that there are clearly weaknesses in the Latin American NIS. However, "in cities such as Sao Paulo, Campinas, Santiago, and Monterrey, elite universities have established well designed systems to both create and commercialize knowledge in S&T fields. In general, these initiatives have significant financial support from state and federal governments" (Sargent and Matthews, 2014, p. 184). They recommended exploring how legal barriers in Latin America affect the evolution of licensing efforts and university spin-offs, and analyzing the support received by the industry in the success or failure of university commercialization systems.

For its part, the recent study prepared by Fischer, Schaeffer, Vonortas, & Queiroz (2018), empirically assesses the extent to which institutional openness in universities toward UIC linkages affect the generation of knowledge-intensive spin-offs and academic patenting activity in the context of the State of Sao Paulo, Brazil. They concluded that in terms of science and technology policy, it is necessary to promote deeper linkages between companies and universities, saying "a stronger coordination between industrial policy, regulation of the competitive environment and the institutional framework of UIC is needed to build an environment conducive to the deep links we are discussing" (p. 280).

In a similar way, a study by Guerrero, and Urbano (2017) tried to provide a better understanding of the influence of Triple Helix agents on the performance of entrepreneurial innovations in emerging economies. They analyzed the effects on innovation performance resulting from the links of enterprises with other enterprises, with universities, and with government. The study concluded that it is necessary in these countries to reinforce both the innovation system and the entrepreneurial ecosystem.

On the other hand, Jefferson, Maida, Farkas, Alandete-Saez, and Bennett, (2017) focused on comparing the structure and operation of programs for IP management and technology transfer, and the mechanisms through entrepreneurship is fostered in five high-profile research institutions across the Americas. Their study, based on five universities in three countries found that there were "common goals and core activities, shared and implemented in similar ways among all five institutions. However, some divergent areas within the structure and operation of the technology transfer and entrepreneurial support programs […] represented significant differences between the five institutions" (p. 1307).

Finally, in relation to the business models that can be derived from the Intellectual Property of the innovations, a good part of the universities have chosen to establish Technology Transfer Offices (TTO), which are responsible for the orientation of the mechanisms for the commercialization of patents. Some studies suggest (Siegel & Wright, 2015) that different types of business models applied by universities can be associated with the characteristics of their corporate governance and this directly influences the ability of TTOs to achieve their objectives. In addition, the longitudinal study conducted at 60 US universities by Baglieri, Baldi and Tucci (2018) found that "business models that leverage high-quality research (ie, catalyst) and startup creation (ie, orchestrator of local buzz) are associated with higher economic performance" (p. 51). Therefore, the way technology transfer is guided is key for value creation and rent capture, according to the university strategic goals.

3. Data Sources

To achieve a better understanding of the dynamics of university patenting in Latin America, we carried out a comparative analysis based on the number of patents granted to universities from four Latin American countries: Chile, Colombia, Mexico, and Peru. These countries are the signatories of the Pacific Alliance (Alianza del Pacífico), a regional integration initiative to promote economic and social development in the region, and are where countries innovation activities have gained importance in recent years (OECD, 2014)

The information for the present analysis comes from secondary sources through the consultation and systematization of public data that are available in electronic databases held by national agencies in the field of IP. These institutions are as follows: the Instituto Nacional de Propiedad Industrial de Chile (INAPI) (www.inapi.cl); the Superintendencia de Industria y Comercio de Colombia (SIC) (www.sic.gov.co); the Instituto Mexicano de Propiedad Industrial (IMPI) (www.impi.gob.mx); and the Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual de Peru (INDECOPI) (www.indecopi.gob.pe). For each of them, information was collected regarding invention patents granted to universities from these countries over the period of 2008 to 2017.

Given that this work seeks to correlate the conditions of the innovation systems with the evolution of granted patents, we gathered information related to the total amount of resources invested in research and development as a percentage of GDP. For this purpose, we consulted the annual reports of the Global Innovation Index Database (www.globalinnovationindex.org). In addition, we consulted information from UNESCO's Science, Technology and Innovation database to identify the capacity to mobilize resources for innovation activities in each one of the four selected countries. To control for the overall level of economic development in each country, we gathered

information on the national GDP per capita at purchasing power parity (PPP) at constant prices for 2011 expressed in US dollars from the World Bank's World Development Indicators database.
Because one of the two central questions of this study aim to correlate the institutional capabilities of universities with obtaining patents, we collected information for a sample of 165 higher education institutions that have received patents in the period of the study. To have an indicator of the production of knowledge derived from research in each university, we found the number of scientific publications registered on two platforms, Scopus® and Web of Science® -WOS, between 2013 and 2017. To identify the size of each institution as a proxy of its capacity to mobilize resources over the same years, we compiled information about the number of students enrolled by consulting the Statistical Yearbooks in the Ministries of Higher Education of each country. Similarly, in order to control for the research institutional capacity, we collected the number of researchers with a PhD degree for a subsample of the universities available at QS University Rankings database.
This entire battery of information was used to organize the descriptive statistics and perform the econometric analyses, whose results are presented below.

1. Descriptive Statistics and the Results

4.1 Descriptive Statistics

Table 1 presents some descriptive statistics on innovation outcomes in the four countries in this study: Chile, Colombia, Mexico, and Peru. Clearly, Mexico reports the highest average number of patents granted per year (69) from 2008 to 2017; this is more than twice the average for Chile and more than three times the average for Colombia. At the other extreme, Peru averages only nine patents per year. These results are somewhat correlated with the average expenditure of R&D as a percentage of GDP. Mexico reports the highest average value (0.52%), which is more than double the average for Colombia and Peru and 1.4 times that observed for Chile. Although GDP per capita in Chile is nearly double that of Colombia and Peru, the size of the Mexican economy and its R&D expenditure might entail some advantages in terms of scale economies that could explain its superior performance in terms of patents granted.
The superior performance of Mexico over the other three countries deserves some qualification. In absolute terms, Mexico's average budget in R&D is 7.6 times that reported in both Chile and Colombia and 34 times that of Peru. Although such a level of expenditure should entail some scale economies in terms of technological research and development for Mexico, it is in Chile where the expenditure in R&D is the most effective in materializing innovation patents between 2008 and 2017. Every registered patent in that country required an average investment of US $1.25 million dollars over this period, a figure that is just 43% the average for Mexico, 46% that of Colombia, and 33% that of Peru. However, variations in the required investments in R&D might be quite diverse across scientific fields or economic sectors and our data lacks the required details to disentangle the nature of such differences.

Table 1. Descriptive statistics on innovation trends in Chile, Colombia, Mexico, and Peru (average values for 2008–2017)

Average values	(1) Colombia	(2) Chile	(3) Mexico	(4) Peru
Number of granted patents to Universities	20.7	29.3	68.6	8.7
	(6.4)	(4.7)	(12.3)	(3.8)
GDP per capita at constant prices of 2011	11,977	21,088	16,412	10,905
	(333)	(506)	(209)	(345)
R&D expenditure % of GDP	0.24	0.37	0.52	0.09
	(0.01)	(0.01)	(0.01)	(0.01)
Observations	10	10	10	10

ource: own estimates based on OECD (2014), Instituto Nacional de Propiedad Industrial de Chile (INAPI) (www.inapi.cl); the Superintendencia de Industria y Comercio de Colombia (SIC) (www.sic.gov.co); the Instituto Mexicano de Propiedad Industrial (IMPI) (www.impi.gob.mx); and the Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual de Peru (INDECOPI) (www.indecopi.gob.pe).

In Table 2, we report some additional descriptive statistics based on a database of 165 universities from the four countries selected for this study. The averages displayed in Table 2 show the (arithmetic) annual average of the total number of granted patents, enrolment and publications reported by each university in the sample over the period 2013-2017. For instance, the table indicates that each one of the 39 Chilean universities included in the sample reported an average of 0.94 granted patents per year between 2013-2017. According to these statistics, Mexico not only reports the highest number of universities in the sample but also records the highest average annual number of granted patents per university over 2013 to 2017. The scale effects mentioned above in relation to Mexico could be explained at least in part, by the larger size of the universities in this country, with an average enrolment of 28.4 thousand students per institution, which is 1.3 times higher that Peru and about 1.8 times higher than Chile and Colombia.

The same figures reveal that both Chilean and Mexican universities report a similar average number of scientific publications per institution in Scopus (with 359 and 354 publications, respectively) for 2013 to 2017, while Colombian universities report about half of that average and Peruvian schools, one fourth. With the smallest visible sample, Peruvian universities were able to obtain an average of 0.76 granted patents per institution, not far from their Chilean counterparts (0.94) and above the average for the Colombian ones (0.60) although such differences are not statistically significant.

Table 2. Innovation statistics in universities from Chile, Colombia, Mexico, and Peru (average annual values per university for 2013–2017)

VARIABLES	(1) Chile	(2) Colombia	(3) Mexico	(4) Peru
patents	0.95	0.60	1.70	0.76
	(0.19)	(0.10)	(0.33)	(0.25)
enrollment	15,609	16,124	28,438	22,131
	(697)	(589)	(2,012)	(1,585)
Publications in Scopus	359	177	354	83
	(41)	(21)	(51)	(12)
Publications in WOS	270	110	257	52
	(31)	(13)	(37)	(7)
Observations	195	255	290	85

Source: own estimates based on OECD (2014), Instituto Nacional de Propiedad Industrial de Chile (INAPI) (www.inapi.cl); the Superintendencia de Industria y Comercio de Colombia (SIC) (www.sic.gov.co); the Instituto Mexicano de Propiedad Industrial (IMPI) (www.impi.gob.mx); the Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual de Peru (INDECOPI) (www.indecopi.gob.pe); Scopus® and, Web of Science® -WOS.

4.2. Econometric Results

Table 3 displays the results of a preliminary econometric analysis of panel data for the four countries included in this study over the period 2008 to 2017. Given the limited number of ($i \times t = 10 \times 4=$) observations, only 40, for this stage of research, it is necessary to interpret these results with caution. In this analysis, the dependent variable is the natural log of the annual number of registered patents in each one of the four countries. As explanatory variables, we have the natural logarithm of GDP per person at PPP values (*lnpibpc*) and the overall expenditure of the country in R&D as a percentage of GDP (*gerddelpib*). Other variables, such as the number of researchers per million people in the country and FDI as a percentage of GDP were not statistically significant and, therefore, were excluded from the results presented here.

The results in Table 3 display different estimation techniques: ordinary least squares (*OLS*), random effects (*RE*), fixed effects (*FE*), fixed effects with robust standard errors (*FE_robust*), and FE with cluster-robust standard errors (*FE_cluster_robust*). According to the results of a Hausman type test for fixed versus random effects, there is strong evidence to reject the null hypothesis of non-systematic differences between coefficients from these two

models. Therefore, we conclude that the appropriate estimator is the fixed effects model.[1] For this reason, we further elaborate on the fixed effects results and display alternative estimates of the standard errors for this model in columns (4) and (5) to control for either general serial autocorrelation or country (cluster) specific autocorrelation of the error term.[2] According to these results, we validate, under all five specifications, a positive relationship between a country's GDP per capita and its number of registered patents annually. Such a relationship is statistically significant at the 1% level under the FE specification with uncorrected standard errors (see column 3 in Table 9); however, its precision diminishes to 10% significance with robust standard errors (in columns 4 and 5). Given the small number of observations for each combination of year and country, this loss of precision is not a surprising result. We also verify a positive relationship between public expenditure as a percentage of GDP and the log of annual number of registered patents, with the same loss of precision when adjusted robust standard errors are applied.

Table 3. Regression coefficients from panel data models for the (log) number of granted university patents in Chile, Colombia, Mexico, and Peru (2008–2017)

	(1)	(2)	(3)	(4)	(5)
Variables	OLS	RE	FE	FE_robust	FE_cluster_robust
lnpibpc	0.7461	0.7461	5.1505***	5.1505*	5.1505*
	(0.5396)	(0.5396)	(1.8470)	(2.0279)	(2.0279)
gerddelpib	7.0357***	7.0357***	12.5595***	12.5595*	12.5595*
	(1.2849)	(1.2849)	(4.1936)	(5.0382)	(5.0382)
Constant	−6.6985	−6.6985	−51.7167***	−51.7167*	−51.7167*
	(5.0525)	(5.0525)	(16.9170)	(20.5518)	(20.5518)
Observations	40	40	40	40	40
R-squared	0.5757		0.6334	0.6334	0.6334
Number of countries		4	4	4	4

Own estimates based on OECD (2014), Instituto Nacional de Propiedad Industrial de Chile (INAPI) (www.inapi.cl); the Superintendencia de Industria y Comercio de Colombia (SIC) (www.sic.gov.co); the Instituto Mexicano de Propiedad Industrial (IMPI) (www.impi.gob.mx); and the Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual de Peru (INDECOPI) (www.indecopi.gob.pe). Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Given the small number of observations in the models just discussed above, we implemented an alternative approach based on a sample of 165 universities in the four countries. We initially gathered data on the annual number of patents granted, the number of scientific publications in both Scopus and WOS and the enrolment size.[3] Table 4 displays the results of panel data coefficients for i = 165 universities and t = 2013 to 2017. All variables in this analysis are expressed in logs. The results on the top of the table three columns, numbered from 1 to 3, include all regressors for OLS, fixed effects and, random effects. The results in the middle part of the table, numbered from 4 to 6, only control the number of papers using data from WOS in addition to the enrollment size. Lastly, the results in columns 7 to 9 display the number of published papers in Scopus with the enrollment size. All standard errors are robust to serial autocorrelation within universities.

Table 4. Regression coefficients from panel data models between the annual number of granted university patents in Chile, Colombia, Mexico, and Peru, and their number of publications in Scopus and WOS, and the enrollment size, 2013–2017

[1] The test yields a Chi-squared statistic = 50.08 with an associated p-value = 0.000. We computed the Hausman test in Stata 13.0 with the *Hausman* command.

[2] The robust standard errors and the cluster-robust standard errors implemented in this application are a generalization of White's (1980) procedure for the estimation of the robust covariance matrix with panel data. Chapters 8 and 9 on Cameron and Trivedi (2009) provide an overview of procedures to obtain robust standard errors, which are serially correlated in the context of panel data.

[3] We are grateful for a comment from one of the referees in which it was suggested to include the number of published papers from WOS. It was very satisfying to see that the results obtained from this variable corroborate those derived from the number of papers published in Scopus.

Variables (All)	(1) OLS	(2) Fixed Effects	(3) Random Effects
ln_enrollment	0.1257**	0.1407	0.1472***
	(0.0505)	(0.1333)	(0.0527)
ln_publications	0.1383***	0.0100	0.0792***
	(0.0376)	(0.0218)	(0.0276)
ln_wos	0.0181	0.0472*	0.0407**
	(0.0178)	(0.0263)	(0.0193)
Constant	-1.6840***	-1.3627	-1.7109***
	(0.5329)	(1.2789)	(0.5321)
Observations	825	825	825
R-squared	0.2603	0.0152	
Number of institutions		165	165
Variables (only WOS)	(4) OLS	(5) Fixed Effects	(6) Random Effects
ln_enrollment	0.1584***	0.1450	0.1745***
	(0.0563)	(0.1367)	(0.0592)
ln_wos	0.1114***	0.0511**	0.0833***
	(0.0216)	(0.0224)	(0.0171)
Constant	-1.7370***	-1.3733	-1.7814***
	(0.5561)	(1.2907)	(0.5637)
Observations	825	825	825
R-squared	0.2355	0.0151	
Number of institutions		165	165
Variables (only Scopus)	(7) OLS	(8) Fixed Effects	(9) Random Effects
ln_enrollment	0.1265**	0.1656	0.1528***
	(0.0508)	(0.1327)	(0.0536)
ln_publications	0.1573***	0.0509**	0.1194***
	(0.0311)	(0.0213)	(0.0242)
Constant	-1.7063***	-1.6021	-1.7875***
	(0.5301)	(1.2756)	(0.5364)
Observations	825	825	825
R-squared	0.2597	0.0110	
Number of institutions		165	165

Own estimates based on OECD (2014), Instituto Nacional de Propiedad Industrial de Chile (INAPI) (www.inapi.cl); the Superintendencia de Industria y Comercio de Colombia (SIC) (www.sic.gov.co); the Instituto Mexicano de Propiedad Industrial (IMPI) (www.impi.gob.mx); the Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual de Peru (INDECOPI) (www.indecopi.gob.pe); Scopus® and, Web of Science® -WOS. Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

The results in Table 4 point to a positive relationship between the size of the institution, measured by the (log) of total enrolment (including undergraduate and postgraduate students), although the significance of the coefficient for this variable is statistically insignificant for this regressor under the fixed effects estimator in all cases. On average and ceteris paribus, the elasticity of the number granted patents with respect to the enrollment size ranges from 0,12 to 0,18.

The same results point towards a positive and statistically significant relationship between the (log) number of registered patents by a university and the (log) number of scientific publications either in Scopus or in WOS. The elasticity coefficients tend to be less statistically significant, particularly in the case of the fixed effects estimator, when they are included jointly. When included separately, these two variables are statistically significant under all specifications with point estimates ranging from 0,5 to 0,15, on average and ceteris paribus. It is worth to mention

that fixed effects estimate for this variable tend to be smaller and, comparatively, less significant than those from pooled OLS and random effects.

According to the results from a robust Hausman test based on a method developed by Wooldridge (2002) for fixed versus random effects models with cluster-robust standard errors, we find sound evidence in favor of the fixed effects model when the variable for the number of published papers is obtained from Scopus.[4] When we use the number of published papers in WOS, the same test does not allow to reject the null hypothesis of differences in coefficients and, therefore, the random effects model could be appropriate.[5]

The random effects model is attractive from an analytical point of view given the fact that this estimator allows to identify the effect of time-invariant regressors such as country effects and the public/private nature of university institutions. Based on this intuition, we further advance the analysis to explore the possible effects of time-invariant regressors: (4-1=), three dummies for Chile, Mexico, and Peru (we leave Colombia as the base category) and a control for public/private universities. We also include the (log) number of enrolled students (in thousands) and the (log) number of published papers in WOS. These results are displayed in Table 5 under two specifications, OLS and RE, both with clustered-robust standard errors.
According to these results, country-specific effects, as well as the private/public nature of the universities, are not statistically significant.[6] As such, these results also confirm that both the enrolment size and the scientific output (measured by the number of publications in WOS) are positively correlated to the annual number of registered patents by universities in the four selected countries of this study. All of this indicates that the relationship between the specific characteristics of an institution and its innovation activity at the university level is of a complex nature. A specific country environment does not emerge as a differentiating factor in determining the innovation activity of universities in Colombia, Chile, Mexico, and Peru, nor the private/public nature. This also suggests that other institutional, managerial or regional factors play a significant role in universities' performance of technological innovation and, probably, justify a qualitative approach to further investigate the behavior of university innovation.

Table 5. Relationship between the annual (log) number of granted university patents in universities from Chile, Colombia, Mexico, and Peru and their (log) number of publications in Scopus and WOS, with dummies for country location and public/private origin, 2013–2017

Variables	(1) OLS_ROB	(2) RE_ROB
ln_publications	0.1762***	0.1272***
	(0.0338)	(0.0256)
ln_enrolment	0.1099**	0.1455***
	(0.0488)	(0.0525)
Chile	−0.0782	−0.0424
	(0.0735)	(0.0733)
Mexico	0.0913	0.0900
	(0.0866)	(0.0873)
Peru	0.1388	0.0940
	(0.1071)	(0.1052)
public_uni	−0.0711	−0.0474

[4] The conventional Hausman test requires that the random effects estimator is efficient, an invalid assumption under cluster-robust standard errors. To overcome this difficulty, we implemented in Stata 13.0 a robust version of the Hausman test proposed in Cameron and Trivedi (2009: 261-262) based on a Wald test developed by Wooldridge (2002), which is asymptotically equivalent to the conventional test when the random effects model is fully efficient. The test yields an estimated F-statistic (with 2 and 820 degrees of freedom) =3.55 and an associated p-value= 0.0292; this suggest that differences in the coefficients from fixed and random effects models are systematic. The result of this test is conclusive at the 5% level (but not at the 1%) against the random effects model.
[5] In this case, the estimated F-statistic (with 2 and 820 degrees of freedom) is 2,47 with a probability value of 0,0855, indicating that the null hypothesis of systematic differences in coefficients cannot be rejected by the data at hand.
[6] We obtained a similar result when the log number of published papers in WOS is replaced with the number of papers included in Scopus. However, as explained in the previous footnote, when the log number of papers in Scopus is included in the specification, the random effects model is inappropriate and that is why we prefer not to include it in the table.

	(0.0742)	(0.0730)
Constant	−1.6252***	−1.7605***
	(0.5164)	(0.5325)
Observations	825	825
R-squared	0.2726	
Number of institutions		165

Own estimates based on OECD (2014), Instituto Nacional de Propiedad Industrial de Chile (INAPI) (www.inapi.cl); the Superintendencia de Industria y Comercio de Colombia (SIC) (www.sic.gov.co); the Instituto Mexicano de Propiedad Industrial (IMPI) (www.impi.gob.mx); the Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual de Peru (INDECOPI) (www.indecopi.gob.pe); Scopus® and, Web of Science® -WOS. Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Finally, we expand the analysis by including the (log) number of research staff with a PhD, an additional variable which was only available for a subsample of 93 university institutions in 2016 and 2017 in the QS Universities' Database.[7] With such data, we estimated five different comparable models that are displayed in Table 6 where column 1 presents OLS estimates, columns 2 and 3 feature fixed and random effects, respectively, and column 5 shows random effects estimates with dummy variables.

Table 6. Relationship between the annual (log) number of granted university patents in universities from Chile, Colombia, Mexico, and Peru and their (log) number of publications (Scopus and WOS), (log) number of researchers with PhD degrees and with dummies for country location and public/private origin, 2013–2017

	(1)	(2)	(3)	(4)
VARIABLES	OLS_ROB	FE_ROB	RE_ROB	RE_ROB
ln_enrollment	0.2594**	-0.1708	0.2459**	0.2407**
	(0.1012)	(0.9110)	(0.0971)	(0.1123)
ln_publications	0.2874***	0.1964	0.2761***	0.2560**
	(0.0964)	(0.1489)	(0.0819)	(0.1029)
ln_wos	-0.0355	-0.0898	-0.0351	0.0068
	(0.0783)	(0.1319)	(0.0648)	(0.0785)
ln_staff_phd	0.2469*	0.1255	0.2620**	0.2332*
	(0.1438)	(0.1825)	(0.1158)	(0.1201)
dummy_chl				-0.0621
				(0.2187)
dummy_mx				-0.0591
				(0.2019)
dummy_pe				0.1309
				(0.2629)
public_uni				-0.1187
				(0.1525)
Constant	-4.4394***	0.9731	-4.3143***	-4.1615***
	(1.0702)	(8.8633)	(1.0172)	(1.1319)
Observations	170	170	170	170
R-squared	0.3789	0.0076		
Number of institutions		93	93	93

[7] For more information about this database, see: https://www.topuniversities.com -retrieved: 28 October 2019. We are also grateful for the suggestion from one of the referees to include the number of researchers with PhD as an additional regressor.

Own estimates based on OECD (2014), Instituto Nacional de Propiedad Industrial de Chile (INAPI) (www.inapi.cl); the Superintendencia de Industria y Comercio de Colombia (SIC) (www.sic.gov.co); the Instituto Mexicano de Propiedad Industrial (IMPI) (www.impi.gob.mx); the Instituto Nacional de Defensa de la Competencia y de la Protección de la Propiedad Intelectual de Peru (INDECOPI) (www.indecopi.gob.pe); Scopus®, Web of Science® -WOS and QS World University Rankings (https://www.topuniversities.com). Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

According to these results, the fixed effects estimates (in column 2) perform poorly as all its coefficients are statistically insignificant and some are even negative. Such a result could be explained, at least in part, by the substantial reduction of the sample size. Conversely, results from the RE model corroborate the statistical significance of all continuous regressors, except in the case of the (log) number of papers published in WOS. The elasticity coefficients for the (log) enrollment size are statistically significant at the one percent level ranging from 0,241 to 0,251 while the (log) number of publications fluctuates between 0,256 and 0,287.

The same results suggest a positive relationship between the (log) number of granted patents and the (log) number of research staff with a PhD degree with an elasticity of 0,262 in the case of the random effects model, a result that is statistically significant at the five percent. With the inclusion of time-invariant regressors, this coefficient decreases in terms of both size and statistical significance at the 10 percent level. Again, the coefficients for the time-invariant regressors reflecting both the country-specific effects and the public/private nature of institutions are not statistically different from cero. To some extent, the limited number of observations for the number of PhD entails limitations to present comparable evidence of its effects on the innovation performance in the universities of these four countries. Nonetheless, these results are indicative of the importance of having qualified research staff in the technological innovation performance of universities in the four selected countries of this study.

5. Final Remarks

In the regressions at the country level, we verify a positive relationship between a countries's GDP per capita and its annual number of registered patents. We also verify a positive association between public expenditure as a percentage of GDP and the (log of) the annual number of registered patents. This evidence suggests that the amount of resources invested in research and development at the national level is strongly associated with the performance of innovation systems, measured by the number of patents granted. This evidence is in line with the related literature in this field (see: Ho, Liu, Lu, & Hang, 2014; Hsu, Shen, Yuan, & Chou, 2015; Drivas, et al., 2016). Another related finding is that the level of economic development, measured by the GDP per capita, is an important determinant of the performance of the innovation systems at the national level (Rasmussen, Mosey, & Wright, 2014; Calcagnini, & Favaretto, 2016; Chang, 2017; Guerrero, & Urbano, 2017). Although there are limitations based on the number of observations reported in this four-country study, these results are coherent with the relevant literature in this field.

Looking at university-specific data in the four countries for 2013–2017, we corroborate a relationship of technology transfer from universities to society in terms of granted patents with both enrollment size and scientific publications. We find a positive statistically significant relationship between the (log) number of registered patents at the university level and the (log) number of scientific publications in Scopus. This result was confirmed using WOS as an alternative source of information for the number of scientific papers published annually at the university institutions level. Such a conclusion corroborates the findings in a number of related studies in this field (Hsu, & Ken, 2014; Thompson, Ziedonis, & Mowery, 2016). The same data suggests that larger universities are able to generate larger numbers of registered patents; this suggests the possibility that larger institutions are able to afford certain types of research infrastructure such as specialized laboratories and related facilities that endow them with higher innovation performance (Ho et al., 2014; Moutinho, Au-Yong-Oliveira, Coelho, & Manso, 2016; Cantu-Ortiz, Galeano, Mora-Castro, & Fangmeyer, 2017). The inclusion of the number of research staff with PhD as an additional regresor further confirms that universities with larger research teams tend to produce more granted patents. This line of analysis points to the presence of both scale economies and institutional capacities at play in the generation of technological innovation in the universities of the four countries reviewed in this study. Interestingly, the public/private nature of the university and their country location do not emerge as relevant factors in the determination of innovation performance.

The findings reported so far point to the relevance of investing resources at the national level to achieve higher levels of innovation patents. This coincides with Number Nine of the Sustainable Development Goals set by the United Nations, which seeks to increase the public and private research and development spending (UNDP, 2017). This conclusion is also valid at the university level, where the scientific output of published papers in peer-

reviewed journals (measured by publications in both Scopus and WOS) appears to be a significant factor related to the production of scientific innovation. There is also a positive association between both the enrolment size and the number of PhD researchers of a university, on the one hand, and its innovation output, on the other, as measured by the number of registered patents. This again suggests that the size of an institution is a relevant factor in the generation of scientific innovations. Certainly, universities' infrastructure in terms of laboratories, highly trained scientific human resources and related facilities can be more affordable with a large number of students. This could be a possible limitation for small universities where economies of scale do not allow expensive investments in R&D. A way out in this case could be an association among several smaller universities around common scientific innovation agendas in which the pooling of economic resources and scientific capabilities enable the economies of scale to reach higher levels of scientific innovation. Such association among universities could be highly relevant at the regional level for developing countries where infrastructure and scientific expertise are scarce resources.

This present study could be further advanced in several ways. One limitation relates to the number of countries included in the analysis. The collection of data for four countries was certainly a challenging task but we believe that a similar effort with an increase in sample size would certainly enhance the capacity to generalize the conclusions, as well as the recommendations, presented here. Moreover, the measurement of a university's variables related to its innovation capacity, such as the number of published papers and number of researchers in different areas of knowledge, would enable the elaboration of more refined conclusions for innovation policy in the higher education sector. A similar remark applies to other variables related to the production function of university innovation, such as the resources and infrastructure devoted to R&D. We were unable to differentiate between the numbers of scientific patents in different areas of knowledge in which the production function for each of them could be subject of a high degree of heterogeneity. For instance, the infrastructure requirements in diverse fields of knowledge could be highly differentiated; this is an unaccounted factor in this research that could be addressed in the future in discipline-specific studies of innovation for relevant sectors in emerging-market economies such as biotechnology, medicine, agricultural production, and alternative energies.

References

Audretsch, D.B. (2014). From the entrepreneurial university to the university for the entrepreneurial society. *Journal of Technology Transfer, 39*, 313-321

Baglieri, D., Baldi, F., & Tucci, Ch. (2018). University technology transfer office business models: One size does not fit all. *Technovation, 76–77*, 51–63

Bradley, S., Hayter, C. S., & Link, A. N. (2013). Models and methods of university technology transfer. *Foundations and trends in Entrepreneurship, 9 (6)*, 571 - 650.

Bush, V. (1945). *Science, the Endless Frontier: a Report to the President*. Washington, D.C.: U.S. Government Printing Office.

Calcagnini, G. & Favaretto, I. (2016). Models of university technology transfer: analyses and policies. *Journal of Technology Transfer, 41*, 655 – 660

Cameron, C. & Trivedi, P. (2009) *Microeconometrics using Stata.* College Station, Texas, Stata Press.

Cantu-Ortiz, F., Galeano, N., Mora-Castro, P., & Fangmeyer Jr., J. (2017). Spreading academic entrepreneurship: Made in Mexico. *Business Horizons, 60*, 541-550

Chang, S. (2017). The technology networks and development trends of university-industry collaborative patents. *Technological Forecasting & Social Change, 118*, 107-113

Czarnitzki, D., Doherr, T., Hussinger, K., Schliessler, P., & Toole, A. (2016). Knowledge Creates Markets: The influence of entrepreneurial support and patent rights on academic entrepreneurship. *European Economic Review, 86*, 131 – 146

Drivas, K., Economidou, C., Karamanis, D., & Zank, A. (2016). Academic patents and technology transfer. *Journal of Engineering and Technology Management, 40*, 45-63

Edquist, C., & Hommen, L. (1999). Systems of innovation: theory and policy for the demand side. *Technology in Society, 21(1)*, 63-79.

Fish, C., Hassel, T., Sandner, P., & Block, J. (2015). University patenting: a comparison of 300 leading universities worldwide. *Journal of Technology Transfer, 40(2),* 318 - 345. doi:10.1007/s10961-014-9355-x

Fischer, B., Schaeffer, P., Vonortas, N., & 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

Geuna, A., & Rossi, F. (2011). Changes to university IPR regulations in Europe and the impact on academic patenting. *Research Policy, 40*, 1068 - 1076.

Godin, B. (2006). The Linear Model of Innovation: The Historical Construction of an Analytical Framework. *Science, Technology & Human Values, 31*, 639 - 667

Grimaldi, R., Kenney, M., Siegel, D., & Wright, M. (2011). 30 years after Bayh-Dole: Reassessing academic entrepreneurship. *Research Policy, 40,* 1045 – 1057

Guerrero, M., & Urbano, D. (2017). The impact of Triple Helix agents on entrepreneurial innovations' performance: An inside look at enterprises located in an emerging economy. *Technological Forecasting & Social Change, 119*, 294 – 309

Hayter, C., & Rooksby, J. (2016). A legal perspective on university technology transfer. *Journal of Technology Transfer, 43(8),* 270 - 289. doi:10.1007/s10961-015-9436-5

Ho, M., Liu, J., Lu, W., & Hang, C. (2014). A new perspective to explore the technology transfer efficiencies in US universities. *Journal of Technology Transfer, 39*, 247 – 275

Hsu, W., & Ken, Y. (2014). License income of technology commercialization: The case of U.S. universities. *The International Journal of Organizational Innovation, Vol 6*, Num. 3, 21-30

Hsu, D., Shen, Y., Yuan, B., & Chou, C.J. (2015). Toward successful commercialization of university technology: Performance drivers of university technology transfer in Taiwan. *Technological Forecasting & Social Change, 92*, 25-39

Jefferson, D.J., Maida, M., Farkas, A., Alandete-Saez, M., & Bennett, A.B. (2017). Technology transfer in the Americas: common and divergent practices among major research universities and public sector institutions. *Journal of Technology Transfer, 42,* 1307 – 1333

Kesan, J. P. (2015). Economic rationales for the Patent System in current context. *George Mason Law Review, Vol 22:4*, 897-924

Lundvall, B.A. (Ed.). (1992). *National innovation systems: Towards a theory of innovation and interactive learning.* London, UK: Pinter

Moutinho, R., Au-Yong-Oliveira, M., Coelho, A., & Manso, J.P. (2016). Determinants of knowledge-based entrepreneurship: an exploratory approach. *International Entrepreneurship Management Journal, 12,* 171-197

Nelson, R. (Ed.). (1993). *National innovation systems: A comparative analysis*. New York, NY: Oxford University Press

OECD (2014). *Gross domestic spending on R&D* (indicator). http://dx.doi.org/10.1787/d8b068b4

OECD (2016). *Start-Up Latin America 2016: building an innovative future*. Paris, France: OECD Publishing

Primi, A. (2014). *Promoting Innovation in Latin America: What Countries Have Learned (and What They Have Not) in Designing and Implementing Innovation and Intellectual Property Polices* (Doctoral Thesis, Maastricht University, Maastricht, The Netherlands).

Rasmussen, E., Mosey, S., & Wright, M. (2014). The influence of university departments on the evolution of entrepreneurial competencies in spin-off ventures. *Research Policy, 43,* 92– 106

Rodeiro, D., López, F., Otero, L., & Sandías, R. (2010). Factores determinantes de la creación de spin-offs universitarias. *Revista Europea de Dirección y Economía de la Empresa, 19(1),* 47 – 68.

Russo-Spena, T., Tregua, M., & Bifulco, F. (2017). Searching through the jungle of innovation conceptualizations: System, network and ecosystem perspectives. *Journal of Service Theory and Practice, Vol. 27 (5),* p.977-1005

Sargent, J., & Matthews, L. (2014). Latin American Universities and Technology Commercialization. *Latin American Business Review, 15*, 167–190

Savescu, D. (2017, January). The importance of Intellectual Property Protection in Technological Transfer. Some aspects. *Fiability & Durability, No. 1*, 135 – 141

Siegel, D.S., & Wright, M. (2015). Academic Entrepreneurship: Time for a Rethink? *British Journal of Management, 2*, 582-595

Thompson, N.C., Ziedonis, A.A., & Mowery, D.C. (2016). University Licensing and the Flow of Scientific Knowledge. *MIT Sloan School Working Paper, 5189-16*, 1-33

UNDP (2017). *The Sustainable Development Goals Report.* New York, NY: United Nations Publications

White, H. (1980). A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. *Econometrica, 48*, 817-838.

WIPO (2016). *Understanding Industrial Property*. Genève, Switzerland: WIPO Publications.

Wooldridge, J.M. (2002) *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press.

Chapter 5: Conclusions and Recommendations

Conclusions

A political concern in the agenda for governments and universities alike has been the relationship between science and technology and the corresponding link between universities and industries. Globally, as a key element of their institutional missions, universities search to find the most efficient way to transfer the outcomes of their research to society and to industries. In this sense, much of the specialized literature has been oriented to study the transfer of innovation and technology from the university sector to the rest of the economy in the developed world, while, this topic has received less attention in developing countries, particularly in Latin America.

However, in the last decade innovation has gained increasing importance in Latin America. Most of the countries in the region have created national strategies for innovation and governing institutions for this purpose. While these countries have accumulated experience in designing innovation policies, they still sometimes struggle to articulate industrial policies and domestic production from the generation of scientific knowledge and technological capabilities (Primi, 2014).

Each country differs in the magnitude of resources applied to the promotion of innovation and in the way that the resources are assigned. However, for all Latin American countries, progress has been made in at least three areas: (i) institutional strengthening, with the creation of bodies charged with guiding the innovation policy with sufficient autonomy and capabilities; (ii) new funding sources for innovation programs through the collection of royalties for the production of commodities and through the establishment of sectorial funds for technological development; and (iii) improvements in the legal framework for innovation, through the establishment of clear policies on industrial property, and the simplification of

procedures for access to resources and the promotion of technology-based companies (OECD, 2016)

The governments of the region have improved policies for innovation, especially in the last decade. Today, institutions are empowered, available budgets have been increased to finance programs for innovation, and regulatory frameworks support industrial property and encourage the creation of companies based on innovation. An adequate alignment of innovation policies with efforts for productive transformation will generate new development opportunities for these countries in the immediate future (Chatterjee, & Sankaran, 2015; Guerrero, & Urbano, 2017).

It is in this field where the technological transfer from universities to the productive sector acquires relevance. The new knowledge and innovations resulting from university research must be in line with social and industry needs given their positive externalities (Audretsch & Lehmann, 2005), and countries should benefit extensively from the investments that allow the development of knowledge. This also facilitates universities to comply with what is called their "Third Mission" (Lukovics & Zuti, 2014) which is characterized by "all activities concerned with the generation, use, application and exploitation of knowledge and other universities capabilities outside academic environments" (Molas-Gallart & Castro-Martinez, 2007, p. 322).

According to international experience, academic entrepreneurship (Osiri et al., 2014; Wood, 2011), understood as all the efforts and activities that university and their associated industries carry out in the expectation of commercializing the results of university research, is the key to put into action the scientific research that takes place in the universities. This because it delivers commercial applications capable of generating revenue especially in the case of university patents.

The dynamics of university patents developed strongly in the United States since the issuance of the Bayh-Dole Act in 1980, which allows United States universities to retain intellectual property and to appropriate the proceeds of the licenses from those patents obtained from federal resources provided for research (Fish et al., 2015). Based on this experience, different countries in Asia, Europe and even Latin America adopted similar legislation in this area (Bradley et al., 2013; Geuna & Rossi, 2011).

However, according to the literature, success in the commercialization of a patent is determined by two main concepts: applicability and marketability of the underlying technology (Wu et al., 2015). Applicability understood as to what extent university research produces technology that can be used for the development of products and improved services. Marketability represents the degree to which the inventions are recognized by industry as important input that can be sold in the innovation market. This is particularly important in the case of the licensing of university patents, as we will see ahead.

Based on the conceptual model (see Figure 3) to address the purpose of this study, three research questions were asked in order to identify the factors that at the university level affect the effective technology transfer of patents and which explain the selection of the mechanism used, in particular the choice between licensing and the creation of university spin-offs. Additionally, three groups of testable null hypotheses were formulated depending on the most relevant factors that intervening at the university level: 1. Closeness to the market. 2. Innovation type. 3. Financial aspects.

Initially, in order to achieve a better understanding of the dynamics of university patenting in Latin America, a comparative analysis was carried out based on the number of patents granted to universities from four Latin-American countries: Chile, Colombia, Mexico and Peru, in relationship with certain institutional characteristics.

For this aim, we collected a database of granted patents at the national level for four countries and 165 universities in combination with information from a variety of sources to construct a set of plausible explanatory variables. Based on panel data at the national level, we verified that the number of patents granted to universities is strongly associated with the share of resources as a percentage of GDP invested in science and technology.

At the university level, we found that those universities with more scientific publications and higher enrolment size tend to obtain more granted innovation patents. To some extent, the evidence indicates that both the absolute and relative size of the resources invested in scientific and technological research are subject to scale economies whereby a larger size of resources invested in technological research is associated with an increasingly larger innovation and patenting.

The econometric results showed a positive relationship between the countries' GDP per capita and their number of registered patents annually. Such a relationship is statistically significant at the 1% level under the fixed effects (FE) specifications with uncorrected standard errors, but its precision diminishes to 10% significance with robust standard errors. We could also verify a positive relationship between public expenditure as a percentage of GDP and the log of annual number of registered patents, with the same loss of precision when adjusted robust standard errors were applied.

The findings reported so far point towards the importance of investing resources at the national level in order to achieve higher levels of innovation patents. This coincides with the Number Nine Sustainable Development Goals set by the United Nations, which seeks to increase the public and private research and development spending (UNDP, 2017).

At the university level in the four countries for 2013 - 2017, it was confirmed the relationship between the technology transfer from universities to society in terms of granted patents and both their enrollment size and their publications in peer-reviewed journals

(measured by publications in Scopus). We found a positive statistically significant relationship between the (log) number of registered patents at the university level and the (log) number of scientific publications in Scopus with an estimated elasticity between 0.15 and 0.40. Such a conclusion corroborates the findings in several related studies (Hsu, & Ken, 2014; Thompson, et al., 2016).

The same data suggests that larger universities can generate higher rates of granted patents. This indicates the possibility that larger institutions, measured by the (log) total enrolment (including under and postgraduate students), can afford certain types of research infrastructure such as specialized laboratories and related facilities that endow them with a higher innovation performance. These results are in line with the findings in some recent studies related to this field (Ho, et al., 2014; Moutinho, et al., 2016; Cantu-Ortiz, et al., 2017).

The positive association between the size of the university and the innovation output measured by the number of granted patents suggests that the size of the institution is a relevant factor for the generation of scientific innovations. Certainly, universities' infrastructure in terms of laboratories, highly trained scientific human resources and related facilities can be more affordable when having a large number of students and this could be a possible limitation for small universities where the scale economies do not allow expensive investments in R&D.

A way out in this case could be the association of several universities around common scientific innovation agendas in which the pooling of economic resources and scientific capabilities enable the scale economies to reach higher levels of scientific innovation. Such association amongst universities could be highly relevant at the regional level of developing countries where infrastructure and scientific expertise are scarce resources. This has important implications for university management since it is necessary developing internal capabilities and assessing academics' intentions for different levels of entrepreneurial engagement as a

strategic priority for university management in order to remove existing barriers to innovation activity.

In relation with the three main research questions, in order to study the relationships between university patents and the main factors that affect the effective technology transfer and explain the decision at the University level at the moment to choose the mechanism to commercialize the patents of invention, the primary information was obtained from the application of a survey to a random sample of 87 invention patents, whose holder is a Colombian university. The sample of patents was discriminated in 48 (55%) whose holder is a Public University and the remaining 39 (45%) are headed by a Private University. In total, 21 universities located in nine urban centers were studied. The surveys were submitted using the QuestionPro® platform on October 12, 2018, ending the electronic data collection on November 20, 2018, in total 60 forms were received, duly completed, that is a response of 68%.

At the descriptive level, the statistics delivered the following results. Almost 90% of the patents were granted in the last five years, which reflects the recent university dynamics in subject of intellectual property at the level of the Colombian Innovation System. In addition, it was found that 70% of patents granted are headed by only seven universities - four of a public nature and three of a private nature - all of them with a large number of students, which coincides with the findings for the Latin-American countries of this study, situation that we have already analyzed.

The dynamics in terms of patents are located in the main urban centers of the country, which could be explained because in these cities there is the greatest availability of qualified human resources and the expense associated with research and development available for the generation of new knowledge, as already analyzed for the four countries of Latin America.

According to the technological sector, most patents of invention (73 patents) belong to the Chemical and Engineering sectors.

Of the answers received, the one that generates the most concern is the fact that in Colombia almost 80% of university invention patents have not been commercialized. This discovery is new for the Colombian case and it is something for which until now there was no scientific evidence. This fact not only questions the effectiveness of the country's Innovation System, but also forces us to review the processes of scientific research and patenting carried out by universities.

This is because there is a high cost involved in obtaining a patent for invention, among others: time of researchers, use of laboratories, testing, materials, legal advice and official procedures. For the case of Chile who presents the greatest effectiveness in materializing innovation patents between 2008 and 2017, according to the information obtained, each patent has required an average investment of more than US $ 1.25 million dollars over this period.

If for the Colombian case 80% of their investment to obtain patents remains without being able to be transferred to the productive sector, this means a high country cost in terms of the resources assigned to the National Innovation System as well as for research budgets of the universities. In the end, it demonstrates weaknesses in academic entrepreneurship to the extent that scientific research is not producing commercial applications capable of generating revenue and incomes for those universities (Wood, 2011). Apparently, university development strategies have placed more emphasis on the “knowledge creation” elements such as new basic research centers, with less attention being given to “knowledge exploitation” elements such as applied research and technology transfer services.

As stated in a recent study Dalmarco, Hulsink, & Bloisa (2018), for the case of emerging economies the promotion of academic entrepreneurship is high at the level of public policy, but "it is not clear as yet which policies or structures are needed to foster the effective

transfer of academic knowledge and the incubation of start-up firms, and eventually contribute to socio-economic development "(p. 99). In this sense, a basic principle determines that all technologies can only be considered innovation once they reach the market.

However, this situation does not seem to be exclusive of Colombia. Other studies carried out in Latin America conclude “the Brazilian universities have a significant number of patent applications, but these technologies do not reach the market, considering that they are not licensed or transferred to any industries” (Viana, Jabour, Ramirez, & da Cruz, 2018, p. 31). This study showed that by 2014, only 18% of the Brazilian university patents had reached a technology transfer agreement between the university and industry (p. 29).

The primary information received from the surveys was analyzed by using the Partial Least Squares SEM (also called PLS path modeling), statistical modeling technique used to develop theories in exploratory research. A trajectory model of formative character was designed in which the directional arrows point from the indicator variables to the construct, or latent variable that indicates a causal (predictive) relationship in that direction (Hair et al., 2017)

According with the results, for the first research question the path coefficients *Characteristics of the invention patent -> Innovation type* and *Innovation type_ -> Closeness to the market* are significant since their p values are less than 0.05. In addition, the variable Closeness to the market (0.588) has a moderate R^2 and the variable Innovation type (0.333) has a coefficient of determination (R^2) that can be classified as weak or moderate. On the other hand, the variable Financial resources (0.248) has a coefficient of determination that can be considered as weak.

This means that factors such as area of knowledge, type of University, size of the university and year of recognition of the patent, have a high relation with the type of innovation in terms of the attributes of the technology, the commitment of the inventor and

the institutional support. In the same way, the type of innovation has a close relationship in terms of Closeness to the market, understood as the links with industry, collaboration with companies and access to the market.

For its part, the determination level R^2 values of the endogenous constructs considered substantial the variable Closeness to the market (58.8%) which seems to be a determining factor in order to achieve an effective commercialization of patents. This second finding represents a new contribution to knowledge in this area for a developing country and respond to unresolved issues that the specialized literature suggests addressing.

The above coincides with the specialized literature that emphasizes market-related variables, such as links to industry or institutional openness towards university-industry collaboration (Dahlborg et al., 2017; Fernández-Esquinas et al., 2016; Fischer et al., 2018; Lee, 2012; Wu et al., 2015). In fact, there are numerous studies on the University-Industry Collaboration (UIC) addressed from the point of view of technology transfer, usually interacting through patents, license agreements and joint research (Barcelo, España, & Prieto, 2012).

For the Mexican case, a recent study found that the probability that a company has a collaboration agreement with universities is increased by .70 when the company is interested in developing radical innovations associated with new products (Guerrero, Urbano & Herrera, 2019). There is no doubt, that UIC allow them to have access to the new knowledge and technological resources required to explore opportunities and initiatives to acquire innovations.

Indeed, the processes that determine the UIC play a crucial role in achieving economic growth in today's knowledge-based societies. Additionally, it contributes to develop the 'third missions' of the universities in addition to the two traditional core missions of research and teaching (Perkmann et al., 2013). However, the quality and duration of these relationships is

something that is still under investigation, trying to identify those factors that influence success in such collaboration.

A recent literature review by Rybnicek and Königsgruber (2019) identified four moderators that appear essential for the establishment of a successful UIC. They are flexibility, honesty, clarity and awareness (p. 235). According to their conceptual model, each of them facilitates or inhibits the UICs' success, becoming the most relevant factors for the generation of long-term relationships with companies, allowing the creation of spaces for exchanges of value that benefit the parties and society in general.

Following with this topic, based on the answers received for the indicators included in the survey, the factors that have impeded the effective technological transfer of the patents in the universities object of the sample are: i) the lack of an adequate market analysis, ii) the insufficient marketing mechanisms and, iii) weak strategies to spread innovation. Given the above, it is possible to conclude that the universities that have limited experience in the field of Intellectual Property do not yet have the capacity to determine the real possibilities of commercialization of their innovations and do not carry out previous studies to identify potential markets, price of sale or volumes of uses derived from their innovations. This coincides with what previous studies have determined as Knowledge-based entrepreneurship (Kesan, 2015; Moutinho et al., 2016) and Entrepreneurial capabilities (Huynh et al., 2017; Senelwa, 2016), among others.

In summary, as for the hypotheses formulated, it is necessary to consider both the path coefficient and the *p* value in order to reject or not each approach, having as a reference a confidence level of 5%. In this way, we found the Closeness to the market as a determinant factor for the effective technological transfer of university patents (0.601, $p = 0.007$). Based on this evidence it is possible to reject the Null H1 and affirm that the Closeness to the market affect the effective technology transfer of university patents.

For the second question related to the factors that explain licensing as a mechanism for the transfer and commercialization of university patents, we obtained few observations to guarantee their statistical reliability. However, with the aim of contributing to a preliminary inquiry into the factors that affect this marketing mechanism, it was decided to address the analysis of the answers.

In this case, the variables Innovation type (0.985) and Closeness to the market (0.885) have coefficients of determination (R^2) that can be considered as substantial. For its part, the variable Financial resources (0.543) have a coefficient R^2 that can be considered as moderate. This means that factors as institutional support, inventor binding and attributes of the technology are determinants for effective licensing patents. In the same way, factors as links with industry, collaboration with companies and access to the market, look as substantial in order to achieve the same objective.

This third finding of this research allows us to infer that the technical characteristics of innovation are key when it comes to achieving the effective licensing of the patent in the market. Therefore, universities should guide their research efforts to the generation of solutions that have a level of development that allows their application at the industry level. The type of innovation should also guide decisions regarding the type of licensing that is most convenient for the University. That is, exclusive or non-exclusive license, territoriality, duration of the license and how to obtain royalties, among others.

This coincides with previous studies that affirm that the nature of the invention, in particular if it is in an embryonic state or if it already has high technical development, is key when defining the strategy for its commercialization (Öcalan-Özel & Pénin, 2016). Additionally, it has been found that the probability of licensing is determined by individual factors including inventors' attitude towards commercialization of research. In this way, individual factors play a more important role in university licensing than institutional factors

(Wu, et al., 2015). A recent multilevel regression study confirms that the relationship between researches and their organizational context are appropriate for the commercialization of academic innovations (Halilem, N., Amara, N., Olmos-Peñuela, J., & Mohiuddin, M., 2017).

Taking into account the answers received, the factors that determine the transfer and commercialization of university patents through licensing are: i) the degree of applicability of the invention, ii) the inventor's links with related industry and, iii) the inventor's commitment to the processes of patent commercialization. The degree of applicability of the invention, that is, if the patent is ready for scaling at the industrial level (Öcalan-Özel & Pénin, 2016; Sargent & Matthews, 2014) is key in terms of the probability of licensing. The innovations protected at the level of pilot tests and without the appropriate scaling means for companies' time and money before they can be used, which decreases the possibility of its licensing. In the same way both the inventor's relational capital and its degree of commitment to the processes are required to achieve licensing; this coincides with other studies previously carried out at the level of specialized literature (Hsu et al., 2015; Marzurkiewiz & Poteralska, 2017).

For its part, effective licensing requires good interaction between researchers and companies or government entities, previous research contracts with the related industry, and existence of market studies. In sum, the relational capital that researchers can offer to the University is basic for a successful licensing of technology transfer.

However, for the Colombian case this seems to be complex to solve given that according to studies presented by the government Universities and Research Centers only have contact with 4% of companies and 90% of the Colombian companies do not use new technology in their production processes (DNP, 2016).

Again, for the hypotheses formulated, it is necessary to consider both the path coefficient and the *p* value in order to reject or not each approach, having as a reference a confidence level of 5%. In this way, we found the Type of innovation as a determinant for the

technological transfer of university patents (0.577, $p = 0.000$). Based on this evidence it is possible to reject the Null H4 and affirm that the type of innovation affects the effective technological transfer of university patents.

Regarding to the third question of this investigation, only two observations were received which does not allow an adequate analysis on this matter. Nevertheless, it can be concluded that the creation of University Spin-Off is the least used patent marketing mechanism among Colombian universities. Although this figure is not so common, it is important for economic development and for helping universities with their major missions of research and teaching (Pattnaik & Pandey, 2014). Additionally, the University Spin-Offs are considered one of the significant engines of direct commercialization of university intellectual property.

This confirm the important distance that in Colombia the creation of University Spin-Off has in relation to other countries, especially in the developed world. Canada presents an average of four University Spin-Off created every year by University, while in European countries the average is two annually (Halilem et al., 2017).

The transition from a teaching and research university to an entrepreneur implies substantial changes in institutional policies. At this respect, apparently the Colombian universities still lack an environment that promotes academic entrepreneurship, do not encourage the application of their research projects, and lack the capacity to take risks, all of which is necessary for the creation of University Spin-Offs that can remain in the market.

Given the results obtained, it can be affirmed that although Colombian universities have advanced in achieving research results whose degree of innovation has allowed them to obtain Innovation patents. However, the fact that the vast majority of them have not been transferred to the productive sector through licensing nor have they led to the creation of a University Spin-Off, the university system is still characterized by being of second

generation; this means oriented to teaching and research. There are still many developments before they can be consolidated as third generation universities whose fundamental paradigm shift to embrace "know-how exploitation", in order to creating and maintaining partnerships with economic actors outside the university, absorbing the new knowledge (Wissema, 2009).

In conclusion, the use of these two commercialization strategies, licensing and creation of University Spin-Offs, requires different competences at the institutional level. The licensing strategy primarily requires training in business law and patent practices (Lawson & Sterzi 2014), as well as focus on marketing practices; while the spin-off strategy “requires competencies in business development and support capabilities for the start-up and early growth phases, such as incubators, science parks, and seed funding, integrated into relational-focused commercialization practices” (Bengtsson, 2017, p. 567).

Up to this point, what can be evidenced is that for an effective technological transfer, it is necessary for universities to orient their knowledge generation processes from Mode 2 (Gibbons et al., 1994) that involves collaboration teams between academia and industry working on solving real-world problems (Hsu, et al., 2015). Universities that persist in generating knowledge autonomously based only on their own interests and motivations (Mode 1), few possibilities have to transfer the innovation of their patents to the industry.

For this reason, the model of the Triple Helix (Etzkowitz & Leydesdorff, 2000; Leydesdorff, 1998; Leydesdorff, 2000; Leydesdorff & Meyer, 2003) that fosters a set of relationships between academia, industry and governments in a knowledge-based economy, and its subsequent developments that extend it to quadruple (Carayannis & Campbell, 2009) or quintuple Helix (Carayannis, Thorsten & Campbell, 2012), continues to be fundamental to promote the economic and social development of the countries.

In this sense, Mascarenhas, Ferreira, and Marques (2018) affirm, “The triple helix model is an emerging entrepreneurial paradigm in which universities play an enhanced role in

technological innovation. Governments have encouraged this academic transformation as an economic development strategy, which also reflects changes in the relationship between knowledge producers and users" (p. 3)

On the other hand, it is necessary to recognize that the processes of technology transfer also depend on a series of qualitative factors associated with the performance of university organizations. This has been well analyzed from the perspective of the Capability-based framework (Cantu-Ortiz et al., 2017; Rasmussen & Wright, 2015); Academic engagement (Hsu et al., 2015; Perkmann, et al., 2013); and Absorptive capacities (Fernández-Esquinas et al., 2016; Zou, Ertug & George, 2018). All these analysis frameworks are also useful for identifying the factors that determine the effective technological transfer of university patents in emerging countries.

Implications

Based on the results obtained in this research, several implications emerge for the policy makers of the innovation systems in Latin America, for the agents involved in the Science, Technology and Innovation System of Colombia, for university innovation management, and for researchers in the universities of the region. In the first place, for innovation systems it is necessary to strengthen the policies that allow academic entrepreneurship in such a way that it increases its levels of efficiency and effectiveness.

A successful academic entrepreneurship depends on a series of factors such as an adequate management of incentives at the individual level and the strengthening of capacities at the institutional level. This new role of universities presents a challenge to university leadership and management and requires entrepreneurship and innovation being placed at the heart of university development strategies.

Innovation systems should strive for universities in Latin America to consolidate their third mission looking to contribute to the economic development of countries. Given that,

currently at the regional level, most universities have the characteristics of second generation universities and only a few are transitioning to third generation universities, it is required that their levels of technology transfer effectively impact the markets, which is fundamental for a knowledge society. This encourages the creation of new industries, fosters leadership in the regional economy, and generates dynamic innovation systems and culturally enriched spaces.

As stated by Gümüsay and Bohné (2018), "Policies aimed at enabling and encouraging the commercialization and dissemination of research through entrepreneurial ventures have to address both individual and organizational levels as well as structural, relational, and cultural-cognitive challenges" (p. 374). We need efforts to decentralize entrepreneurial competency development, and commitment to incentivize nascent academic entrepreneurs.

In terms of the Science and Technology policy considering the results presented, it is necessary to promote closer links between the industry and the universities of the region. Foster higher quality relationships between market and academia in Latin America is related to more fundamental economic determinants of the innovative activity in the countries. A strong coordination between industrial policy and incentives for the use of university innovation patents, is shown as key when it comes to building a favorable system for effective technology transfer. In this sense, recent studies (Correa-Henao, Londoño, & Tavera, 2018) show that in the quality of the university-business relationship, universities must not only work to generate trust with the industry, but must go further, towards a commitment that manages to become loyalty relationships in the long term.

For its part, the recent study prepared by Fischer, Schaeffer, Vonortas, & Queiroz (2018), empirically assesses the extent to which institutional openness in universities toward UIC linkages affect the generation of knowledge-intensive spin-offs and academic patenting activity in the context of the State of Sao Paulo, Brazil. They concluded that in terms of

science and technology policy, it is necessary to promote deeper linkages between companies and universities, saying, “a stronger coordination between industrial policy, regulation of the competitive environment and the institutional framework of UIC is needed to build an environment conducive to the deep links we are discussing” (p. 280).

On the other hand, given that the challenge of financing persists at the level of Latin America, state policy must encourage a determined investment in research directed at all areas of knowledge. Universities with the resources they allocate from their budgets can do basic research but with a reduced impact. Therefore, the diversification of funding sources to leverage strategic Science and Technology projects is fundamental, as being supported only in part of the income from enrollment is insufficient.

In this sense, recent studies (Belitskia, Aginskajab, & Marozauc, 2019) indicates, “Direct industrial funding is an effective conduit of knowledge transfer and knowledge spillover from universities, which may function as a substitute for public and angel finances. It is important that ownership is shared between an inventor and industry” (p. 613)

In the case of the Science, Technology and Innovation System of Colombia, it is necessary to refine the indicators associated with the technology transfer, given that although the universities present a good dynamic in terms of obtaining patents, the empirical evidence shows that most of these innovations are not reaching the market. This means a high cost for the country and generates inefficiency in the use of the resources associated with the research assigned by the universities. Both at the level of licensing of patents and the creation of University Spin-Off, the effectiveness indexes are far from international standards.

Additionally, important efforts must be made to foster relations between Colombian universities and the national industry, in such a way, that the research processes respond to improve previously identified products or services, in whose solution work in an articulated way universities as companies that gives greater guarantee on the effective application of

innovations. This, in turn, also allows greater financial support to cover the costs associated with qualified human resources, materials, and laboratory tests required by applied research.

Although the Colombian Innovation System through calls encourages and partially subsidizes the costs associated with obtaining patents, it must be clear that achieving this recognition in terms of Intellectual Property is only a first step before universities can register an effective use of the new knowledge and generate income that encourage research processes. And how this investigation showed that about 80% of university patents have not been commercialized, this fact alone should call for reflection on the part of the agents involved in the design and application of the country's Science and Technology policy. In the end, there is no point in patenting if you are not going to obtain an income.

For the innovation and knowledge management departments of the universities, since a positive relationship was found between the size of a university and its innovation output, measured by the number of granted patents, this fact suggests that the size of an institution is a relevant factor in the generation of scientific innovations. This indicates that small universities should be associated around common research agendas, so that resources and research capabilities can be shared. Such association among universities could be highly relevant at the regional level for developing countries where infrastructure and scientific expertise are scarce resources.

For their part, large universities should seek to irrigate their experience at the regional context and consolidate international alliances with high-level academic institutions. This allows the execution of joint research projects, so that the entire innovation system can benefit from best practices and the advances in knowledge resulting from scientific research. Universities should also promote an environment conducive to academic entrepreneurship, both for their researchers and students. For this, the consolidation of technology transfer

offices, innovation parks, and business incubators are adequate sources to guide initiatives that arise within the academic community.

Regarding the researchers, although scientific networks are important for the dissemination of knowledge, in relation with technology transfer processes, links with the research and development departments of companies are more important. Hence, the relational capital that can be provided by innovators is shown as a determining factor for the commercialization of university patents. In this sense, this research found that in the Colombian case, almost 60% of the effective technology transfer the patens depends of the Closeness to the market and that the relationship between researches and their organizational context are appropriate for the commercialization of academic innovations.

Therefore, universities must ensure that from the beginning research projects involve the industry, so that when obtaining the results there is enough confidence in the quality of scientific processes associated with innovation. This facilitates not only the future licensing but also the possibility of scaling it up at an industrial level, with benefits for both parties.

Given that the transfer of technology from the knowledge generated in universities is still a process of consolidation in Latin America, a coordinated effort is required between the guidance of innovation systems, university innovation managers, researchers and leaders of the industries to overcome the institutional, technical and cultural barriers that prevent the investigative effort and innovation patents from be used for benefit of the economic development of the countries.

Recommendations

Given the originality of the subjects that were studied, this research could be further advanced in several ways. One limitation relates to the number of countries included in the analysis. The collection of data for four countries was certainly a challenging task but a similar effort with an increase in sample size would certainly enhance the capacity to

generalize the conclusions, as well as the recommendations, presented here. Moreover, the measurement of a university's variables related to its innovation capacity, such as the number of published papers and number of Ph. D. researchers in different areas of knowledge, would enable the elaboration of more refined conclusions for innovation policy in the higher education sector.

A similar remark applies to other variables related to the production function of university innovation, such as the resources and infrastructure devoted to R&D. We were unable to differentiate between the numbers of scientific patents in different areas of knowledge in which the production function for each of them could be subject of a high degree of heterogeneity. For instance, the infrastructure requirements in different fields of knowledge could be highly differentiated; this is an unaccounted factor in this research that could be addressed in the future in discipline-specific studies of innovation for relevant sectors in emerging-market economies such as biotechnology, medicine, agricultural production, and alternative energies.

On the other hand, as it was done with the sample of patents applied to universities in Colombia, a study in Latin America could also identify the degree of utilization of university patents in different countries, in order to measure the efficiency and the effectiveness of the different innovation systems that exist in the region. Finally, although obtaining the primary information about the sample of patents granted to Colombian universities was a difficult task, the results presented here could be refined if a similar analysis were made, but on the universe of granted patents, differentiating them by areas of knowledge, technology transfer mechanism and type of university.

Appendix A. Informed consent

Bogotá, octubre 8 de 2018

Apreciado Directivo Universitario:

Desde la Universidad de La Salle en asocio con la Pontificia Universidad Católica del Perú nos encontramos adelantando un estudio acerca de la utilidad que han tenido las patentes universitarias en algunos países de América Latina.

En particular se pretende indagar sobre los factores que a nivel institucional determinan la selección de mecanismos para la transferencia y comercialización de las patentes universitarias. Para el caso colombiano fueron consultadas las bases de datos de la Superintendencia de Industria y Comercio, y sobre el universo de patentes de invención otorgadas a universidades nacionales en los últimos diez años, se ha seleccionado una muestra representativa.

Dados los importantes avances que en esta materia registra su institución quisiéramos invitarle a contribuir con este estudio diligenciado la encuesta electrónica anexa. La información recibida será considerada como confidencial, y nos comprometemos a garantizar la reserva sobre los datos suministrados a nivel de cada institución.

Una síntesis de los resultados que arroje esta investigación será entregada en el primer semestre del 2019 a las universidades participantes con el fin de que puedan ser utilizados al momento de seleccionar algún mecanismo para la comercialización de las patentes que en el futuro le sean concedidas, con el propósito de lograr una efectiva contribución del nuevo conocimiento a la sociedad.

Quedamos atentos a su contribución. La encuesta estará disponible en línea hasta el próximo 24 de noviembre.

Cordialmente,

LUIS FERNANDO RAMIREZ H.

Vicerrector de Investigación y Transferencia

Universidad de La Salle

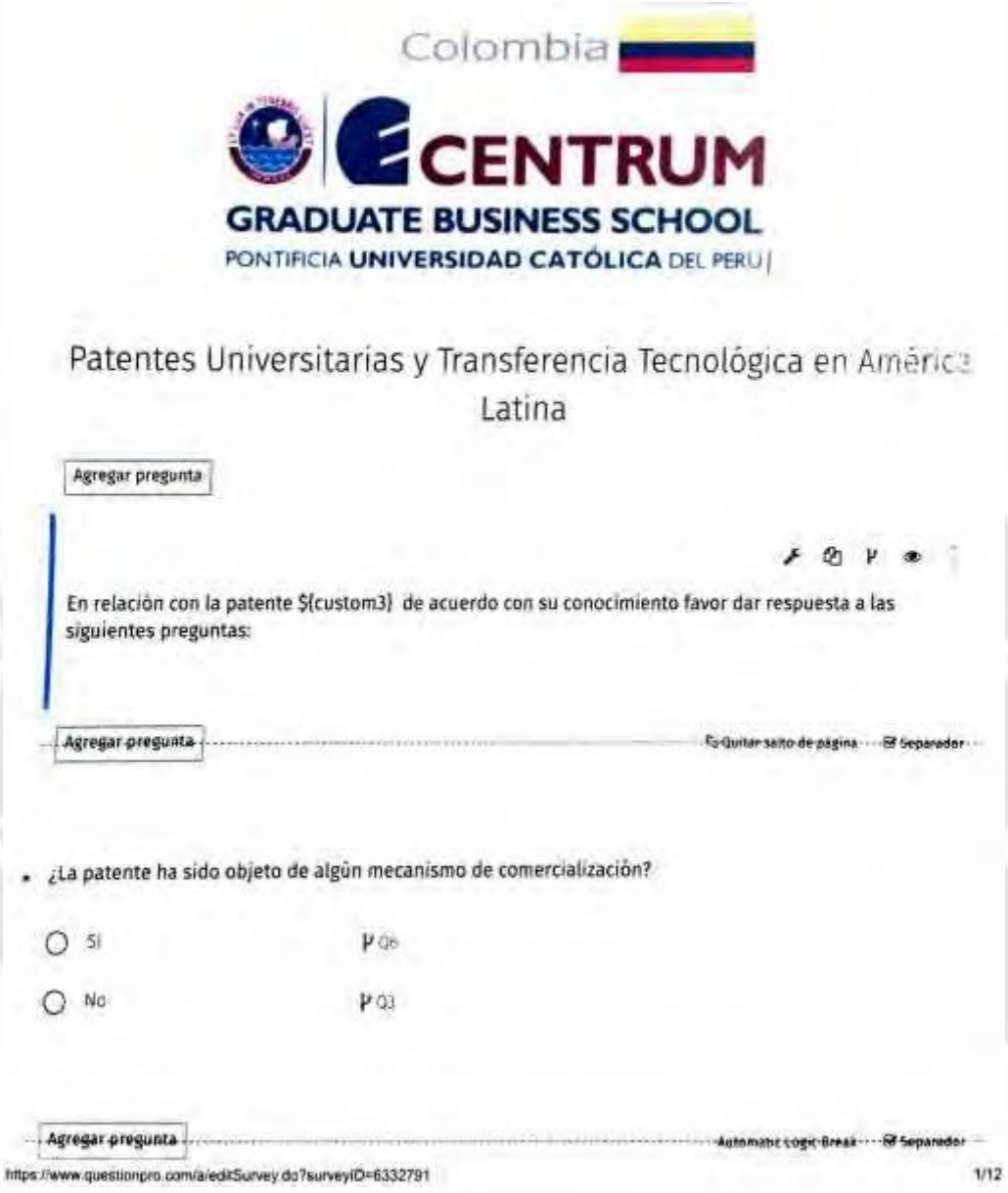
lramirez@lasalle.edu.co

Se deja constancia de que la información obtenida mediante esta encuesta se tratará de forma absolutamente confidencial y solo para fines académicos. Bajo ninguna circunstancia se revelará la identidad del encuestado. Asimismo, nos comprometemos a que los datos se presentarán de forma agregada y no se ofrecerán resultados que permitan deducir la información aportada por cada Universidad.

<SURVEY_LINK>

Muchas gracias por su tiempo

Appendix B. Survey form



Colombia

CENTRUM
GRADUATE BUSINESS SCHOOL
PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ

Patentes Universitarias y Transferencia Tecnológica en América Latina

Agregar pregunta

En relación con la patente ${custom3} de acuerdo con su conocimiento favor dar respuesta a las siguientes preguntas:

Agregar pregunta ---- Quitar salto de página ---- Separador

- ¿La patente ha sido objeto de algún mecanismo de comercialización?

○ SI

○ No

Agregar pregunta ---- Automatic Logic Break ---- Separador

https://www.questionpro.com/a/editSurvey.do?surveyID=6332791 1/12

* **Atendiendo a la variable "Cercanía al Mercado", a nivel de su institución los siguientes factores en qué grado de importancia han impedido que esta patente haya sido comercializada**

	Sin importancia	De poca importancia	Moderadamente importante	Importante	Muy importante
¿Falta de un adecuado análisis del mercado?					
¿Débiles estrategias para divulgar esta innovación?					
¿Insuficientes mecanismos de comercialización?					
¿Falta de contratos de investigación previos con la industria relacionada?					
¿Baja interacción de los investigadores con las empresas o con entidades gubernamentales?					
¿Falta de contratos previos de consultoría o de asistencia técnica con la industria?					
¿Poca cooperación de las empresas con los grupos de investigación de la Universidad?					
¿Falta de convenios para prácticas empresariales o pasantías de los investigadores?					

Agregar pregunta | Insertar salto de página | Separador

- **Atendiendo a la variable "Ambiente de Innovación", a nivel de su institución los siguientes factores en qué grado de importancia han impedido que esta patente haya sido comercializada**

	Sin importancia	De poca importancia	Moderadamente importante	Importante	Muy importante
¿Falta de políticas en materia de Propiedad Intelectual en la institución?					
¿Baja dinámica o inexistencia de una Oficina de Transferencia Tecnológica?					
¿Escasa experiencia del inventor en el campo del emprendimiento?					
¿Bajo compromiso del inventor con los procesos de comercialización de la patente?					
¿Escasos vínculos del inventor con la industria relacionada?					
¿Bajo grado de originalidad o novedad de la tecnología?					
¿Necesidad de más desarrollo técnico de la patente antes de su comercialización?					
¿Existencia de requisitos normativos o éticos que dificultan la aplicación de esta invención?					

Agregar pregunta ..... Agregar salto de página ☑ Separador

- Atendiendo a la variable "Aspectos Financieros", a nivel de su institución los siguientes factores en qué grado de importancia han impedido que esta patente haya sido comercializada

	Sin importancia	De poca importancia	Moderadamente importante	Importante	Muy importante
¿Dificultades de acceso a más fondos de la Universidad?					
¿Falta de financiamiento de la industria para aplicar la innovación?					
¿Falta de un adecuado Plan de Negocios?					
¿Baja oferta de capitales de riesgo o fondos de capital semilla para el desarrollo de la patente?					

Agregar pregunta ⎘ Salto de página ☑ Separador

- Autorizo a que esta información sea utilizada de forma exclusiva para la investigación titulada: University Patents and Technology Transfer in Latin America: Determinant Factors for Licensing and Creating Spin-offs (CENTRUM Católica, PUCP)

◯ Si ⤵ Thank You Page

◯ No ⤵ Terminate

Agregar pregunta ..... Automatic Logic Break ☑ Separador

- La patente ha sido comercializada mediante cuál de los siguientes mecanismos:

  - ○ Licenciamiento
  - ○ Creación de una empresa Spin-Off
  - ○ Otro

Agregar pregunta ---- Automatic Logic Break ---- Of Separador

- Atendiendo la variable "Cercanía al Mercado", A nivel de su institución los siguientes factores en qué grado de importancia determinaron escoger el licenciamiento como mecanismo de comercialización para esta patente

	Sin importancia	De poca importancia	Moderadamente importante	Importante	Muy importante
Existencia de estudios de mercado					
Diseño de estrategias para divulgar esta innovación					
Proximidad geográfica con los usuarios de la tecnología					
Contratos de investigación previos con la industria relacionada					
Interacción de los investigadores con las empresas o con entidades gubernamentales					
Contratos previos de consultoría o de asistencia técnica con la industria	Sin importancia	De poca importancia	Moderadamente importante	Importante	Muy importante

Cooperación de las empresas con los grupos de investigación de la Universidad

Existencia de convenios para prácticas empresariales o pasantías de los investigadores

Agregar pregunta | Agregar salto de página | Separador

- **Atendiendo la variable "Ambiente de Innovación", a nivel de su institución los siguientes factores en qué grado de importancia determinaron escoger el licenciamiento como mecanismo de comercialización para esta patente**

	Sin importancia	De poca importancia	Moderadamente importante	Importante	Muy importante
Políticas definidas en materia de Propiedad Intelectual en la institución					
Existencia de una Oficina de Transferencia Tecnológica					
Experiencia del inventor en el campo del emprendimiento					
Compromiso del inventor con los procesos de comercialización de la patente					
Vínculos del inventor con la industria relacionada					
Grado de originalidad o					

novedad de la tecnología

Nivel de desarrollo técnico de la patente

Grado de aplicabilidad de la invención

Agregar pregunta — Quitar salto de página — Separador

- **Atendiendo la variable "Aspectos Financieros", a nivel de su institución los siguientes factores en qué grado de importancia determinaron escoger el licenciamiento como mecanismo de comercialización para esta patente**

	Sin importancia	De poca importancia	Moderadamente importante	importante	Muy importante
Acceso a más fondos de la Universidad					
Financiamiento de la industria para aplicar la innovación					
Existencia de un Plan de Negocios					
Disponibilidad de capitales de riesgo o fondos de capital semilla para la comercialización de la patente					

Agregar pregunta — Quitar salto de página — Separador

- Autorizo a que esta información sea utilizada de forma exclusiva para la investigación titulada: University Patents and Technology Transfer in Latin America: Determinant Factors for Licensing and Creating Spin-

Offs (CENTRUM Católica, PUCP)

○ Si

○ No

Agregar pregunta ---- Automatic Page Break ---- Separador

- **Atendiendo a la variable "Cercania al Mercado", a nivel de su institución los siguientes factores en qué grado de importancia determinaron escoger la creación de una empresa Spin-Off como mecanismo para la comercialización de esta patente**

	Sin importancia	De poca importancia	Moderadamente importante	Importante	Muy importante
Existencia de estudios de mercado					
Diseño de estrategias para divulgar esta innovación					
Proximidad geográfica con los usuarios de la tecnologia					
Contratos de investigación previos con la industria relacionada					
Interacción de los investigadores con las empresas o con entidades gubernamentales					
Contratos previos de consultoria o de asistencia técnica con la industria					
Cooperación de las empresas con los grupos de investigación de la Universidad					

Sin importancia De poca importancia Moderadamente importante Importante Muy importante

Existencia de convenios para prácticas empresariales o pasantías de los investigadores

Agregar pregunta ... Contar salto de página ... Separador

- **Atendiendo a la variable "Ambiente de Innovación", a nivel de su institución los siguientes factores en què grado de importancia determinaron escoger la creación de una empresa Spin-Off como mecanismo para la comercialización de esta patente**

	Sin importancia	De poca importancia	Moderadamente importante	Importante	Muy importante
Políticas definidas en materia de Propiedad Intelectual en la institución					
Existencia de una Oficina de Transferencia Tecnológica					
Experiencia del inventor en el campo del emprendimiento					
Compromiso del inventor con los procesos de comercialización de la patente					
Vínculos del inventor con la industria relacionada					
Grado de originalidad o novedad de la tecnología					
Nivel de desarrollo técnico de la patente					
Grado de aplicabilidad de la					

invención

Agregar pregunta — Quitar salto de página — Separador

- Atendiendo a la variable "Aspectos Financieros", a nivel de su institución los siguientes factores en qué grado de importancia determinaron escoger la creación de una empresa Spin-Off como mecanismo para la comercialización de esta patente

	Sin importancia	De poca importancia	Moderadamente importante	Importante	Muy importante
Acceso a más fondos de la Universidad					
Financiamiento de la industria para aplicar la innovación					
Existencia de un Plan de Negocios					
Disponibilidad de capitales de riesgo o fondos de capital semilla para la comercialización de la patente					

Agregar pregunta — Salto de página — Separador

- Autorizo a que esta información sea utilizada de forma exclusiva para la investigación titulada: University Patents and Technology Transfer in Latin America: Determinant Factors for Licensing and Creating Spin-Offs (CENTRUM Católica, PUCP)

○ SI — Thank You Page

○ NO — Terminate

Agregar pregunta ..... Automatic Logic Break Separador

- ¿Cuál fue el tipo de mecanismo utilizado?

Fila de texto respuesta multiple

Agregar pregunta Salto de página Separador

- Autorizo a que esta información sea utilizada de forma exclusiva para la investigación titulada: University Patents and Technology Transfer in Latin America: Determinant Factors for Licensing and Creating Spin-Offs (CENTRUM Católica, PUCP)

  ○ Si

  ○ No

Agregar pregunta Salto de página Separador

Editar pie de página Página de Agradecimiento

Appendix C. Research Proposal PPT Presentation

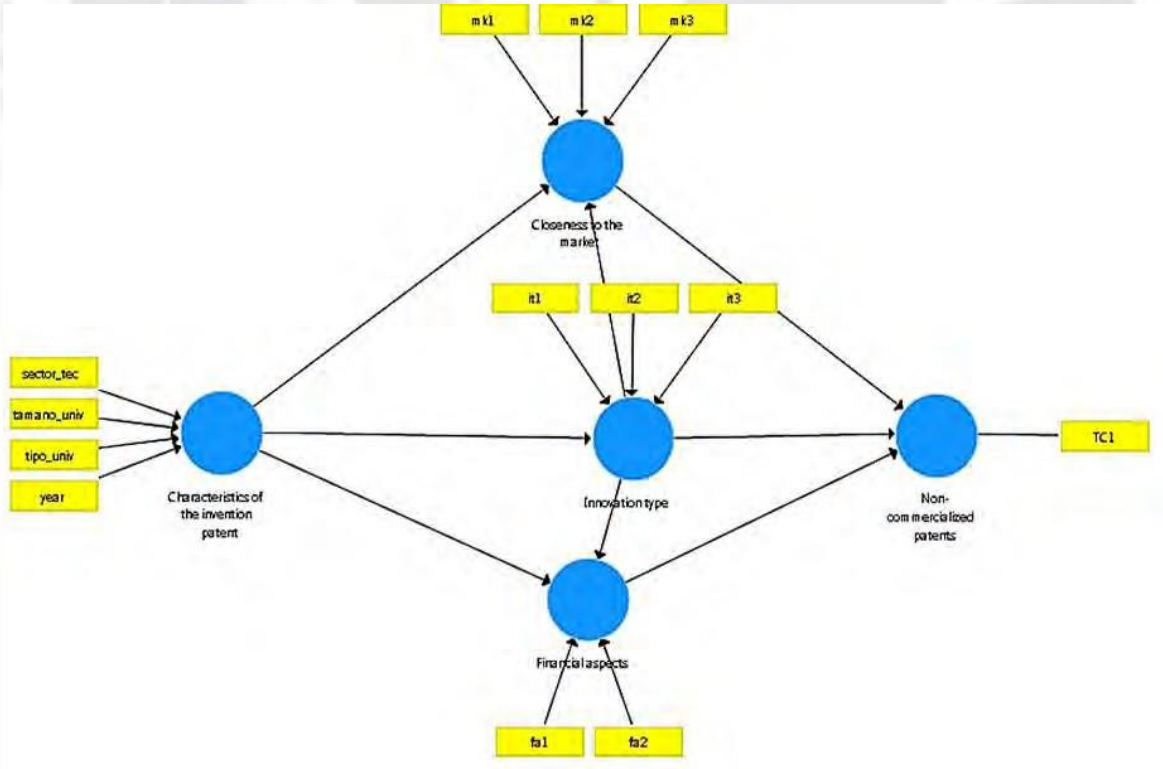
University Patents
and Technology Tra

Appendix D. Thesis PPT Presentation

PPT DBA Thesis -
Luis Fernando Rami

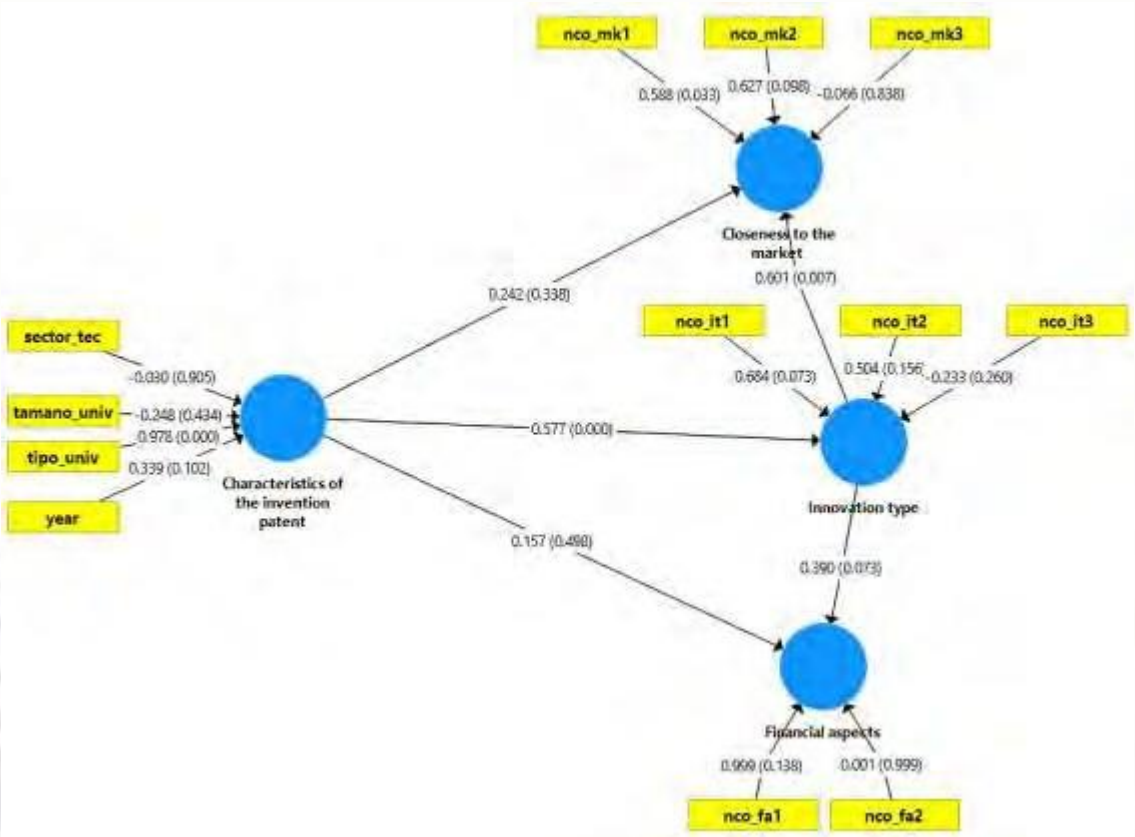
Appendix E.

PLS Trajectory model for non-commercialized patents



Appendix F

Trajectory coefficient and p-values of the structural model obtained by bootstrapping



Appendix G:

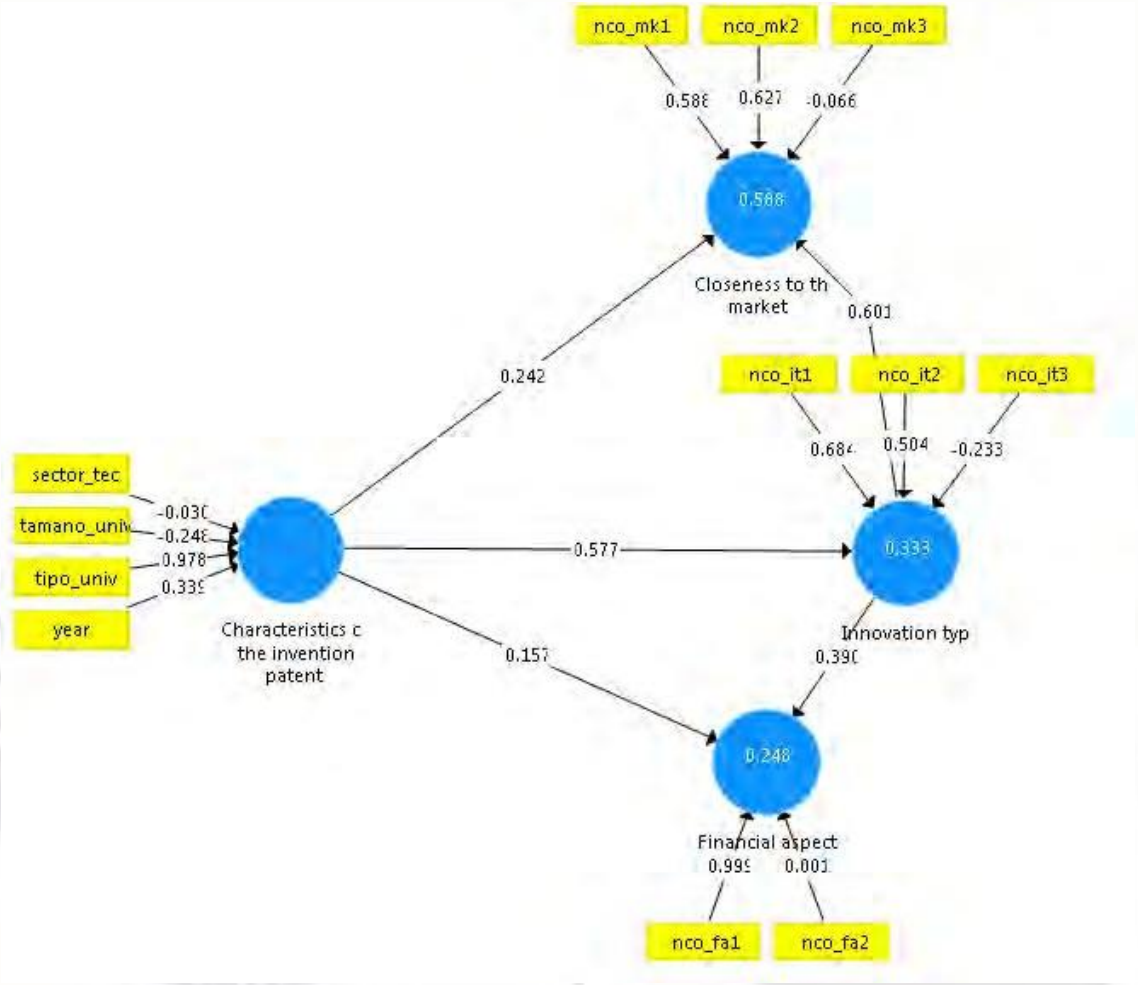
Values R^2 of the Endogenous Variables

	R Square	R Square Adjusted
Closeness to the market	0,588	0,569
Financial resources	0,248	0,213
Innovation type	0,333	0,318

Source*:* PLS – SEM

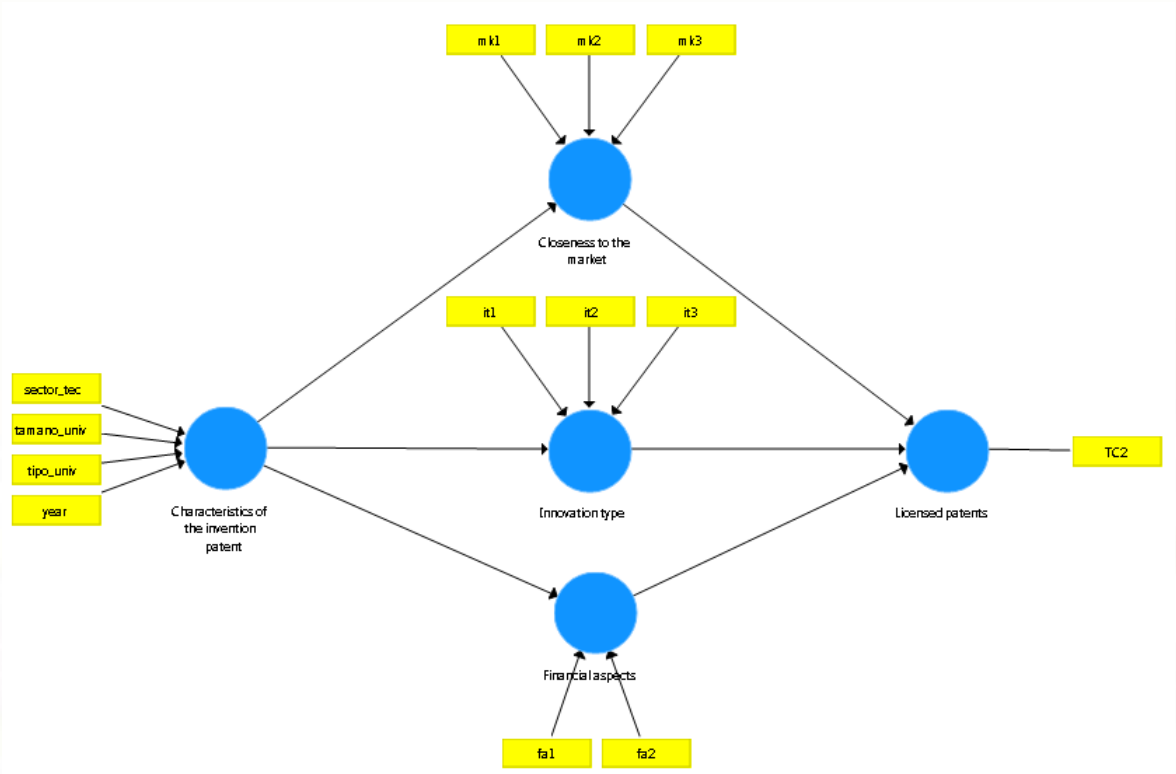
Appendix H

Model calculation for non-commercialized patents



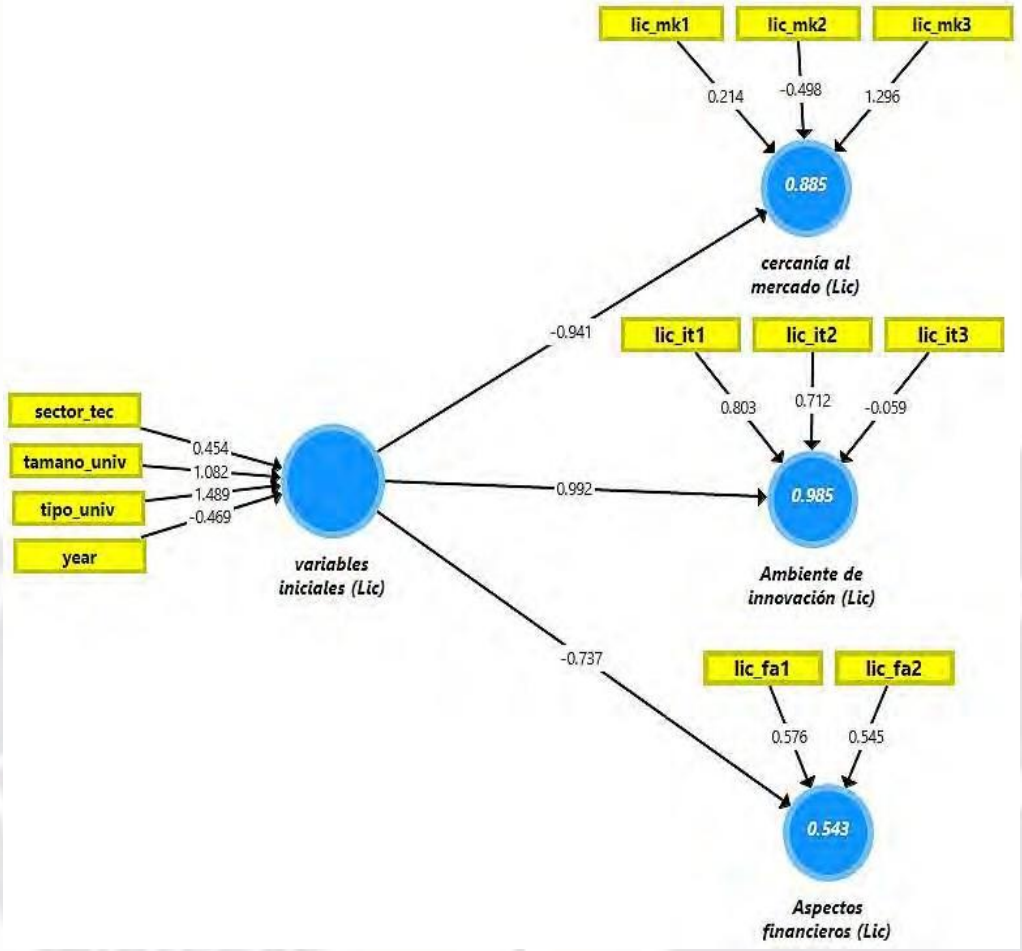
Appendix I

PLS Trajectory model for commercialized patents through licensing



Appendix J

Model calculation for commercialized patents through licensing



Appendix K

Values R^2 of the Endogenous Variables

	R Square	R Square Adjusted
Innovation type (Lic)	0,985	0,982
Financial resources (Lic)	0,543	0,466
Closeness to the market (Lic)	0,885	0,865

Source: PLS – SEM