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Acknowledgements.

This work summarizes a wonderful time of my life.

This section to be completed with no rush, and a bit of inspiration…..

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ABSTRACT

Scientific and technological knowledge as well as innovation capacities are elements that contribute to increase national productivity and wellness of societies, it has been considered impulse of economic growth and could explain at least a part of economic development of the countries. The use of patent statistics are often used as a proxy of innovation.

Innovation studies have been made since the earlies 1900, but in this dissertation the role of individuals as inventors is to be explored to the Mexican case. Little or no work has been found in this specific subject. This is interesting as the generation of new ideas that can make some impact in society as new products or processes have positive effects in our nation’s economic development and contribute to social welfare in benefit of Mexican population.

We have focused on the human factor of patent applications, the inventors' field, in order to acknowledge Mexican inventive wherever it is found. This is novel and we consider it to be of interest to academics, policy makers and inventors.

As it can clearly be seen, science, technology and innovation are hot topics in Mexico nowadays. And although the politic mechanism is working to produce adequate policy that impulse this sector, there are not specific studies that can give a complete panorama on the state of the matter in the country apart from that made in the diagnostic section of PECYTI

This dissertation focuses on the technological and innovation capacities shown by Mexicans as inventors. The analysis is on PCT patent filings, as they denote strong interest in commercialization of the inventions and have endured international search to ensure the principles of originality, novelty and utility. With this, the document tries to characterize one of the activities that can promote regional sustainable and inclusive development, the degree of technology transfer and usage, and the linkage between academic and other sectors (in matter of new knowledge production).

The analysis begins with a general comparison on patenting activities between three Latin American countries: Brazil, Chile and Mexico. These countries are members of the Patent Cooperation Treaty (PCT), but entered the treaty on very different stages. Brazil began its participation early, in 1975 (PCT was adopted june 1970) being one of the first countries to of the treaty until 2009. Our findings reveal a strong influence of the PCT in Mexico and Chile, but none on the Brazilian case.

Then the special case of Mexico is studied in detail, taking into account the Mexican inventors, rather than patent holders. This decision was made given the proportion of Resident/Non-resident patent applicants, and with the interest of the human factor of the patenting process. This is novel and we thing of great interest to understand the inventive of Mexicans in whichever economic sector they are. There are few studies regarding inventors, and the ones found are centered on either a specific technological branch, or a given country (most of them from the European

Community). Therefore, a profound study on Mexican inventors is pertinent and interesting.

Inventors' analysis was gender desegregated in order to cover gender issues in one of the activities considered to be pillar of innovation. This is strongly recommended by international organizations such as the United Nations and the OECD, and responds to the fact that both international and national development plans and studies have a transversal axis for gender studies.

The last third of the dissertation corresponds to a collaboration study of the academic patents filed by Mexican institutions. Collaboration networks were constructed using the Agnas specialized software.

Finally some conclusions are drawn from the whole study, and further work is established. The subject is rich and complex, and other studies might arise from it. We hope this dissertation helps understand the inventive process for Mexican inventors and help to establish direction on public policy that gives impulse to patenting activities.

Chapter 1. Introduction

1.1 Justification and objectives

Mexican Science has been explored throughout the time using essentially bibliometric approaches to the researchers' publications in mainstream journals either electronic or printed and books. However, there is a portion of science that escapes traditional evaluation and metrics.

The use of patent statistics are often used as a proxy of innovation and even in the OECD Oslo Manual (2006) measurement of patent applications and granted patents is included. Patents serve as a legally based monopoly of the exploitation of inventions, and may be used as a knowledge repository for future developments, as well as indicators of known knowledge of enterprises or even countries (Frietsch et al., 2009; Frietsch and Schmoch, 2006; Schmoch and Hinze, 2004).

Therefore, the study of patents granted or patent applications as a complimentary analysis is not only desirable but in fact necessary to understand the part of the scientific apparatus producing science and technology that could and should make an impact society.

There are some important limitations when studying patent documents. First of all, the fact that many inventions are not patented, some are protected by other forms of IP (Intellectual Property) such as industrial secrecy, utility models or industrial designs. In some technology areas, such as computing and electronics, advancements happen so fast that most of the innovations are not patented before applied, the time for granting a patent is bigger than the time taken for the next advancement to be already in the market. In some countries the IP culture is not well developed or respected, so many inventions are not protected.

There have been some studies on the Mexican patent office (IMPI, acronym for the Spanish Instituto Mexicano de la Propiedad Intelectual) with emphasis on patents granted to foreign or national residents (patent holders), or over the American database (USPTO) in very specific areas, but we have not found evidence of studies made using an international database in a broad spectrum of areas. There has not been found an extensive literature on this subject, especially within developing countries, and particularly for Mexico.

We have focused on the human factor of patent applications, the inventors' field, in order to acknowledge Mexican inventive wherever it is found. This is novel and we consider it to be of interest to academics, policy makers and inventors.

The specific objectives to this dissertation are:

- Comparison of patenting activities in Mexico, Brasil and Chile in the period comprehending the inclusion of each country to the Patent Cooperation Treaty (PCT) and up to date.
- Determination of whether the adhesion to the TCP is determinant to impulse patenting activities in each of the countries compared.
- Desegregated analysis of Mexican inventors by gender, technological areas, sector of adscription from 1995 to 2015.
- Co-authorship study for Mexican inventors.
- Collaboration analysis between Academy and Industry in patent applications where Mexican inventors participate.

Research questions include:

- How does Mexican patenting activities compare with those from Brazil and Chile?
- Can we establish a relationship between adhesion to the PCT international treaty and a significant impulse of patenting activities in Mexico, Brazil and Chile?

- Can we establish indicators for gender dimensioning the patenting activities of Mexican inventors?
- Which Mexican academic institutions have a collaboration policy in terms of patent filing?

The dissertation contribution to the knowledge on innovation studies resides on the quantitative analysis of patent applications that would be exploited in a vast number of member countries of the PCT (and therefore have a true purpose of commercialization) with focus on the human element of patenting activities.

We haven´t found patent statistics concerning Mexican inventors in the literature, nor gender desegregated statistics about them. This is valuable information for academic groups interested in the gender/innovation relationship, but also to decision makers in government, industry and academy that have stated de necessity to incorporate women in all kind of productive and creative processes in their yearly, sexennial or long term objectives.

Finally, we want to make a precedent study to compare patenting activities today in our country, with those in future years when changes in Science, Technology and Innovation Legislation reflect positive or negatively in the development of the Nation.

1.2 Importance of Innovation Studies

Scientific and technological knowledge as well as innovation capacities are elements that contribute to increase national productivity and wellness of societies, it has been considered impulse of economic growth and could explain at least a part of economic development of the countries (Schumpeter, 1911; Cozzarin, 2006).

International experience has continuously shown that in a global and intercommunicated global environment as the one we live today, development of countries is increasingly based on their capacity to generate, adopt and transfer knowledge. These activities allow production of new ideas and products to face modern challenges concerning economic, social, ecological and medical challenges we face nowadays. Though the countries promoting and taking them to action have achieved higher levels of competitiveness and have provided their society with weapons to face modern life problems with technology based solutions.

Knowledge and information are nowadays the force to impulse competitiveness and development at short or long term, according to the theory of the construction of Knowledge Economy. If Mexico wants to be part of this global tendency, the country's efforts should be put into science, technology and innovation (PECYTI, 2014)

Innovation studies have been made since the earlies 1900, but in this dissertation the role of individuals as inventors is to be explored to the Mexican case. Little or no work has been found in this specific subject. This is interesting as the generation of new ideas that can make some impact in society as new products or processes have positive effects in our nation's economic development and contribute to social welfare in benefit of Mexican population (CEPAL, 2008; Romer, 1990).

1.3 Innovation policy

A national science, technology and innovation system (NSTIS) is formed by "each and any part and aspect of the economic structure, as well as by the institutional establishment affecting learning, acquisition and knowledge exploitation" (Lundvall, 1985).

Studying knowledge producers (companies or institutions) and their research products (publications, patents, and benchmarks) can as well serve to understand how well NSTIS promote interactions between actors that constitute them.

The role of the Government as a key factor for the NSTIS to work is undeniable (Niosi et al, 1993), as it provides funds, develops a great amount of research and development activities (R&D) in a country through Public Research Organizations (Hereafter PROs) such as state owned universities, national institutes or research centers, and because it is the responsible entity to dictate, adopt and implement technological strategies, intellectual property laws, education policies and information activities.

According to OECD (2007), government must:

- Support the creation of human capital through sustained investment in education and training both from public and private sources.
- Set framework conditions that are conducive to innovation. Some, such as well-functioning markets, sound corporate governance and financial institutions, may not be specifically aimed at fostering innovation but may have a significant impact. Others, such as the legal protection of intellectual property rights, direct financial support, tax incentives for R&D, and the setting of technological standards, may have a more direct effect on innovation.
- Develop and implement policies to encourage science, technology and innovation in the presence of market or systemic failures, such as provision of financial support for R&D.

Private companies and institutions such as universities, laboratories, state corporations and government agencies that coordinate, fund create and spread new technologies have the essential role ok knowledge producers (Nelson, 1993).

OECD has made periodic reviews on the state of development of its country members, including Mexico. In their Review of innovation policies (2008) it is stated that Mexico has made a “significant progress towards macroeconomic stability” opening the economy further to (foreign) trade and investment although living standards of Mexicans are not comparable with wealthier OECD countries. This is explained in the document as a consequence of the slow reaction of public and private Mexican decision makers to the need of investing in innovation as a driver of growth and competitiveness. This is of course a delicate subject. The failure to promote competitiveness in knowledge based activities can be chronic as it leads to weak innovation capabilities thus limiting the capability of taking advantage of technological spillovers from international firms or individuals in the country.

The NSTIS in Mexico has been organized and maintained by the National Council of Science and Technology (CONACYT) and the Ministry of Economy. These entities coordinate and promote scientific, technological and innovation activities within PROs and enterprises. There are also local state councils although they do not have sufficient funding to develop the necessary R&D projects. (Solleiro, 2010). The main institutions involved in R&D activities are CONACYT research centers, federal institutes and Universities that mainly depend on federal budget.

The documents in which objectives and strategies to achieve progress on science, technology and innovation that Mexico will follow are the recently reformed Law of Science, Technology and Innovation, as well as the Special Science and Technology Program (PECYTI, 2014). These documents, prepared by the Government in conjunction with academics and experts, have the purpose of establishing priorities and public policy in order to achieve the inclusion of our country in the global "Knowledge Society", in which production, distribution and intensive use of knowledge and information are the everyday working basis.

According to PECYTI (2014), Mexican NSTIS has the following actors and elements:

- Public policy for Science, Technology and Innovation (ST&I) defined by the General Council of Scientific Research, Technological Development and Innovation.
- PECYTI and other regional programs (concerning ST&I)
- Legal, administrative and economic instruments that support research, development and innovation (RD&I)
- Federal Public agencies involved in scientific research, technological development, innovation or support any of those activities , as well as public or private institutions and local governments through coordination, participation and linkage between actors
- The National Network of Research Centers, and scientific activities of universities

Performance of innovation systems rely not only on existing and dedicated policies that promote ST&I, but also on the generalized belief of the importance of investments on this sector and effective budget allocation. The policy implementation and observance of its correct management is important as well. Innovation systems must be flexible to the changes institutions and actors face over time and they must incentivize businesses, firms and institutions to innovate. An environment with fair competition and strong respect to intellectual property (IP) is essential for an innovation system to grow. Finally, the physical infrastructure of information technologies and communications in the country is the vehicle in which creation and distribution of knowledge and knowledge based development is to be made, managed by human capital with the correct academic profile and high skills.

To illustrate the fact that public policy can actually shape the ways a certain sector of the society works and relates to the other sectors, we propose the reading of Annex A, which is an original research article to be published in Revista Mexicana de Física, and studies the decentralization process of the community of physics' researchers in México.

1.4 The National Development Plan (PND, Spanish acronym for Plan Nacional de Desarrollo), the Special Program on Science, Technology and Development (PECYTI, Spanish Acronym for Programa Especial de Ciencia Tecnología e Innovación) and our study

PECYTI is a special program described in Article 3 of the Federal Law of Science and Technology. This program is one of the pillars of the Mexican NSTIS. It is updated every three years although a long term vision of the policies and objectives described in it have to envision a long term application.

PECYTI has a direct relation with NDP of the current government that states in Objective 3.5 that Mexico must "Make scientific and technological development, as well as innovation, pillars for sustainable economic and social progress" (PND, 2013).

Strategies defined to accomplish this specific objective of the Mexican government include (PECYTI, 2014):

- Making the national investment on scientific research and technological development grow annually to up to 1% of GDP
- Creation and consolidation of high level human capital
- Promoting regional sustainable and inclusive development by giving impulse to scientific technological and innovation local capacities
- Contribute to transfer and use of technology, by linking academic sector with other sectors (private and/or public)
- Strengthen the scientific and technologic infrastructure around the country.

As it can clearly be seen, science, technology and innovation are hot topics in Mexico nowadays. And although the politic mechanism is working to produce adequate policy that impulse this sector, there are not specific studies that can give a complete panorama on the state of the matter in the country apart from that made in the diagnostic section of PECYTI (2014).

Existence of inventors and researchers in a country is often linked to education levels, specifically to postgraduate studies (masters, PhDs and specialties) and to technological capacity building (Lucas, 1988), and to that extent the 2nd objective in PECITY (and the PND) becomes highly relevant. The more resources are dedicated to preparation of masters and PhDs and their incorporation to economic life in the country, the better prepared and specialized in terms of technological capacities the scientific and technological apparatus will be (Becker, 1975; Blundell et al., 1999).

This dissertation focuses on the technological and innovation capacities shown by Mexicans as inventors. The analysis is on PCT patent filings, as they denote strong interest in commercialization of the inventions and have endured international search to ensure the principles of originality, novelty and utility. With this, the document tries to characterize one of the activities that can promote regional sustainable and inclusive development, the degree of technology transfer and usage, and the linkage between academic and other sectors (in matter of new knowledge production).

1.5 Innovation indicators

There are commonly used indicators to assess the nation's scientific performance. Many of them are based on inter-country comparison of publications and citations of papers published by researchers on mainstream journals. Others analyze publications or citations in relation to the countries expenditure on S&T (Science and Technology) related activities. We have found in the literature several studies in these directions, mainly focused on European countries. However, in González-Brambila et al. (2016), the analysis is performed on developing countries (Argentina, Brazil, China, India, Mexico, Poland, South Africa and Turkey). The indicators shown in this paper consider R&D investment as the input, and citations as a measure of scientific impact.

- Gross domestic spending on R&D (GERD) is defined as the total expenditure on R&D carried out by all resident companies, research institutes, university and government laboratories, etc., in a country. This indicator is measured in million USD and as percentage of GDP. Proportion between GERD/GDP is an international indicator to measure expenditure of a government in R&D related activities. This indicator permits to establish the degree in which the development of a given country is based on R&D. Developed countries allocate between 1.5 and 3.8% of their GDP to GERD, while Mexico ranges in around 0.5% (OECD, 2016).

- Another important indicator is proportion given to GERD by government and private sectors. In Mexico the highest proportion corresponds to the Government with 73.6% (OECD, 2016bis).

- Human capital. The number of high qualified professionals is important to establish the potential of technological absorption and development of new technologies. Mexico has implemented two basic strategies for the constitution of human capital: giving scholarships in universities in the country and in other countries, and reinforcement of postgraduate degrees in Public Research Centers and universities (PECITY, 2014)

- Number of researchers per 1000 habitants. This indicator is useful to analyze the degree in which people tend to adopt scientific careers and are dedicated to R&D activities. The National Researchers System (SNI for its Spanish acronym) was created in 1984 with the main objective of evaluating and promoting researchers with high productivity. The system has been determinant in the academic profession and has helped to standardize national research with international levels. Human capital in the SNI are considered the scientific nucleus of Mexican research. Up to the last OECD (2016bis) report, Mexico counts 38,823 full time equivalent researchers.

- Number of publications in indexed journals. This is by far the most used indicator in terms of evaluation of scientific productivity. Although publication among Mexican researchers has increased year by year, productivity levels are low compared to developed countries.

- Patents filed and/or granted to national residents.

1.6 The power of invention as a pillar of innovation

It is common to think that inventions and innovations are the same, but let us not be mistaken, they are not. Inventions are ideas that translate to new devices, methods or processes that occur to someone, while innovations, according to the OECD Oslo Manual (2006) "is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations". To include the invention (idea) in the innovation definition, the Product Development and Management Association (Belliveau, 2004) establishes the innovation is "a new idea, method, or device. The act of creating a new product or service. The act includes invention as well as the work required to bring an idea or concept into final form". As it is clearly seen, there are no innovations without the ideas and of course without inventors.

This is the main reason for studying the inventors' information given in PCT patent applications, and although the task is cumbersome (as these data have to be revised opening the full document of each of the patent applications), the conclusions that can be drawn from it are important and would be of special interest for the academic community wishing to extract the human factor out of the patent indicators. This also applies for institutions willing to establish connections with the inventors, or the government offices in charge of the promotion of ST&I.

There are several factors that affect the predisposition for inventing and innovating in a country. Some of these are:

To create an environment that promotes innovation, with an articulated National Innovation System, it is needed to have a strong IP system. This would promote the existence of inventors willing to commercialize their inventions and create new knowledge (Metcalfe, 1995; Furman et al., 2002, Niosi, 2002).

Taking this into account, studies regarding the strength of Mexican IP system and culture result relevant. In the present dissertation only PCT patent filings are analyzed, although other IP figures such as trademarks, industrial designs and utility models might be of interest too.

Chapter 2. Patent data as an approximation to innovation studies

Patents are one of the oldest forms of intellectual property protection. These instruments intend to encourage economic and technological development by rewarding intellectual creativity (in the form of inventions). A patent is a document by which a government (via a patent office) describes an invention and gives its owner the right for retribution when this invention is commercialized (by himself or by others given the owner's previous consent) giving him exclusive rights over his invention for a limited period of time. The intellectual property protection given by a patent title rewards the conception of an invention, and also perfecting it in order to make it technically and commercially possible. This of course promotes the continuous development of new technology that is useful for people.

According to international agreements, patents can be granted to any invention (processes or products) in every technology branch. However there are certain exceptions. Human genes, things that already existed in nature or inventions that may disrupt public order are not patentable (WIPO, 2016). Other non-patentable things are scientific theories, laws or methods used for mental processes or game rules, diagnostic or treatment medical method (Each national office has a set of rules for patentability). Criteria on the patentability of an invention include novelty (the invention has not been created or used before), present an advance on the state of the art of the technical knowledge to which it applies, and applicability (that has some use).

Patent titles are thus an exchange between society (represented by the government that grants the patent) and the patent holder. With the grant of a patent title, the holder gets the right to prevent others use or recreate their invention and the government offers intellectual property protection for a 20 years period (given the holder pays the annual fee to keep this right) and after this period the information relative to the invention is made public, and therefore can be exploited by anyone.

The acronym PCT stands for Patent Cooperation Treaty. It is an international treaty that groups 150 countries in the world. PCT is used when inventors seek patent protection for their invention in more than one country, by filing one single international patent application instead of many separate national or regional patent applications. This treaty is administered by WIPO (World Intellectual Property Organization). However, WIPO does not grant the patents, this is done by the national or regional patent offices in what is called the national phase.

Procedure for filing a TCP patent application takes the following steps (WIPO, 2016):

1. Filing of an international application in a national or regional patent office or in WIPO. The application must comply with the formality requirements found in http://www.wipo.int/pct/en/texts/index.html, in only one language and paying a set of fees.
2. International Search made by an "International Searching Authority" (ISA) to indentify the published patent documents and technical literature that may have influence on whether the invention presented is patentable. The opinion on the invention´s potential patentability is established in a written opinion.
3. International Publication after an 18 month period from the first filing date. When the applications are published, the knowledge they contain is disclosed to the world.
4. Optional Supplementary International Search and International Preliminary Examination, in which a second ISA carries out a second search and an additional patentability analysis on amended versions of the applications.
5. National Phase taking part usually after 30 months from the earliest filing date of the initial application. This is made directly on a national or regional patent office of the countries in which protection is desired.

WIPO, as the authority on international patenting, has established since 1883 (with the Paris Convention) the priority principle in which given the first application filed correctly on one of the countries attached to the PCT, the applicant can ask for intellectual protection in other of the member countries in a period of 12 months counted from the first application date, giving priority over other people claiming protection on the same invention in the same period of time. The complete process can be viewed in Figure 1.

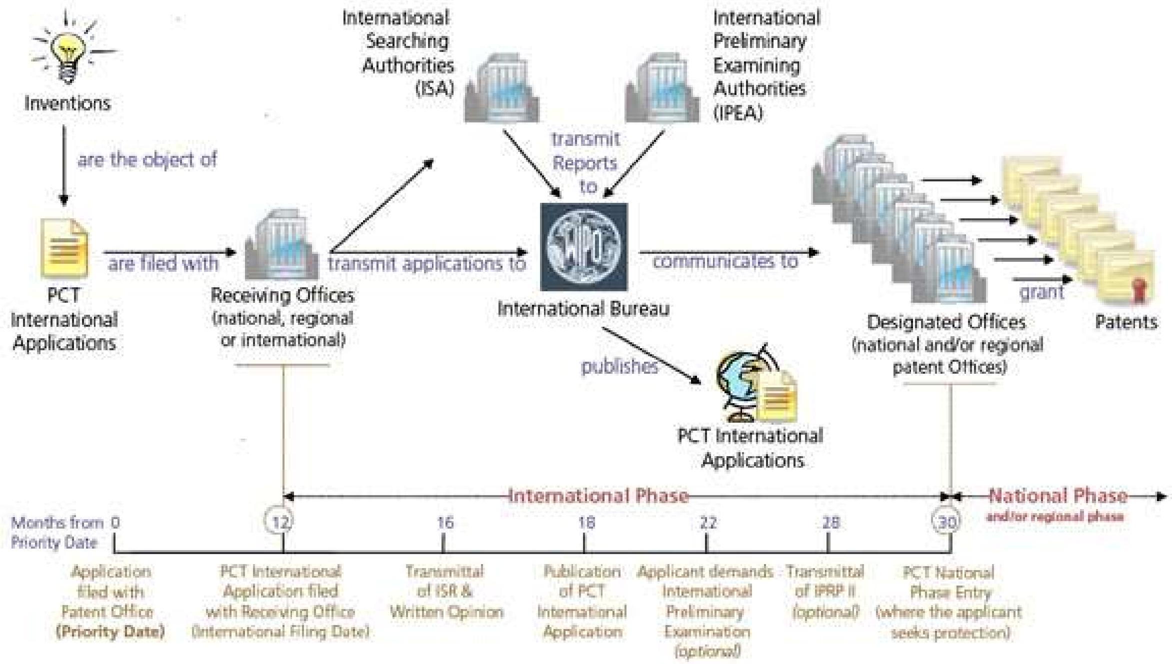


Fig.2.1. The PCT international patent application. Source: WIPO (2016). http://www.wipo.int/pct/en/faqs/faqs.html

2.1 Using patent data as an outcome of scientific and technological activities

There are bibliometric studies that address the determinants of scientific productivity (González-Brambila, 2014; Long, 1990; Marmolejo-Leyva, 2015; Mauleón and Bordons, 2006) in terms of the number of publications in indexed journals either printed or in electronic media. These studies take into account researchers in different countries and in different areas of knowledge and have built a knowledge base on how research products help to make knowledge available. However, there are other research products that have not been taken into account often when measuring the scientific and technological progress. This is the case of the number of patent applications or granted patents generated as a result of either academic or industrial research efforts.

The use of patent statistics as indicators of innovation has been used extensively (Archibugi, 1992; OECD, 1994; Patel and Pavitt, 1995). International organizations such as OECD have developed manuals in order to measure economic progress and innovation (OECD, 2006) that include the measurement of patent applications and granted patents. The importance of the study of patenting activity is based on the fact that patents are obtained for commercialization purposes of the inventions, serve as a legally based monopoly of the exploitation of those inventions, and may be used as a knowledge repository for future developments. Patents are used as indicators of known knowledge of the enterprises or even countries (Frietsch et al., 2009; Frietsch and Schmoch, 2006; Schmoch and Hinze, 2004). There is a vast literature in which patents are thought to be good for the entire world as they promote new scientific and technological applications and serve as catalysts for economy growth (Kieff, 2001; Loise and Stevens, 2010).

Patent applications, especially the ones registered via the Patent Cooperation Treaty (PCT), administered by the World Intellectual Property Organization (WIPO), might give a lot of information about the inventive and innovation activities throughout the world. This dissertation is based on PATENTSCOPE database to analyze patent applications rather than granted patents, partly because of the time elapsed from the publication of an application to the grant of the patent, and also because applications reflect the technological competitiveness of an invention (and granted patents reflect the market strength of the inventor or the market attractiveness of the invention). This is an important tool for technology surveillance and forecasting, used for the research and development process and even for prospective studies of a particular technology.

Other studies in which patent applications or patents granted are counted and analyzed use the United States Patent Office (USPTO) database (Guzmán, 2012; Sugimoto et al., 2015), the Worldwide Patent Statistical Database (PATSTAT) (Frietsch et al., 2009; Toivanen and Suominen, 2015), or even country specific patent databases (Mauleón and Bordons, 2010; Meza-Rodriguez et al., 2015) according to the availability of the databases to the authors and the scope of the research.

It is our special interest the study of Mexican inventors that are listed on the patent applications in the between 1995 and 2015. This period has been chosen because of the addition of México to the PCT in 1995. The addition to an international treaty might result on a great impulse to the patenting activity in every country, so the effects of this public policy should be seen in the posterior years to the inclusion.

Chapter 3. PCT and its effects on patenting activities in Mexico, Brazil and Chile

3.1 Factors influencing the patenting activities

There are several factors that influence the capacity and interest in patenting activities within the people of each country such as education, technological specialization, knowledge spillovers, interaction between basic and applied science, regional or national industry, R&D investment, the intellectual property system, inventors' adscription and mobility, retribution for inventions, special university programs or national public policy.

In terms of education of inventors, it has been found that higher academic degrees and specialization are important for the constitution of an available knowledge repository for inventors and a bigger capacity for knowledge absorption from other countries, from knowledge transfer from academic institutions, international commerce, training, etc. (Hoils, 2009; López, 2008; Zúñiga, Guzmán and Brown, 2007). In other studies (Latham el al., 2012; Whittington and Smith-Doerr, 2008;), it has been found that technological specialization of inventors favors scientific productivity in terms of publications and also incentivizes patent filing. Productivity of inventors also depend on the benefits received for the inventions, whether they are monetary, scholarships, prices or status (Koulopoulus, 2009; Latham et al. 2012).

For the country level, knowledge spillovers are very important. Interaction of agents that constitute de National Innovation Systems strengthens inventive capacities and work as a channel for demand and offer of knowledge products (Itubarría, 2007; Jaffe et al. 1993). When actors are close to one another (geographically and in interests) the presence of universities, research centers, qualified labor force, industries that invest in R&D and local or regional governments are prone to benefit from one another and generate interest in patenting activities (Audretsch and Feldman, 1996). This of course depends on the firms acting as agents, their level of R&D investment to gain competitive advantages (García y Romero, 2010), and of the availability of financial capital (Audretsch and Feldman, 1996; López, 2008; Membribes and Chacón, 2010) to generate, concentrate and share new knowledge (thus generating new technologies).

It is important to be said that frequently technological innovations depends deeply on scientific research (the so called basic science). Many times application of the research products is not immediately used to generate technology, nevertheless every technological development has its basis in science. Thus, it is important that at a country level, "both" sciences (basic and applied) coexist and nurture (Normaler and Verspagen, 2007).

Finally, but not the least important, comes the intellectual property system. Patent promotion and respect of intellectual property promotes investments to generate new inventions, as they ensure returns on the R&D investments and additional benefits from the commercial exploit of the invention. Inventors might perceive profits also as patent holders. Patent systems act also as a knowledge, information and technological advance spreading channel by making public patent applications and granted patent titles inclusive of all the documentation that supports them. To make profit of this, inventors and firms might continuously revise patents concerning their own fields of interest to have knowledge of the state of the art of a given technology and use that information to develop or enhance their own invention.

3.2 Public Policy that shapes the innovative activity of the countries

This factors combined with public policy established by each government, make each country's innovative environment unique. In order to make a comparison between three Latin American countries, we have chosen a particular public policy that has shaped one of the pillars of their innovation systems, the patenting activity in each of them, this is the inclusion to the international Patent Cooperation Treaty (PCT). We have chosen Mexico as our focus of study, and Brazil and Chile for comparison. Entrance of each country to the TCP is very distant in years, thus, we pretended to analyze if this specific policy, intended to homogenize patenting criteria between the members of the Treaty (150 up to date) had a significant impact in their patenting trends.

In table 3.1, the comparison between countries is shown, including the date in which each entered the PCT as active members.

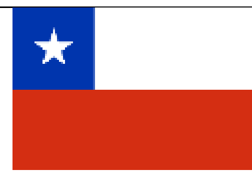
Country	Brasil	Chile	Mexico
Flag			
Entered TCP date	1975	2009	1995
Rank in Global Innovation Index	70	42	57
Population	202 (millions)	17.8 (millions)	123.8 (millions)
GDP per capita	12,525.7 (US$)	19,887.3 (US$)	16,111.5 (US$)

Table 3.1. Data from GII (2015)

Table 3.2 shows the number of PCT patent applications by country. We have taken into account since 1980 (the entry year is marked with green). For Brazil, the early entrance to the PCT (1978) as one of the first member states, WIPO only concentrates historical data from 1980, thus prior PCT filings were not included in the analysis. However, we have found that patenting activities in this country were bounded to the PCT creation and had a low rate of increase until year 1997.

	Brazil	Chile	Mexico
1980	8377	825	5472
1981	8284	836	5997
1982	7678	761	5313
1983	7202	743	4591
1984	6719	707	4459
1985	6519	672	3681
1986	6268	688	3700
1987	7153	729	4251
1988	6884	733	4400
1989	6980	817	4574
1990	7537	811	5061
1991	6944	989	5271
1992	6474	1127	7695
1993	6650	1334	8212
1994	6497	1637	9944
1995	7448	1706	5393
1996	8057	1947	6751
1997	16235	2572	10531
1998	16037	2775	10893
1999	17509	2812	12110
2000	17283	3120	13061
2001	17849	2750	13565
2002	16685	2538	13062
2003	16411	2405	12207
2004	16713	2867	13198
2005	18498	3007	14435
2006	19842	3215	15505
2007	21663	3806	16599
2008	23170	3952	16581
2009	22406	1717	14281
2010	24999	1076	14576
2011	28649	2792	14055
2012	30435	3019	15314
2013	30884	3072	15444
2014	30342	3105	16135

Table 3.2. Patent applications by country. Highlighted in green is the year of inclusion of Mexico and Chile to the PCT. Brazil's entry in 1978 is not shown in the dataset.

Using the same dataset we have constructed the graph for the patent count of each country. This is shown in figure 1. The patent growth for Brazil is considerable, especially in year 1996 where the number of patent applications almost doubled. Mexican and Chilean growth rate is also positive but much lower than the Brazilian, which experienced an important change in 2007, when their economy grew 5.3% according to CEPAL (2007). The highest peak for the three countries has been in 2013, even with economic deceleration in the whole Latin American region CEPAL (2012).

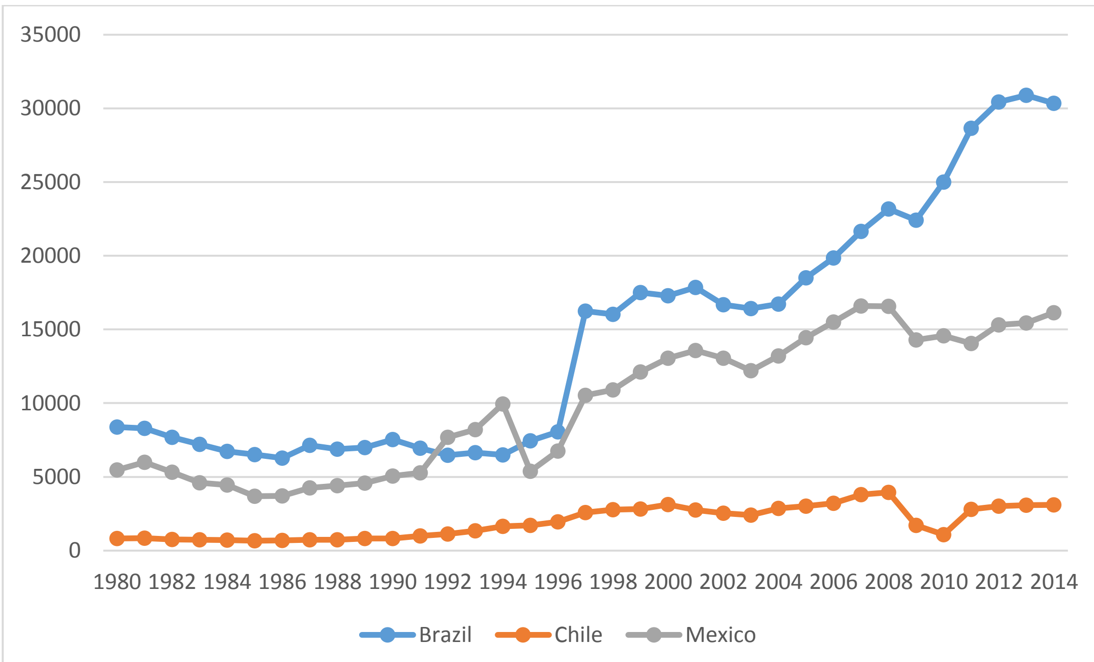


Figure 3.1. Patent applications by country origin of the applicant.

Mexican and Brazilian profiles obey to the world trend shown in figure 3.2, from year 2000 and up to date. Chilean case results interesting while the late entry to the PCT slowed the rate of patent applications growth. Brazil shows a great increase from year 2006, corresponding to the second presidential period of Luiz Inacio Lula da Silva, president of the South American country that gave a strong impulse to Science and Technology and promoted the production of non-fossil fuels such as ethanol for the internal and external market.

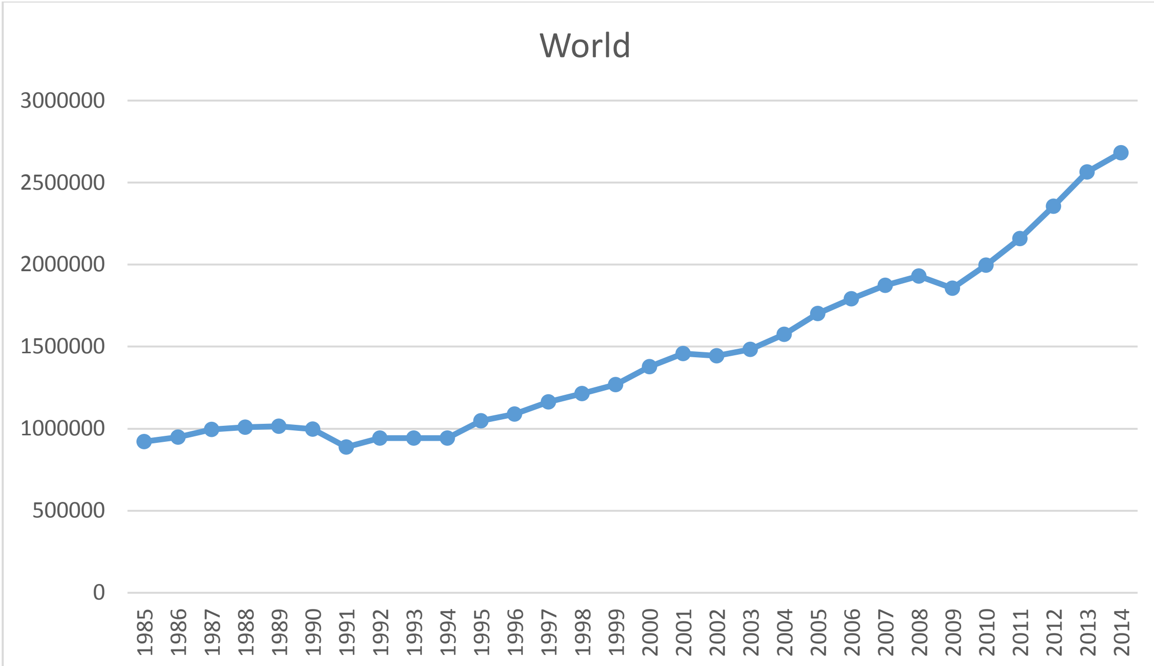


Figure 3.2. World patent applications. Data obtained from http://ipstats.wipo.int

In figure 3.3, the PCT applications for the three country patent offices are compared with the Latin American trend for the period between years 2000 and 2014. Taking this close-up allows us to observe that after the Chilean entry to the PCT, the growth rate in total patent applications (direct and PCT national phase entries) has equaled the Mexican.

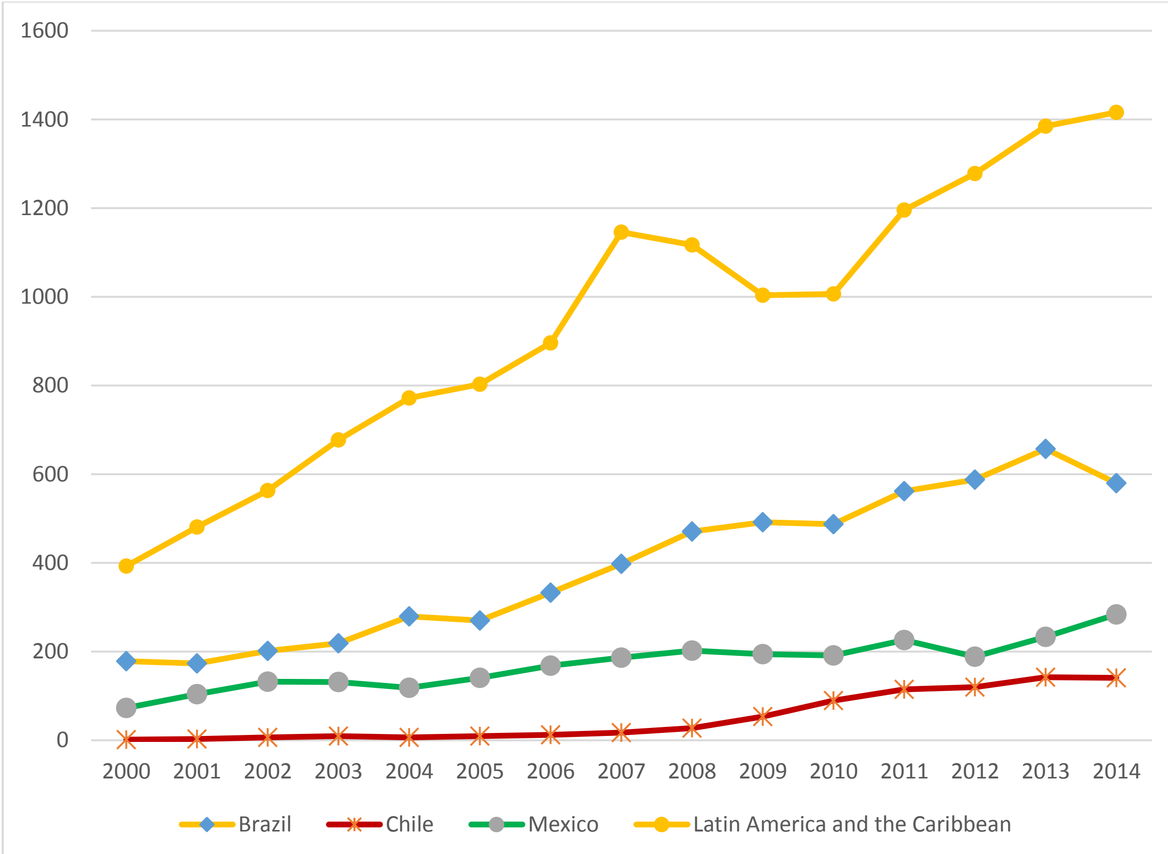


Fig. 3.3. Direct and PCT national phase entries county comparison. Constructed with data from WIPO http://ipstats.wipo.int

Accounting for the total number of patent applications made up of Direct applications to the national offices and PCT applications entering national phases, we found that the entry to the TCP did have a strong influence in Mexico and Chile promoting patenting activities with clear criteria that was imprinted in the national regulations to comply with international rules, and substituting a big number of applications prior taken to the national offices to the TCP treaty. Chile, despite being the last of the three countries to enter the treaty has the biggest share of TCP applications in national phase; Brazil, the one with the most patent applications relies strongly on their internal market, thus the biggest proportion of patents are found in direct applications until year 1996, 20 years from their entry to the treaty. This can be seen on figures 3.4a. 3.4b. and 3.4c.

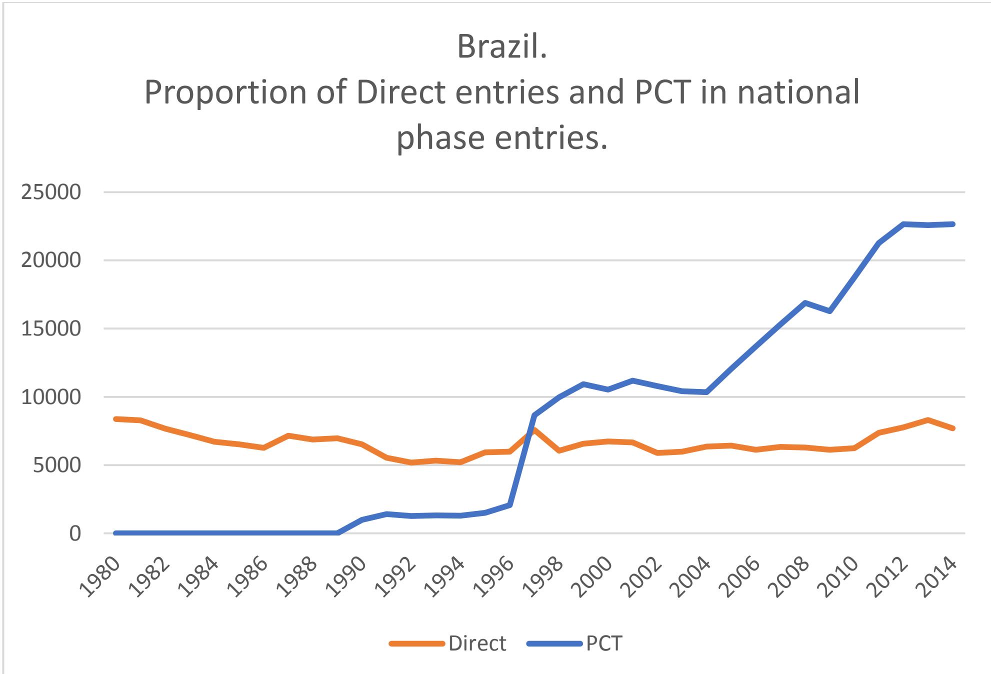


Fig. 3.4a.

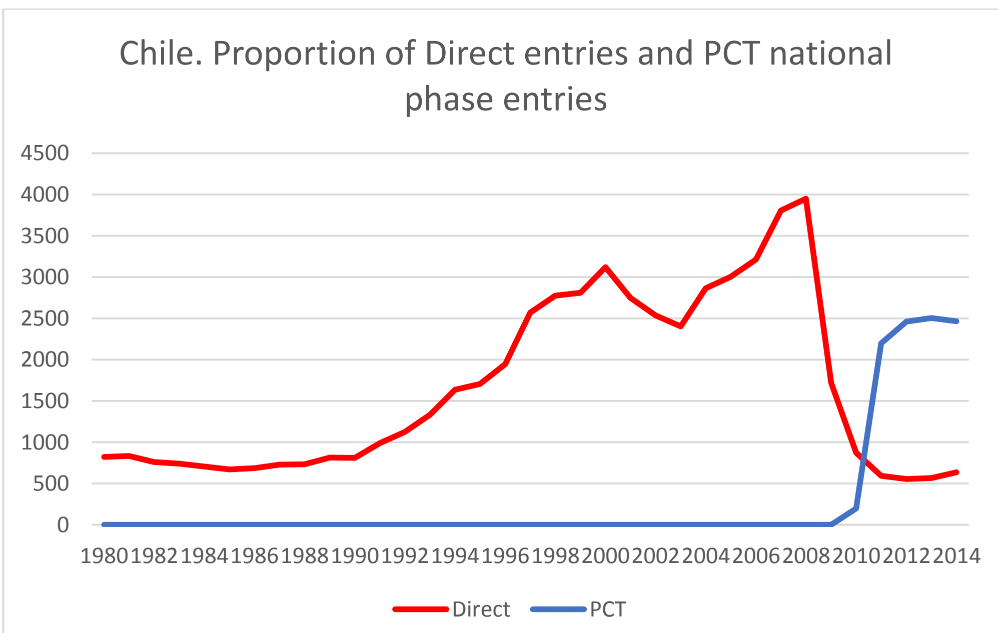


Fig. 3.4b.

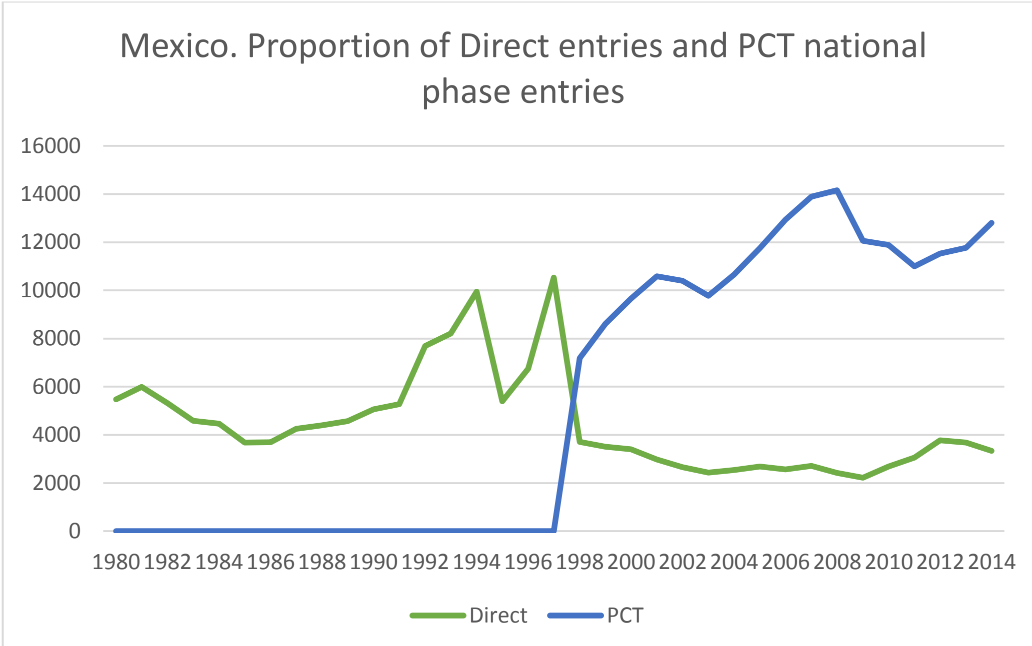


Fig. 3.4c. PCT national phase entries and direct applications for Brazil, Chile and Mexico.

The situation pictured in figures 3.4a, 3.4b and 3.4c is not unique or bound to Latin American countries. According to WIPO, proportion of patent applications in the world is similar: 75% for direct applications and 25% for PCT national phase entries.

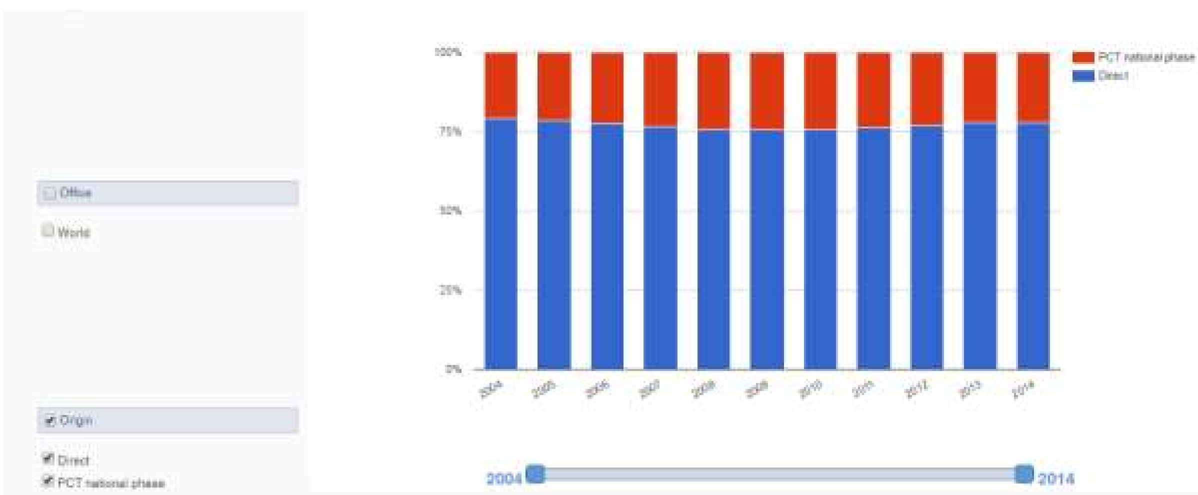
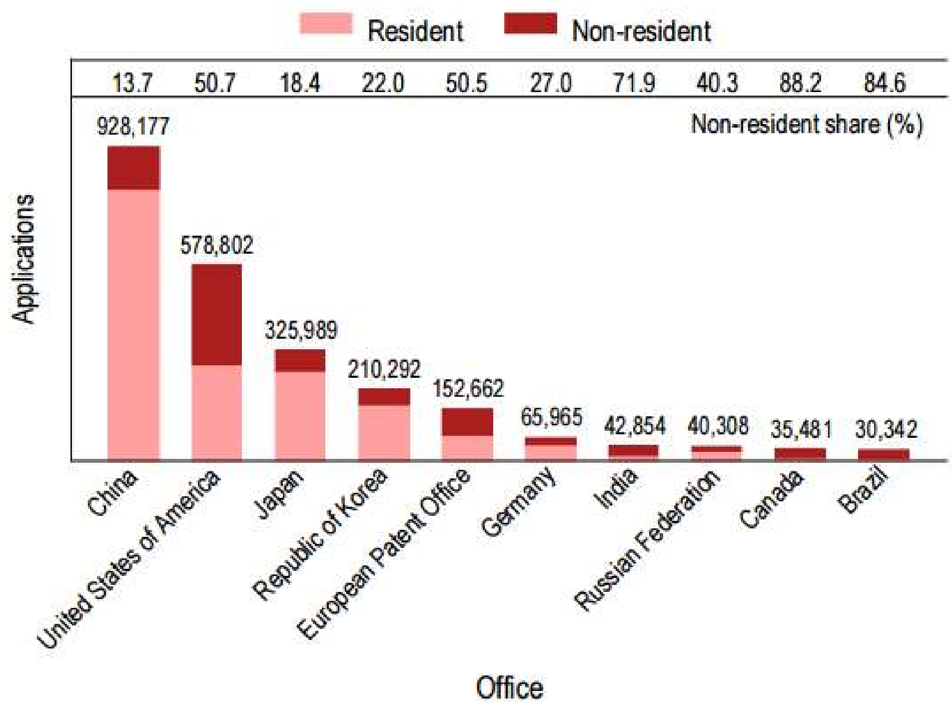


Fig. 3.5. World patent applications by filing route: Direct and PCT System. Source: WIPO http://ipstats.wipo.int

Brazil and Mexico are considered between the top 20 patenting offices in the last years, and their growth rate trend gives an indication that they will continue to be in those places while public policy in both countries continues to promote patenting activities as important for the development of the National Innovation Systems. However, it is important to note that the proportion between Resident and Non-Resident applications is very high in both cases (84.6% of Non-Resident share for Brazil and 92.3% for Mexico).



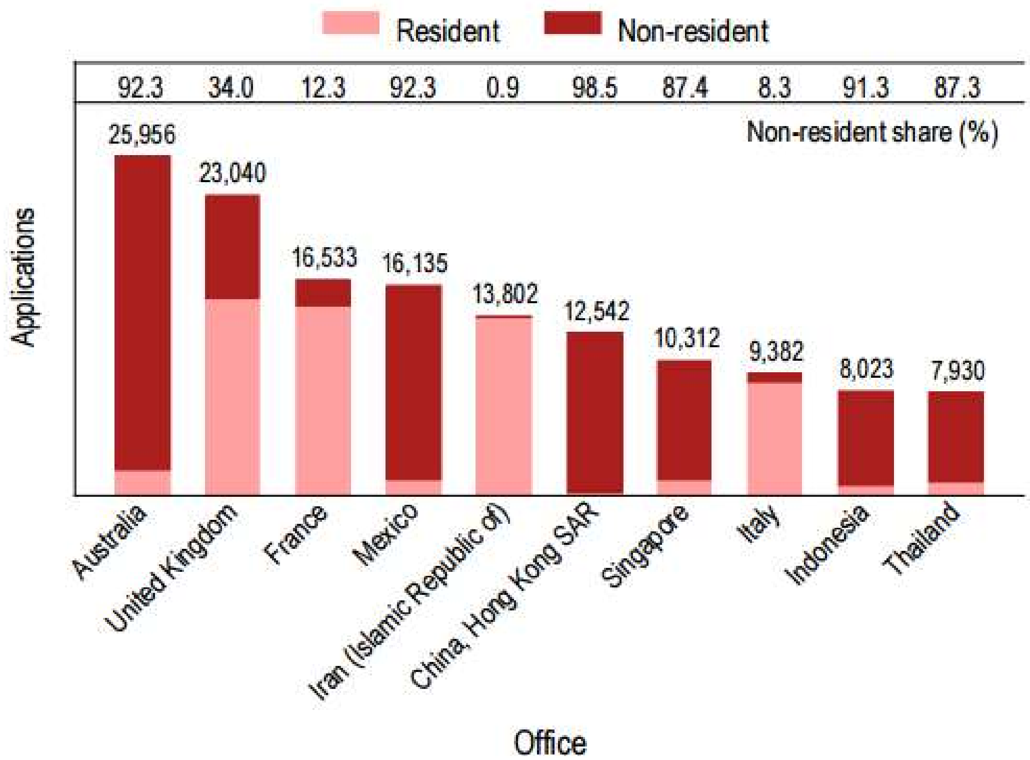


Fig. 3.6. The top 20 patent offices of the world, 2014. Source: World Intellectual Property Indicators 2015. WIPO.

3.2.1 Conclusions

The influence of entry to the PCT treaty is visible in the cases of Mexico and Chile. Most of the patent applications made after their inclusion date to the treaty have followed the TCP route.

The three countries' profiles obey to the World trend in patent applications, although the world's biggest influence resides in Asian numbers.

For Brazilian case, it is important to note the remarkable growth of patent applications shown from year 1996, while for the Chilean case the PCT filing to national phases has experienced an important increase and the trend shows it will exceed Mexican applications in a near future.

Overall, we can conclude that the entry to an international treaty such as the PCT shapes favorably the patenting policy in a national basis, while standardizing evaluation of applications and providing mechanisms to promote IP protection in a big number of member countries.

Other public policies might be important to give impulse to patenting activities and to innovation in general terms, but they are country specific and will not be studied as part of the dissertation.

Chapter 4. Mexican inventors in PCT patent applications and the gender gap

Some parts of this chapter have been submitted to Interciencia as an article still in Editorial Revision:

"Mexican inventors in PCT Patent applications". Cepeda-Zetter; Pérez-Angón and González Brambila.

The results for the gender gap study were presented as an abstract and poster in the Gender Summit 8, held on April 28-29, 2016, and will be published in the Summit Proceedings

4.1 Abstract

There have been studies addressing gender gap in innovation related activities such as patent filing (Ding et al., 2006; Frietsch et al., 2009; Jung and Ejermo, 2014; Mauleón and Bordons, 2010; McMillan, 2009; Sugimoto et al., 2015) in specific areas of knowledge and usually centered on the European Community countries. Following OECD (1994) recommendations we have used patent data comprised in the PATENTSCOPE database (WIPO, 2016) as an indicator of technological innovation (Archibugi, 1992; Schmoch and Sybill, 2004) and to analyze Mexican inventors' involvement on patent filing in a 20 year period (1995-2015). The analysis was gender desegregated to observe patterns and trends of participation of both male and female inventors. Some indicators such as participation, contribution and presence are shown. It has been found that participation of female Mexican inventors is high in comparison to results obtained in other studies addressing the gender gap in patenting activities from other countries. Findings also reveal that Mexican female inventors more often apply for patent titles within a small to medium sized team, while male inventors prefer single-authored applications. It has also been found that the stronger technological area in which both male and female Mexican inventors apply for patent titles is the relative to Chemistry and Metallurgy inclusive of all its subareas. The results reveal gender

disparities that should be addressed in Mexican public policy to accomplish United Nations (UN) Millenium Goals (UN, 2005 and 2015), UN Sustainable Development Goals (WISET, 2016) and promote gender equity in Science and Technology related activities.

4.2 Relevance

Participation of female inventors in patent applications could give an indication of the degree the UN Millenium Goals (UN, 2015) have been covered, as this implies access to science, technology and business. It has also direct implications on the role of gender-based innovations for the UN Sustainable Development Goals (WISET, 2016) as the inventions where they participate could contribute to have clean water and sanitation, affordable and clean energy, improvements for industry, sustainable cities, etc. and by promoting their inclusion on inventors' teams gender equality and decent works would be a step forward. Many of the elements needed to achieve gender equality differ significantly by country and there is little research undergone on Latin American (and other developing) countries (Barroso et al., 2009; Guzmán, 2012; Guzmán et al 2012). Thus the interest of our study focusing on Mexican female inventors is relevant.

4.3 Aims & Objectives

The objective of the study is to characterize the nature and propensity of patenting activities between female Mexican inventors. We address the following questions: 1.What is the involvement of Mexican female inventors in patenting activities? 2. Which are the differences between the inventors' teams formed by males or females? 3. What are the trends over the 20 year period studied? 4. Which indicators can be used to analyze female involvement in patenting activities in our country?

4.4 Introduction

The participation of Mexican inventors is analyzed by gender, and the relationship between the inventors’ team size, the patent categories and the type of patent holders is studied using statistical methods. This analysis will help us determine the strongest technological areas in which Mexican inventors apply for patents, wherever they develop their inventive activities (whereas they work in academy, industry or by their own). In terms of technology forecasting, the knowledge of strengths and opportunities of the nation’s human capital is crucial, as it reflects the next steps a national science and technology system might give, but also the capability of knowledge absorption from other countries in a given field.

The document is organized as follows: First we have established the demographic panoramas related to inventive and patenting activities in the world and in Mexico; next, the methodology applied to the analysis is explained as well as the limitations concerning the data set used; results obtained follow, and finally conclusions are pictured.

4.4.1 Gender disparities, the global view

In the globalized world we are living in, the use of human capital in conjunction with new technologies and specialized workforce mobility is essential to generate richness, growth and competitiveness within countries. Education, specialization, research and development have become crucial factors to achieve goals set not only by countries’ governments, but also by international organizations.

New goals have been set by the UN concerning women and girls' access to education, training, science and technology, as well as women's equal access to full employment and decent work (UN, 2015), as the deadline of Millennium Development

Goals (MDGs) established by the United Nations (UN) approaches this 2015 (UN, 2005). We do believe women participation in patent applications gives us an indication of the degree these goals have been covered, as this implies access to science, technology and business, and that the analysis made may provide elements to accomplish and even surpass the new goals to be set. However, many of the elements needed to succeed differ significantly by country and gender, thus the interest of our study focusing on Mexican female inventors is relevant.

The OECD has interpreted the low presence of female scientists and inventors as a barrier for economic growth of their member countries (OECD, 1994). Women constitute 49.65% of the global population (United States Census Bureau, 2015), thus they represent a potential human capital that has barely being exploited, especially in Latin-American and other developing countries. This might be explained as result of the traditional role women play in the society as mothers and housekeepers (Whittington, 2011), the opportunities they have to access graduate and postgraduate education, and the choice of professional activities.

Gender issues concerning their participation in activities related with invention and innovation have been studied for some years now. We can identify some of the reasons for women's exclusion from education, science and technology. The literature goes as far as the French philosopher Jean Jacques Rousseau, that in one of his most important treatise *Emile, or on education* (1763), which in fact served as an inspiration for the constitution of the new education system in France after the French Revolution, outlines a differentiated education for Emile (a boy) and his female counterpart Sophie stating inferiority of the female with respect to the male in terms of the education she (and therefore all women) should receive. This is clear when we read some of his affirmations (Rousseau, 1762):

"When I consider the special purpose of woman, when I observe her inclinations or reckon up her duties, everything combines to indicate the mode of education she requires. Men and women are made for each other, but their mutual dependence differs in degree … Hence her education must, in this respect, be different from man's education.

… A woman's education must therefore be planned in relation to man …

…Little girls always dislike learning to read and write, but they are always ready to learn to sew.

… Do not be afraid to educate your women as women; teach them a woman's business, that they be modest, that they may know how to manage their house and look after their family …"

However history has made possible for women to have opportunities to interact in different ways with the world itself, and participating in politics, economy, arts and science. Even after the feminist movements and at the beginning of the XIX century, scientific contributions of women were limited due to their exclusion from scientific education. This situation has been slowly changing around the world.

In Mexico, for instance, women are 51.6% of the total population (The World Bank, 2013). However labor force represented by Mexican women older than 15 years of age that are able to work is only 16.4% of the total (INEGI, 2015). According to the National Institute of Geography (INEGI), 95.5% of these women are occupied (INEGI, 2015). In contrast, men constitute 48.36% of the total population, while labor force represented by males older than 15 years of age and capable of working is 62.29% of the total (INEGI, 2015) 95.71% of them being occupied up to date (INEGI, 2015). This is an indication of the fact that there are more men than women with the possibility to participate in science, technology and innovation activities such as patenting, as well as other activities. Therefore, results in these and other studies have to take into account availability of one or the other gender.

Females' situation is different from one country to another and depends on various factors such as participation in scientific and technological activities, the area of study related to each invention (Frietsch et al., 2009), and even the policies implemented to accomplish gender equality. Nevertheless in the whole world, including Mexico, the "leaky pipeline" phenomenon in which the proportion of women decreases in every higher educational step is present (OECD Employment, 2006; OECD iLibrary, 2011; United States Government Accountability Office, 2015). It is therefore important to account for the collection of data at a country level, as well as the development of specific studies for each country in order to see more clearly the reason for the shortage of females in some areas or jobs (especially the ones that are technology related), and determine if there is the need of public policy implementation to improve gender equality. These studies would also serve to compare gender situation throughout time, and evaluate measures taken by firms or governments to reduce gender gap in Science and Technology related activities. Following this order of ideas, this paper relates to the Mexican inventors situation, inclusive of gender issues.

It is important then to examine some country specific demographic information. Mexican women that represent the labor force have an average age of 38.5 years and 10 years of formal studies, while male labor force is in average 39 years of age with a formal education of 9.3 years (INEGI, 2015). According to INEGI, human wealth involved in scientific and technological activities and have covered third degree of International Standard Classification of Education (ISCED) is 19.9% of labor force in the country. However only 11.86% of Mexican labor force was occupied in science and technology activities (INEGI, 2015). This percentage is important to demonstrate capabilities of adoption, implementation and use of new technologies, as well as participation in international technology trade (Toivanen and Suominen, 2015) and might be compared with other countries worldwide to find Mexico's position relative to other countries.

Various studies (Atlas, 2014; Contreras-Gomez et al., 2015) have found that in Mexico women participation in PhD degrees varies between disciplines, with the highest percentage of participation in Humanities (45%) and the least in Physics Sciences (15%). This proportion is consistent to OECD figures for their member countries in which the large majority of degrees in humanities and health are awarded to women (71%) while the majority of degrees in mathematics and engineering degrees are awarded to men (75%). In Mexico, almost 75% of degrees awarded in humanities are for women, and around 60% of degrees awarded in mathematics and computer science are for men (OECD, 2011).

Gender segregated technology indicators are being encouraged (OECD, 2011) in both national (as our analysis does) and international levels. The 2010 America Invent Act stressed the need to understand diversity in patenting, taking special interest in patent applicants that are women, minorities or veterans (AIA, 2010). These may serve well to promote public policies that promote gender equality in developing countries as well as developed ones.

In the last years, several studies have been made in order to analyze women participation in patenting activities in different countries, regions or patent categories especially within the European Union (Frietsch et al., 2009; Jung and Ejermo, 2014; Mauleón and Bordons, 2010; Naldi et al., 2004; Wittington and Smith-Doerr, 2005 and 2008). However, there are only a few studies concerning patenting activity in Latin America (Barroso et al., 2009; Guzmán, 2012; Guzmán et al., 2012). The studies claim that the gender gap is declining, but still male scientists all around the world have more patent applications than female inventors do (Ding et al., 2006; Frietsch et al., 2009; Jung and Ejermo, 2014; McMillan, 2009; Stephan and El-Ganainy, 2007; Sugimoto et al., 2015; Whittington and Smith-Doerr, 2005 and 2008). It is our aim to characterize this important component of innovation in Mexico.

4.5 Methodology

Using gender desegregation we studied the involvement of Mexican inventors in patenting activities in a period of 20 years after the addition of Mexico to the Patent Cooperation Treaty (PCT) in 1995. We used the World Intellectual Property Organization database PATENTSCOPE (WIPO, 2016) to retrieve all patent applications with at least one Mexican inventor and the inventors' field was analyzed. Gender identification of inventors was made using the first name of the inventors given the authors' knowledge of commonly used Hispanic names as in Mauleón and Bordons (2006), although this is a cultural biased process and would be difficult to apply for other countries with a different naming tradition.

It is based on patent applications published in the WIPO database, instead of doing it on granted patents given that the publication of a patent application is the first formal and public knowledge of the invention it describes (Balconi et al., 2004; Breschi et al., 2007; Frietsch et al., 2009) and that the time to grant a patent in the regional or national offices is often very long (the Mexican patent office, IMPI, takes between 4 and 10 years for granting a patent). The WIPO database was used because it concentrates all patents filed under PCT whichever the regional or national patent office has been chosen by the inventor(s).

We have not focused in a given segment, such as academic inventors or in a particular technology to provide a wide characterization of the patenting activities in Mexico throughout the chosen period. This is important for policy makers involved in innovation schemes that cover the complete spectrum of technologies and economic sectors.

The PATENTSCOPE database (WIPO, 2015) has been used to obtain all patent applications from year 1995 to 2015 where at least one of the inventors is Mexican. The search results were then organized and analyzed individually to determine the number, nationality and gender of inventors in each of them. An inventor with more than one patent in a given year is counted as many times as the patent applications in which he or she appears (full counts).

Concerning patents, a two letter code indicating nationality and full name of inventors (one name and surname) are usually recorded in the databases unlike the publications databases such as Web of Science or Journals in which many problems arise when trying to identify the author because of the many ways of signing publications (Costas, 2007; Macías-Chapula et al., 2006; Ruíz-Pérez et al., 2002). Gender aspects of inventors have been studied thanks to the fact that the first name works as a gender identifier in most cultures. But even in the case of patent applications the identification of the gender of scientists is a laborious and often difficult task. There have been studies conducted to determine the gender of the inventors in patent applications (Sugimoto et al, 2015), in which the first name of authors are matched with some universal and country-specific name lists (Sugimoto et al, 2013). The patent data used by Jung and Ejermo (2014) was compared to a national demographic database provided by Statistics Sweden. In the present study, the knowledge of names used in Spanish language was used instead of an already defined list following other studies involving Hispanic inventors such as Mauleón and Bordons (2010), given that there are few cases a name can be used for both men and women and that there is a significant difference between names for men and women.

The demographic information presented in this study comprises only what can be determined from the patent application published in PATENTSCOPE, as no other databases including fields such as age or academic degrees of the inventors were available. The national statistics agency, INEGI, does not have a list of inventors, and there has not been any survey on this subject conducted in the country. Thus, the variable we are capable of analysing regarding the inventors is gender. There have been other studies (Jung and Ejermo, 2014) that have taken into account other variables (age and education of inventors) matching the inventors names with national demographic information of Swedish citizens. In other cases, inventors' surveys have been used to obtain demographic data in Japan, United States and the European Union (Giuri et al., 2007; Walsh and Nagaoka, 2009).

The International Patent Classification (IPC) described also in the WIPO page was used to identify the section the patent applications relate to, in order to analyse the main areas in which Mexican inventors' participation in the patenting activity are more important. The analysis is gender desegregated in order to appreciate differences in technological fields´ influence of either men or women. The IPC proposed by the World Intellectual Property Organization (WIPO) was established by the Strasbourg Agreement in 1971. It consists in a hierarchical system of language independent symbols according to different areas of technology. The IPC version used is the one that came into force on January 1st 2015. The IPC serves as:

(a) an instrument for the orderly arrangement of patent documents in order to facilitate access to the technological and legal information contained therein;

(b) a basis for selective dissemination of information to all users of patent information;

(c) a basis for investigating the state of the art in given fields of technology;

(d) a basis for the preparation of industrial property statistics which in turn permit the assessment of technological development in various areas (Guide to the IPC, 2014).

Statistical analysis was made using R software (R-project.org). The indicators obtained, following Mauleón and Bordons (2010) and Naldi et al (2004), are divided in:

- Participation: Number of patent applications with only male inventors listed, number of patent applications with only female inventors and number of patent applications with male and female inventors.
- Presence: Whole count of inventors both male and female
- Co-inventorship index: total number of inventors in each of the patent applications
- Percentage of female and male patent applications that are single-authored

4.6 Results

A total of 3350 patent applications with at least one Mexican inventor were found. Considering full counts, 1089 inventors of all those listed in the applications were Mexican female inventors. The uncertainty in the gender identification of inventors was 73 registries (2.18%). Cases in which we could not determine gender of the inventors are grouped as follows:

1. The name can be used either by men or by women such as Ari, Magdiel, Merced, or José María.
2. The inventor, even though identified as Mexican, had a name that is not commonly used in Spanish, such as Tetsuya, Naoko or Lurival.

3. The first initial of the inventor´s name was used, as in Andrade F. or Hernandez, T.

4. The names of inventors were written with Cyrillic characters, like in ТЕЙЛОР Брэдли

In the rest of the patent applications, the Mexican inventors' gender was determined with certain ease given the authors´ knowledge of commonly used names in Hispanic countries.

4.6.1 Presence of Mexican inventors in patent applications

An increase in the number of Mexican inventors is shown for both males and females during the period studied. The proportion of women is still low compared to the male and total number of inventors in the applications, as can be seen in the Figure 4.1. The percentage of Mexican inventors in relation to the total number of inventors per year is shown in table 4.1. Note that percentage of Mexican female inventors is considerably low.

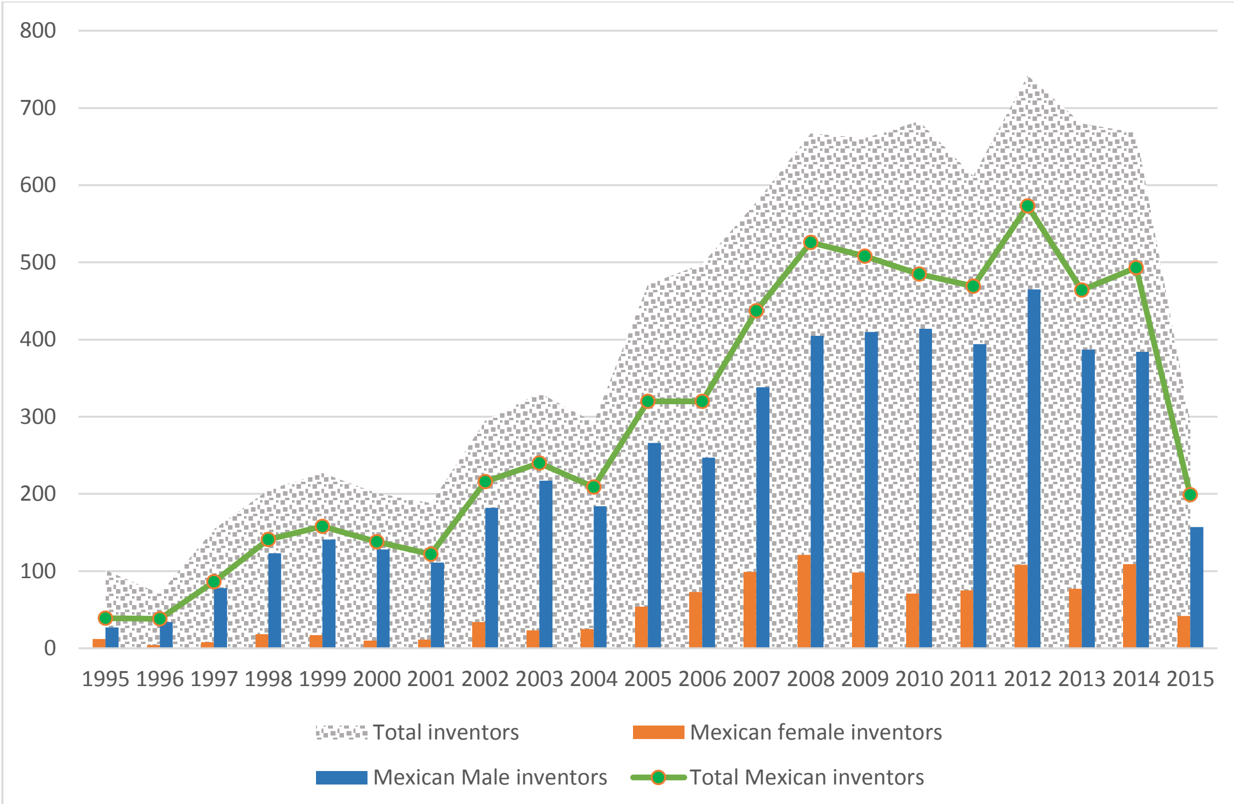


Fig 4.1. Evolution of patenting activities in PATENTSCOPE database in PCT applications with at least one Mexican inventor between years 1995 and 2015.

	Percentage of Mexican Inventors	Percentage Mexican female inventors
1995	0.39	0.12
1996	0.54	0.06
1997	0.56	0.05
1998	0.69	0.09
1999	0.70	0.07
2000	0.69	0.05
2001	0.65	0.06
2002	0.73	0.12
2003	0.73	0.07
2004	0.71	0.09
2005	0.68	0.11
2006	0.64	0.15
2007	0.76	0.17
2008	0.79	0.18

2009	0.77	0.15
2010	0.71	0.10
2011	0.77	0.12
2012	0.77	0.15
2013	0.68	0.11
2014	0.74	0.16
2015	0.68	0.14
Average	**0.68**	**0.11**

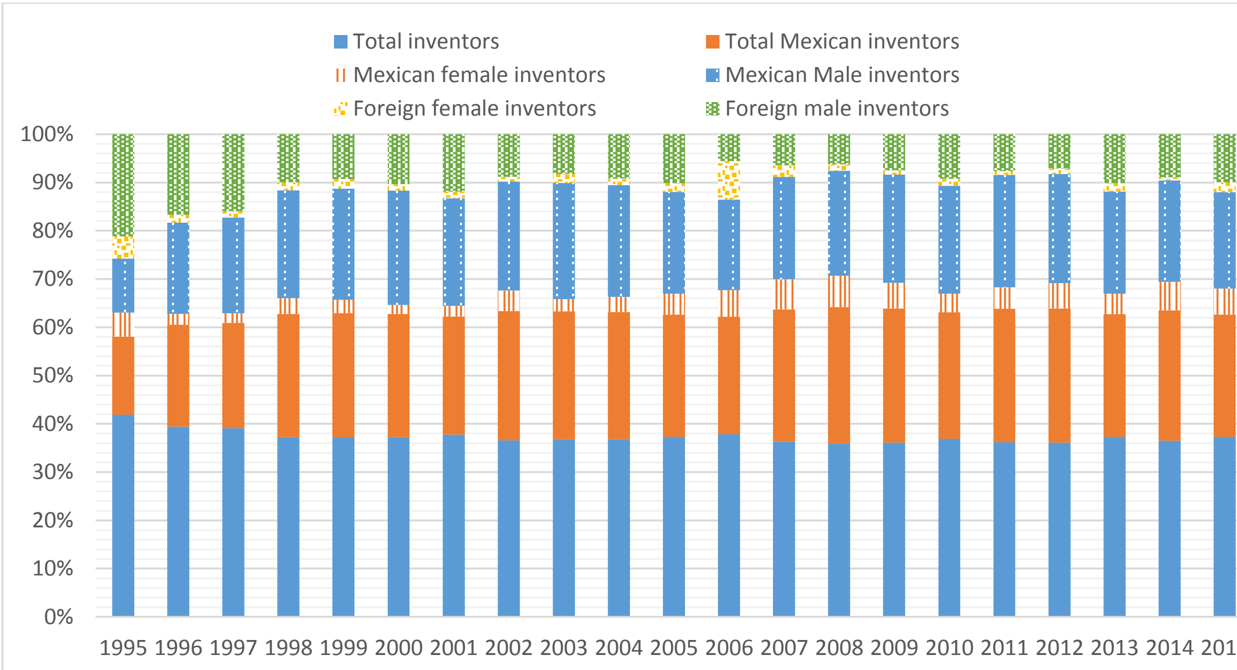
Table 4.1. Percentage of Mexican inventors with respect to the total of inventors listed on the patent applications

4.6.2 Female participation in patent applications

As seen in Table 4.1, male dominance in patenting is found in PCT applications with at least one Mexican inventor. The average percentage of participation of Mexican females/total males is 11% to 89% of the applications studied when the total number of inventors is considered. The percentage of participation of female inventors on the data studied had big fluctuation across the period studied, with an average of 20% of the total PCT patent applications with at least one Mexican inventor (foreign and Mexican females considered). This is consistent with other studies (Mauleón and Bordons, 2010; Sugimoto et al., 2015) conducted in multiple countries, especially those within the European Community where the same phenomena is observed. We can therefore conclude that Mexican inventors´ situation is the same reflected in most countries around the globe, with the exception of few countries which are female dominated, in relation to patenting activities (Sugimoto et al, 2015), and slightly high when compared with other studies analyzing USPTO database (Sugimoto et al., 2015) and others that consider a large number of countries comparing several countries in terms of female participation or the Spanish Patent Office database for a country specific analysis (Mauleón and Bordons, 2010).

According to Frietsch et al. (2009), women's contribution to patents filed by European countries ranges from 2.9% in Austria to 14.2% in Spain up to year 2005.

Therefore, this percentage in patenting activities is high not only given worldwide statistics, but also the proportion of Mexican labor force represented by females.



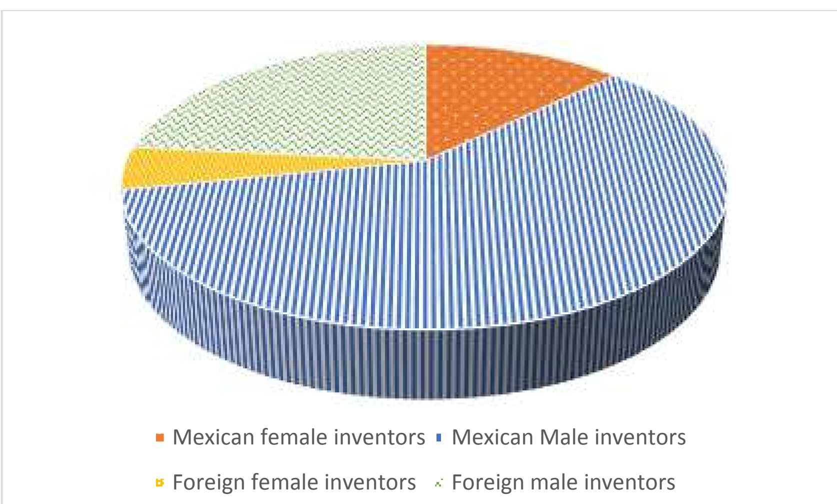


Fig 4.2. Participation by gender and nationality identification in PCT patent applications with at least one Mexican inventor

4.6.3 Collaboration Indicators

We have established the co-inventorship index to explore the collaboration practices of Mexican inventors with other inventors (Mexican or foreign). We have taken into account the average number of inventors per patent application in each of the years studied, and the number of single authored patent applications for the gender segregated groups. There have not been substantial variations throughout the years with the exception of 1995, in which inventors´ teams with at least one female inventor were large.

4.6.3.1 The co-inventorship index

It has been found that Mexican female inventors have more co-inventors on average than Mexican male inventors, who are also prone to produce single-authored PCT patent applications (Figure 3). The index is determined by obtaining the average number of inventors in the total count of patent applications on the whole period, this is:

$$Co\_I = \frac{\sum^{n} Avg\ \#\ inventors_n}{n}$$

Where n is the number of years of the period studied.

The Co-inventorship index can be defined for each year studied by the average of inventors in the patent applications on that specific year.

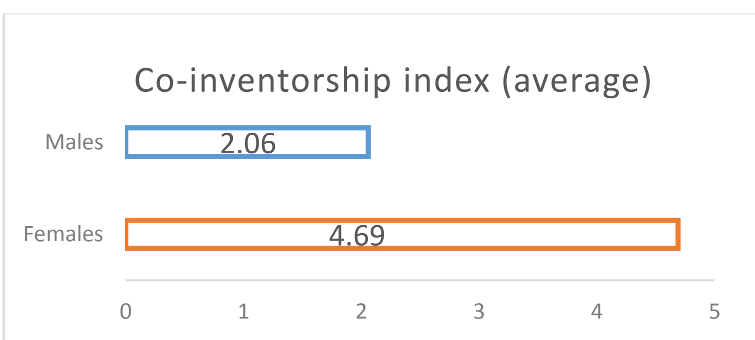
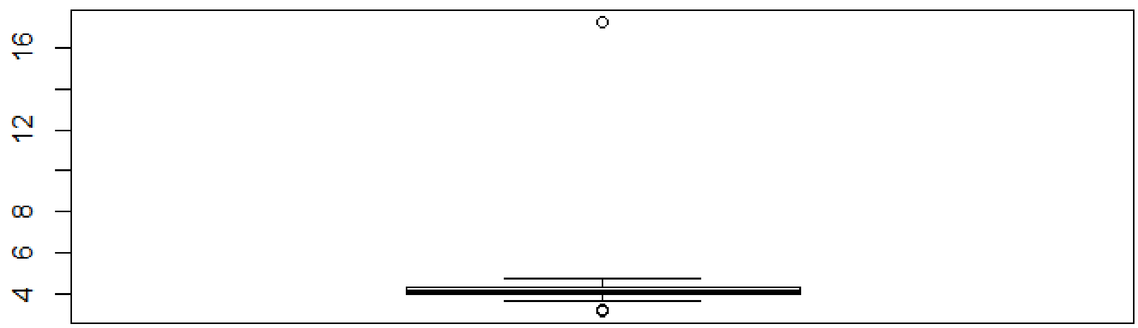


Figure 4.3. Co-inventorship index from 1995-2015

The mean size for mixed teams is 4.69, while males only inventors teams present a mean of 2.06 (Figures 4.4a. and 4.4b.). It is clearly seen that the distribution of team size is dispersed in the case of mixed teams. This is congruent also with the results expressed on Sugimoto et al. (2015), and Mauleón and Bordons (2010), in which it is established that female inventors tend to work in mixed-gender teams more frequently than alone or in female only teams.



The boxplot presents the following statistics:

Extreme of lower whisker: 3.69

Lower hinge: 3.96

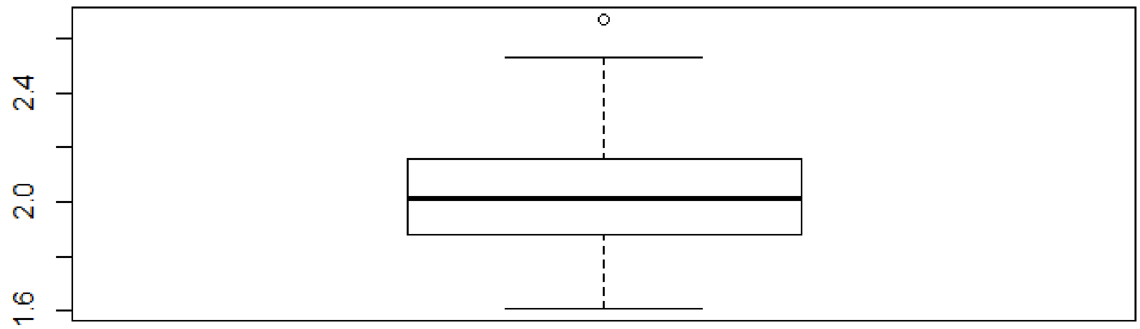
Median: 4.06

Upper hinge: 4.29

Extreme of higher whisker: 4.74

Outliers: 17.25, 3.26, 3.16

Figure 4.4a. Size of mixed inventors teams.



The boxplot presents the following statistics:

Extreme of lower whisker: 1.61

Lower hinge: 1.88

Median: 2.01

Upper hinge: 2.16

Extreme of higher whisker: 2.53

Outliers: 2.67

Figure 4.4b. Size of male only inventors´ teams.

We have examined the trends on the team sizes according to the gender of the inventors participating in patent applications throughout the years comprehended in our study. As seen in Figure 4.5, the most growing group is the male only teams. The female only teams have a non-significant growth. This is related with the lack of female inventors, an issue that must be studied and addressed by policy makers in our country.

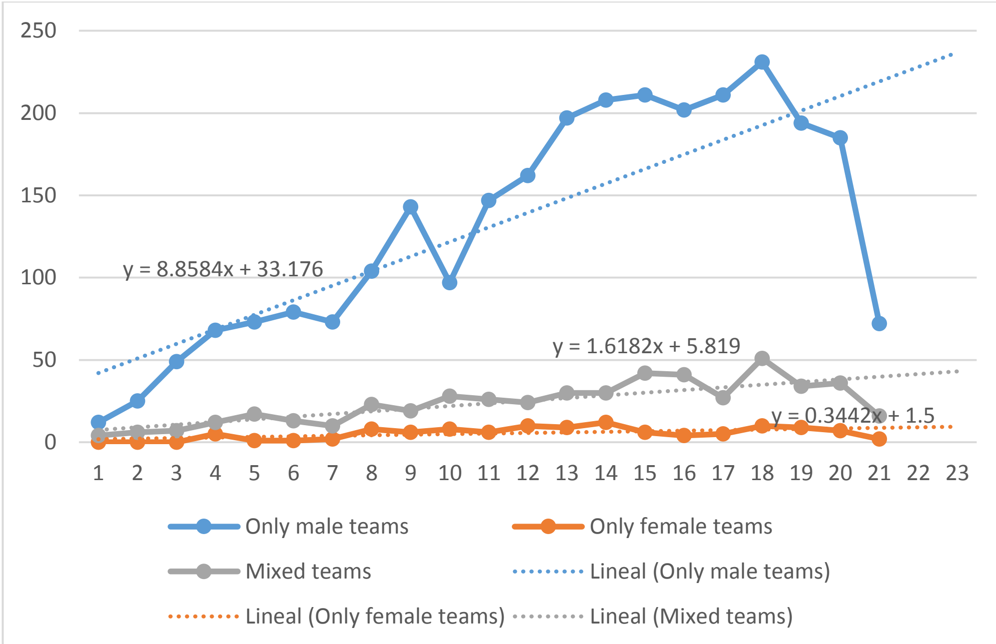


Figure 4.5. Patent application trends according to the gender of the inventors.

4.6.3.2 Single authored patent applications

According to the number of single authored patent applications we established a collaboration indicator that transcends because gender issues condition the participation of female inventors as single authors. This issues should be thoroughly studied to determine their causes and solutions and establish public policy that promote technology related careers between Mexican women. This relates directly to UN Sustainable Development Goals (WISET, 2016). Table 4.2 shows the collaboration trends on the patent applications studied. Figure 4.6 shows the trend of single authoring through the years.

	Mixed Teams	Males only teams	Females only teams
Single authored applications (total count)	---	1367	111
Number of applications (Total count)	496	2743	111
Percentage from the total applications	0.16	0.82	0.03

Table 4.2. Analysis of the inventors' teams.

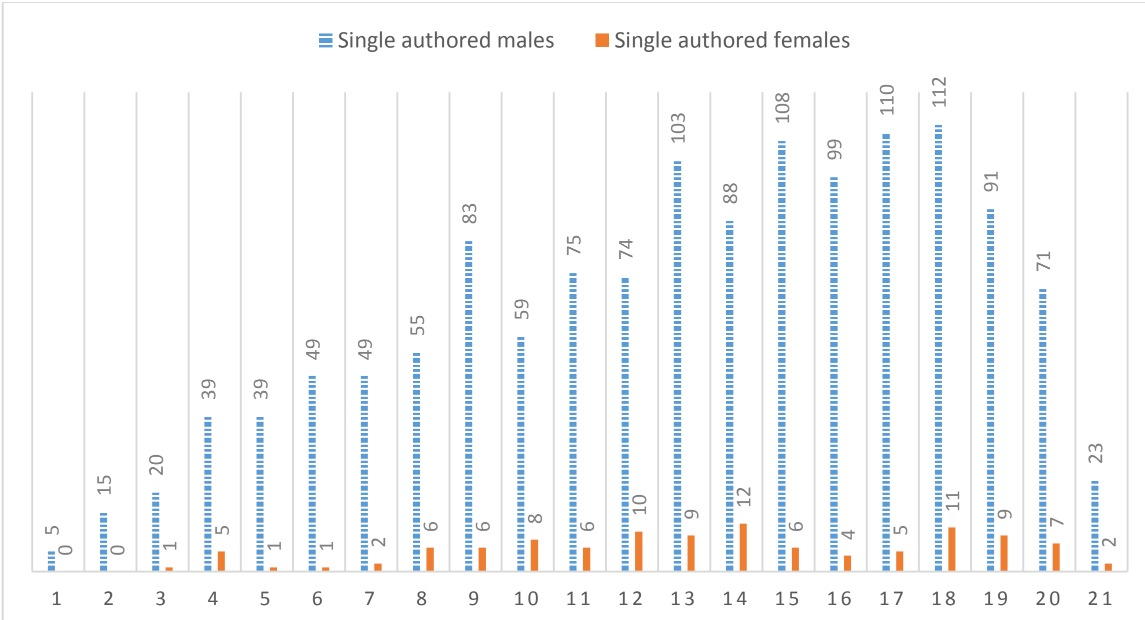


Figure 4.6. Single authored patent applications from 1995-2015

4.6.4 Propensity of patenting between Mexican inventors depending on the International Patent Classification (IPC)

Table 4.3 shows the IPC Sections in which we found patent applications with at least one Mexican inventor. The gender gap varies across Sections, as stated in Mauleón and Bordons (2010), where the analysis of 16 years of patents from the Spanish Patent Office has shown the female involvement in the patent generation by sectors and technological fields. Their findings apply also to the Mexican case in the period studied. Women involvement in patent applications varies depending on the technological Sections. The percentage of applications with at least one Mexican female inventor goes from 8.33% in the Textile/Paper Section, to 34.12% of participation in the Chemistry and Metallurgy Section.

IPC Section	Total count	Female inventors (%)
A. Human Necessities	1106	32.55
B. Técnicas industrials diversas; Transportes	516	14.15
C. Chemistry; Metallurgy	680	34.12
D. Textiles; Paper	36	8.33
E. Fixed Constructions	216	11.11
F. Mechanical Engineering; Lighting; Heating; Weapons; Blasting	243	9.88
G. Physics	336	19.35
H. Electricity	227	10.57

Table 4.3. Number of patent applications by IPC Sections according to WIPO (2015) and female inventors' participation by Section.

Figure 4.7 shows the number of PCT patent applications with at least one Mexican inventor grouped by IPC Sections, while Figure 4.8 normalizes data to see the proportion of participation in these Sections.

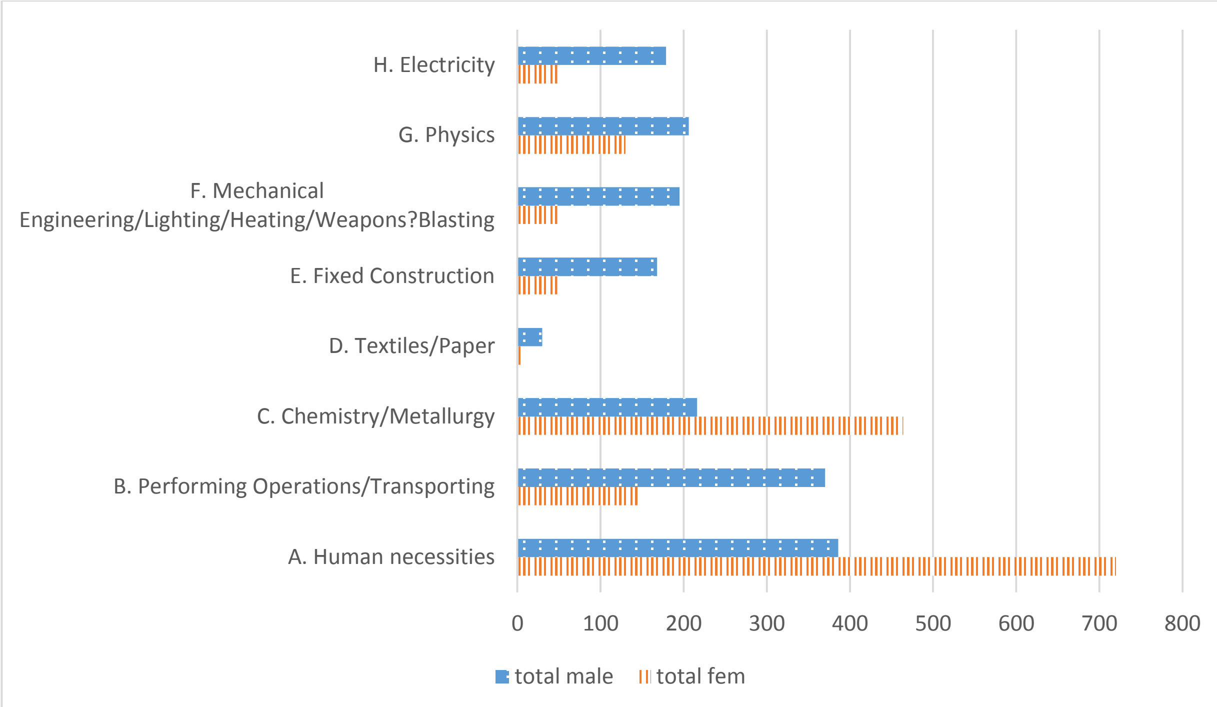


Fig 4.7. PCT patent applications with at least one Mexican inventor by gender and IPC Section

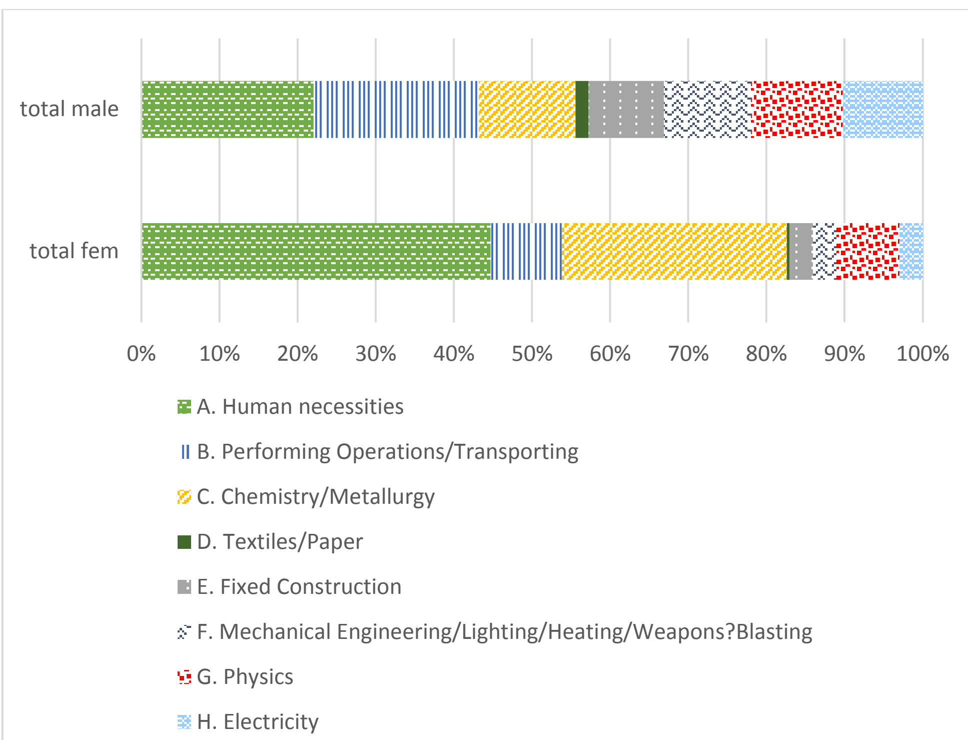


Fig 4.8. Percentage of participation in each of the IPC Sections by gender.

The evolution on the IPC sections throughout the time is pictured in Figure 4.9, in which the period studied is divided in two decades. The growth in the number of patent applications in each section is shown in table 44..

Section	A.	B.	C.	D.	E.	F.	G.	H.
total 95-05	91	18	70	1	8	3	9	5
total 06-15	269	55	162	2	16	21	56	19
growth	33.83%	32.73%	43.21%	50.00%	50.00%	14.29%	16.07%	26.32%

Table 4.4. Growth (percentage) of patent applications by IPC sections

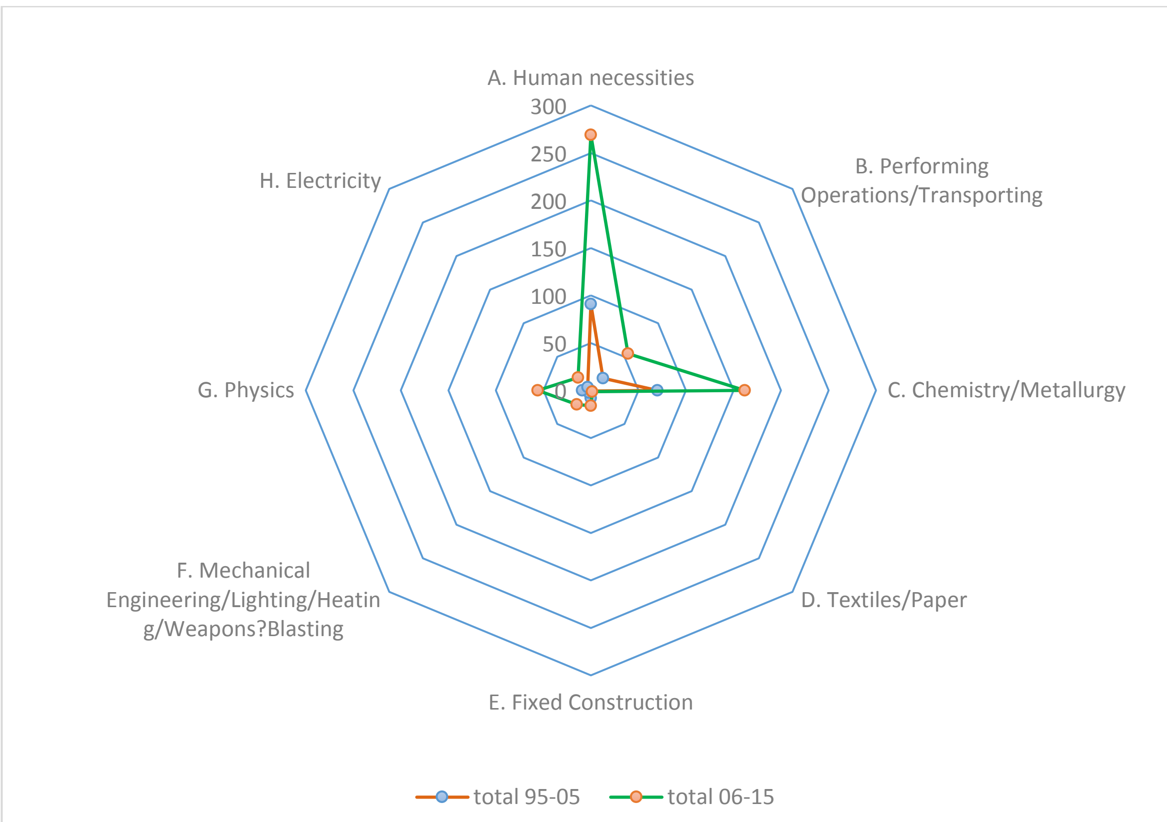


Figure 4.9. Evolution of patent applications by IPC sections

Patents are oriented towards the legal protection of technologies and therefore the classification of patents is based on technologies or products which use specific technologies. Technological competence is the basis for engaging in specific product areas and sectors. The analysis of technologies is a first step in describing and understanding the economic activities and performance of countries.

Various technology classifications have been used by different institutions for many years. These classifications generally follow the systematic of specific patent classifications, either the International Patent Classification or the US Patent Classification. However, these classifications have proved to be quite inconsistent in various aspects. This led the Fraunhofer ISI and the Observatoire des Sciences et des Technologies, in cooperation with the French patent office (INPI), to develop a more systematic technology classification based on the codes of the International Patent Classification (IPC).

Given the variety of Classes and Subclasses in each of the Sections, the IPC-Technology concordance Table constructed by WIPO was used in order to determine the technological branch into which Mexican PCT patent applications can be organized (WIPO, 2015bis); a concordance between predefined fields of technology and the IPC has been used for several years by WIPO and other Intellectual Property Offices. Lately, these fields of technology have been reviewed and the concordance has been revised. There are 35 fields of technology in the table to which we have mapped patent applications with Mexican inventors.

This approach has been taken also in other studies (Sugimoto et al, 2015). The use of the table allowed us to determine the national focus of patent applications in the period studied and gives a better understanding of Mexican inventors' influence in each of the technological fields.

The absolute number of patent applications for each technology field is shown in figure 10. We have established two periods comprising one decade each in order to observe the patent filing pattern and its growth over time. It is clearly seen that the patterns are very similar; the same technological branches that were the most important from 1995 to 2005 are the most relevant from 2006 to 2015. However, an important increase has been observed, specially in the Optics technology (81% growth), Electrical machinery, apparatus, Energy (79% growth), and the presence in the second decade studied of Micro Structural and Nanotechnology patent applications (that were none on the first decade studied). Only two technologies decrease between the two periods, Textile and Paper machines (20% decrease) and Digital Communication (30% decrease).

The he biggest share within the PCT patent applications analyzed corresponds in both decades to the Chemistry and Metallurgy Section, specifically to the Organic Fine Chemistry technological branch. Female inventor' participation in this branch is relevant. This is consistent with the findings of other studies using the first name of the inventors to accomplish gender identification (Frietsch et al., 2009; Jung and Ejermo, 2014; Naldi et al., 2004) in which female participation or contribution is strongest in pharmaceutical technology, followed by chemicals, with least activity in mechanical engineering and machinery in European countries.

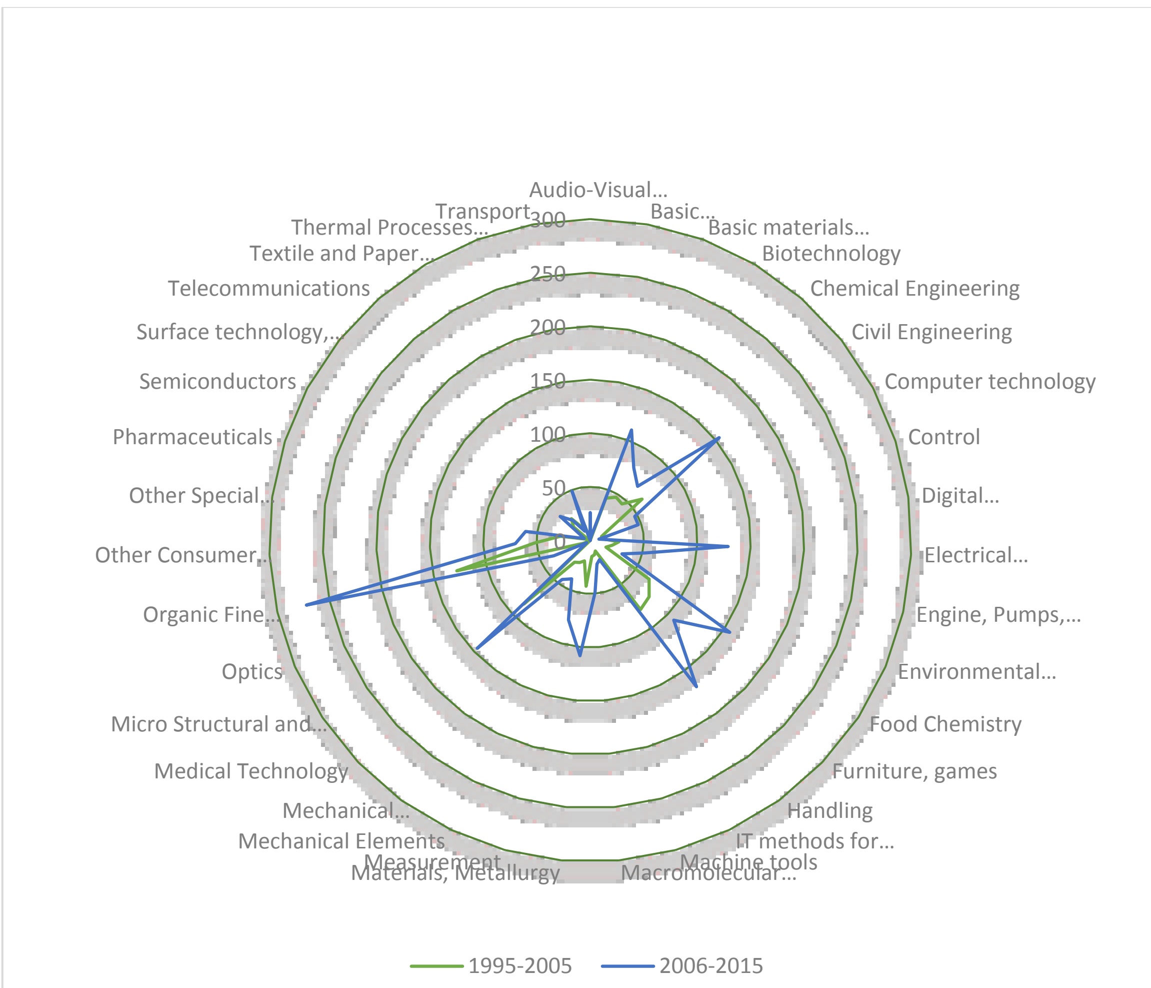


Fig 4. 10. Patent applications with at least one Mexican inventor grouped by technological fields according with the IPC-Technology correspondence table.

This finding relates to the strong Chemistry school in Mexico that has been historically productive in publications and patents in all the branches of the discipline (Atlas, 2014). An example of this affirmation can be found in the specific case of steroids research that led to the contraceptive pill (Hernández-García et al., 2015) yielding a great number of publications in mainstream journals as well as registered patents. It is important to note that even in those early stage of Mexican patenting activities (1952-1965) a Mexican female inventor was involved in this specific development.

4.6.4.1 Technology surveillance using the IPC-Technology concordance data

The number of categories in which Mexican inventors participate has increased consistently during the period studied as can be seen in figure 4.11. In most years of the period studied the category of Organic Fine Chemistry is the one with more patent applications filed, with the exception of years 2002 and 2011. In table 4.5 the absolute count and growth is shown for every technology branch. This information is useful to monitor for emerging and consolidated technologies in the country profile. For example, it is important to note the presence of patent applications in fields such as Biotechnology and Nanotechnology that have appeared in the last years of the study and are considered priority fields in the present National Development Plan.

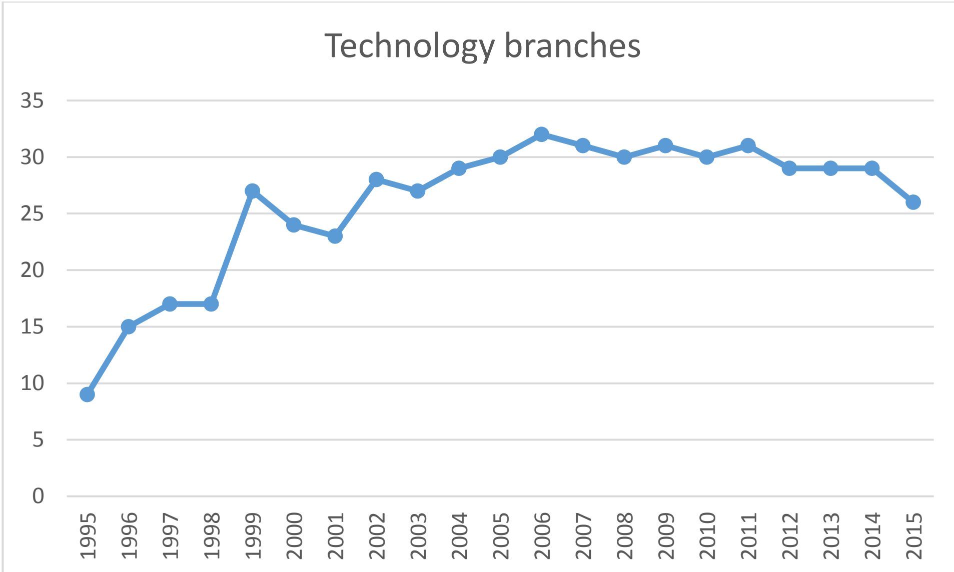


Figure 4.11. Number of categories per year in which Mexican inventors have filed patent applications

	1995-2005	2006-2015	Increase
Audio-Visual Technology	16	26	38.46%
Basic communication processes	0	2	100.00%
Basic materials chemistry	42	110	61.82%
Biotechnology	47	79	40.51%
Chemical Engineering	45	67	32.84%
Civil Engineering	62	154	59.74%
Computer technology	18	47	61.70%
Control	11	47	76.60%
Digital Communication	11	8	-37.50%
Electrical machinery, apparatus, Energy	27	129	79.07%
Engine, Pumps, Turbines	21	53	60.38%
Environmental technology	16	32	50.00%
Food Chemistry	66	156	57.69%
Furniture, games	76	108	29.63%
Handling	80	169	52.66%
IT methods for management	11	20	45.00%
Machine tools	14	23	39.13%
Macromolecular chemistry, polymers	15	49	69.39%
Materials, Metallurgy	43	108	60.19%
Measurement	20	77	74.03%
Mechanical Elements	23	40	42.50%

Mechanical Engineering	25	45	44.44%
Medical Technology	86	146	41.10%
Micro Structural and Nanotechnology	0	4	100.00%
Optics	7	37	81.08%
Organic Fine Chemistry	128	272	52.94%
Other Consumer goods	52	70	25.71%
Other Special Machines	28	61	54.10%
Pharmaceuticals	4	6	33.33%
Semiconductors	2	10	80.00%
Surface technology, Coating	20	36	44.44%
Telecommunications	27	25	-8.00%
Textile and Paper machines	14	10	-40.00%
Thermal Processes and apparatus	14	49	71.43%
Transport	0	0	0.00%
Total	1071	2275	52.92%

Table 4.5. Patent applications by technological branch.

Academic patent applications are studied in the next chapter, as well as their collaboration trends.

4.7 Conclusions

Patent applications are a good source of information about the inventors in a given country, sector or technological field, although they do not comprise all active inventors because some of them might not file a patent application on their invention, or prefer other intellectual property instruments such as industrial secrecy.

This study, unlike the literature found on patenting activities, has focused on the whole universe of Mexican inventors instead of a segment such as academic inventors or those working on a particular technology. The time span of 20 years for the study begins in 1995 with the inclusion of Mexico to the TCP and ends in 2015. The database was consulted up to the 2nd trimester of 2015 therefore giving an incomplete measurement of year 2015 due to the need to limit the time of data retrieving.

We have identified the participation of Mexican inventors analyzing the PATENTSCOPE database of TCP patent applications. We have shown that the addition of Mexico to the PCT in 1995 gave a great impulse to patenting activities, and that the last decade has shown an important increase of 53% in patent applications with respect to the previous 10 year period.

There has been an increase in both patent applications filed and number of inventors throughout the period studied. This is explained with the modern innovation theory in which firms tend to apply for more patents in order to monopolize a certain technology, or have revenues due to the licensing of it. The way of doing this is by increasing the number of inventors.

This article analyzes patent applications comprising all disciplines and sectors with a universe of 3346 patent applications in the whole period. The applications have been separated by gender in order to give a panoramic in the nature of patenting activity for Mexican inventors according to their gender. The gender segregation has proven to be enlightening, the Mexican female inventors represent a small percentage of people dedicated to patenting activities, yet productive and growing.

There have been some difficulties in identifying the inventors´ gender that could be surpassed due to the knowledge of the proper names commonly used in Mexico. The certainty of the name identification was 97.82%. As it is clearly seen, this technique has an inherent cultural bias. Some researchers have developed name matching techniques to determine the gender of the inventors but they cannot be applied to other cultures or in the cases where there are not gender distinctive naming conventions.

We have not been able to cross-match the inventors' names retrieved from the patent applications with other databases, as the coincidences with publicly known inventors, such as the academic researchers found in Web of Science publications were not significant. There have not been any national surveys on inventors, although there have been some efforts to contact the inventors listed in patent titles granted by the Mexican patent office (IMPI) (Meza-Rodríguez et al., 2015).

Participation of Mexican female inventors is high accounting for 12.63% of total inventors in the universe of patent applications, in relation to historical studies which account for female participation between 2 to 14% of the total patenting in many countries in the world (Mauleón and Bordons, 2010; Sugimoto et al., 2015). Participation of female inventors in patenting activities is outstanding, given the proportion of labor force represented by women in Mexico.

There is a strong relationship between the patenting activity of Mexican inventors, and the IPC section of Human Necessities. This is also proved by the use of the IPC-Technology Concordance Table, which shows the highest amount of patent applications in the technological field of Organic Fine Chemistry for both female and male Mexican inventors. This finding relates to the strongest technological areas in which Mexican inventors participate further study could show consistency with the academic subjects and industries developed in the country. This technological fields are likely to be the most productive in further time periods. It is also important to note the presence of patent applications in novel areas of technology such as biotechnology and medical technology that could represent fields of future growth in number of patents in further time spans.

The gender gap between technological fields has also been explored in other studies, and the results here obtained are similar to theirs, although the fields in which each of the countries inventions are most developed vary from one to another. However, there is concordance between the study by Mauleón and Bordons (2010) and ours in terms of the fields in which female inventors participate the most, and their lower participation in technology related activities. These phenomena has also been shown in other studies using national (USPTO, OEPM) and regional databases (EPO), which have pointed to a high involvement of female inventors in Chemistry, Pharmaceuticals and Life Sciences, and the lowest in Engineering and Physics (Frietsch et al., 2009; Giuri et al., 2007; Mauleón and Bordons, 2010; Naldi et al., 2004; Sugimoto et al. 2015). The findings in our study corroborate this information for the case of Mexico.

The differences between male and female Mexican inventors are accentuated by the fact that male inventors often use single-authored patent application, while mixed inventors´ teams are medium sized. This results in the fact that patent applications with male only inventors´ teams are presented to the offices by individuals thus the inventor himself or his representative being the patent holders. This has been used to establish a co-inventorship index related to the number of inventors collaborating in each patent application which could lead to further studies about the way inventors collaborate in each country. The higher co-inventorship index for mixed inventors´ teams show a collaboration pattern that might be studied in order to analyze their conformation. It is worth noting that there is also a high percentage of single authored patent applications within the female only inventor´s teams but given the proportion of this subset of the data analyzed we cannot say female inventors prefer to apply for patents alone, but they are present more often in mixed inventors´ teams.

Finally, the participation in patenting activities of the Academic Sector, both Mexican and foreign is low in comparison with the other sectors. Many papers have analyzed the desirability of patenting from the academic sector, task that could be taken for further work in the case of Mexico. This special case is studied in the next chapter, as well as the collaboration patterns between the academic sector and other national or foreign institutions.

We are convinced that it is very important to promote and develop gender desegregated research in a national basis in order to promote or support public policies that attain gender equality in Science and Technology activities and monitoring them throughout the years. Currently, international organizations such as the United Nations, WISET, UNESCO and PORTIA are publishing important studies inspired by scientific evidence of different countries and comprised in the proceedings of the Gender Summits from different years that clearly show how research and innovation outcomes are influenced by biological and social differences between females and males and by the growing scientific consensus to integrate gender as a dimension of quality and impact in research.

The United Nations and the 17 Sustainable Development Goals (SDGs) would raise the awareness of the importance of obtaining gender desegregated data and statistics. Although the scientific evidence available in other countries shows gender inequality issues can affect knowledge production, transference and application, there is no sufficient published work for the Mexican case.

The analysis in other time spans and comparison with the results obtained in this study might help forecasting participation of Mexican inventors in patenting activities according to the evolution of the technological fields promoted by public policies or new technological developments.

4.8 Further work

In the present study, the gender of the inventors was successfully identified in by using their first names and identification made for their male or female nature. But this couldn't be possible if either the researcher was not familiar with Spanish names, or if the names listed in the application were not Hispanic. When inventors of other cultures and countries are to be studied, this could be a strong limitation for the analysis. A standard list for common first names in many countries might be used in order to ease this task. However, the creation of the list itself might be a thorough and complicated task that would have to be addressed in an intercultural collaboration group, and it might happen that in one country one name is used regardless of the gender, or the situation might arise of a name used for males in one country and for females in another. Given this, the best solution to this problem would be to include an indicator of the gender of inventors in the patent application.

Patent applications do not provide any detailed demographic information of inventors such as age, level of education or gender. Therefore, it is desirable to complement data obtained by this instrument with other information sources. Some methods for collecting data on inventors could be surveys, identification of inventors in population databases using their name or social security numbers, analyzes of CVs in the case of academic inventors or direct contact with them. As no such data has been found in our case, the construction of these other databases must be considered as further work.

It would be interesting to analyze data from other time spans and compare the results with the decade that has been used in the present work. It would be desirable to analyze if the inclusion of Mexico to the TCP had any effect in terms of promoting patenting activities in the country, or if any other public policies have affected them strongly.

The analysis of academic patenting in Mexico is interesting and important. A comparison between Mexican institutions and foreign ones might be made in order to clarify this issue. Patenting activities in the industrial sector might be analyzed in order to find correlations between R&D expenditure and patent applications.

Chapter 5. Collaboration patterns in TCP academic patenting in Mexico

(An article regarding this Chapter has been sent to Science and Public Policy Journal)

Universities and other higher education institutions are key elements in the science system in all countries. They perform research and train researchers and other skilled personnel. The role of universities and scientific research in innovation systems has broadened in recent years. For example, according to the OECD, there is a 'growing demand for economic relevance' of research, and 'universities are under pressure to contribute more directly to the innovation systems of their national economies' (OECD, 1998)

Despite this broader role of universities in innovation, university patents worldwide represent only 5% of all inventions. While the top US university patent assignee - University of California - had almost 600 patented inventions in 2005 and in Asia, the University Quinghua, China, had 900, in Europe, the best university patent assignee - the CNRS (Centre National de la Recherche Scientifique) took the lead with just over 130 inventions (Trotter and Yeatman).

The literature on university–industry relationships is mainly empirical and based on case studies, patent and bibliometric analyses, or large surveys.

5.1 Abstract

A 20 year study was made using the PATENTSCOPE database to analyze patents applications placed by universities and public research institutes (hereinafter PROs) involving at least one Mexican inventor. A total of 367 cases were found, and the collaboration networks between countries and institutions resulting from them were constructed using Agnas. We identified 134 public research organizations from 23 countries including Mexico. Mexican institutions constitute 37% of the total, USA institutions account up to 23%, French institutions 12% and the pending 28% for

institutions from the rest of the world. Mexican institutions with the higher number of patent applications in the studied period were UNAM (61 applications), ITESM (49) and CINVESTAV-IPN (35). Current changes in Mexican legislation concerning technology transfer from academic institutions and research centers might enhance academic patenting, as well as collaboration with other institutions around the world. In terms of collaborations within patent applications, only 76 cases were found. Mexican academic institutions have collaborations in patent applications mostly with USA institutions (16), with other Mexican institutions (11), and French institutions (4). In terms of academy-industry collaborations we have found few cases (20), mainly between Mexican institutions and Mexican industries.

5.2 Introduction

Scientific and technological knowledge as well as innovation capacities are elements that contribute to increase national productivity and wellness of societies, it has been considered impulse of economic growth and could explain at least a part of economic development of the countries (Schumpeter, 1911; Cozzarin, 2006).

Studying knowledge producers (companies or institutions) and their research products (publications, patents, and benchmarks) can serve to understand how well interactions between them work.Most of the literature found on this specific subject focuses on developed nations or regions (European community). There are few studies regarding knowledge production in developing countries (González-Brambila 2014; González-Brambila et al., 2016).

Papers (in mainstream journals) and patents (or patent applications) are only a printed representation of some of the intellectual achievements of science and technology of humanity over time. However, the general trends of basic research efforts can be measured by the quantity of papers, and detailed information about technology inventions can be obtained from patents. Therefore, papers and patents can be used as proxy indicators of technological and scientific activity.

Research performance in academic institutions has been primarily assessed by using production statistics concerning publications in mainstream journals (Engels and Ruschenburg, 2009; González-Brambila 2014; Long 1990; Marmolejo-Leyva 2015; Mauleón and Bordons 2006).

The patent system has been a positive factor in promoting innovation and the diffusion of knowledge, this might lead to greater competitiveness and improved economic performance of the countries promoting the culture of intellectual property. Nevertheless, there are many doubts in terms of the social benefits of patenting no matter how good or bad are the statistics for each country (Elsmore, 2009). The participation of academic and public research institutions in the patenting activity raises even more doubts with respect to the social benefits it could have.

As can be seen, the evaluation of social impact of academic research is a real challenge taking into account only the printed research products: publications and patents. The social impact of academic research may be indirect by the formation of social capital (graduates or postgraduates that could interact with industries requiring a specific development), and direct in terms of a researcher developing and demonstrating a technology in a small scale or prototyping either by the commercialization (or licensing) of a patent title or by the creation of a spin-off. The direct impact has been studied in many countries (Cook and Leydesdorff, 2006; European Commission, 2007; Mathieu et al, 2008).

According to Geuna and Muscio (2009) universities have always been involved in knowledge transfer activities, and that the connection between scientists and their social contribution goes beyond the commercialization activities but this is difficult to measure (Bodas Freitas et al. 2013). Knowledge production at public research organizations (hereafter PROs) has gone well beyond the "first mission" of teaching, to a "second mission" of teaching and research and finally into a so called "third mission", in which research findings should be translated into marketable commodities (Etzkowitz, 2008; Etzkowitz and Webster,1998; Laredo, 2007). Academic patenting may be viewed as part of this third mission of PROs which refers to the social, enterprise, and innovative activities they might perform in addition to teaching and research tasks (Zomer and Benneworth 2011).

In the Mexican case the so called "third mission" of PROs is consistent with the neo-structural or triple helix model that has been applied since the late eighties, and has had a strong influence in the way academics and members of the private sector relate to each other in order to achieve scientific and technological development. The demand for services of all kinds from the private sector to the PROs accelerated the processes of commercialization of and in academy (Webster and Etzkowitz, 1991). Therefore the chosen period of study (1995-2015) is relevant given the historical frame line of the inclusion of this model and the integration of Mexico to the Patent Cooperation Treaty in 1995.

In general terms, technology ownership (in the form of patents) is important for universities because it could be licensed or sold providing revenue over the research process, and with this accomplish knowledge transfer in benefit of industry, government and ultimately society. Therefore, PROs are starting to promote patent filing although the reward system for the Mexican researchers encourages publishing above patenting (CONACyT, 2015). This is understood, as the general conception in the S&T National System (Ibidem) is that academic environments focus on basic knowledge and academics are mainly interested in pushing frontiers of research and understanding particular fundamental phenomena. Their research and innovation behavior is by definition less strongly connected to current technological markets than that of corporations. Therefore, generally speaking, university research is more basic and fundamental than industry research. Although academic patents resulting of research conducted in universities and PROs might be weakly related to specific technologies or other patents, the inventions they contain are likely to be of higher relevance for future technological developments (as they rely on frontier knowledge).

In terms of collaboration for patent filing, there are studies concerning linkages between universities and industry, the propensity of PROs to patent, licensing revenues, spin-offs and science parks mainly for European countries (Nelson 2001; Shane, 2005; Siegel et al. 2004; Thursby et al. 2001). And in the last decade some efforts have been made to document knowledge transfer from university to industry (Baldini 2006; Dutrenit et al. 2010; Fernandes et al. 2010; Ryan et al. 2008; Tijssen 2012). Of very special interest is the work by Dutrenit el al (2010 b) as it explores the Latin American and Mexican (2010) panorama.

This paper characterizes the patenting activities of Mexican inventors that are involved with academic institutions, and explores the collaboration patterns of these institutions with other academic organisms or with industry. The information and conclusions drawn might impulse universities to promote collaboration with other foreign or national entities in patent filing (taking advantage of collaboration links in terms of scientific publication). It would also serve as an indicator for assessing effectiveness of established public policy (CONACYT, 2015b and 2015c).

Academic patenting is important to promote university to industry technology transfer given that patents are a key instrument for protecting innovation in a number of science based technologies. "Academic scientists contribute to these technologies both indirectly, by widening the science base, and directly, by producing inventions susceptible of industrial application, and therefore protected by patents" (Lissoni et al.,2007).

WIPO acknowledges as well that university patenting has increased in importance and provides policy considerations as to the next steps in development of a" framework aimed at fostering a greater interaction between public research and industry in order to increase the social and private returns from public support to R&D" (WIPO, 2016).

5.3 Methodology

The purpose of this study is to analyze the involvement of universities and public research organisms (PROs) in patent applications with at least one Mexican inventor in a 20 year period after the inclusion of the country to the International patent treaty (PCT) in 1995. It is based on applications published in the WIPO (2015) database (PATENTSCOPE) instead of doing it on granted patents given that the publication of a patent application is the first formal and public knowledge of the invention it describes (Balconi et al 2004; Breschi et al 2007; Frietsch et al 2006) and that the time to grant a patent in the regional or national offices is often very long. The WIPO database concentrates all patents filed under PCT whichever the regional or national patent office has been chosen by the inventor(s) or patent holders. We have focused in the segment of academic institutions comprising universities, research centers, public research institutes and government agencies or councils.

The search results were organized taking into account the patent applicant field, and discriminating the academic applications. Afterwards, the registries have been analyzed individually to determine the number and nationality of the institutions. The number of patent applications for each institution accounts for the total number of times it appears (full counts). The two letter code used in PATENTSCOPE for the identification of the nationality of the institutions was used.

The collaboration networks were constructed using Agna (Huisman et al. 2011) and comprise collaboration between academic institutions, collaboration between academy and industry and collaboration between Mexico and the nations in which either foreign academic institutions or industries reside.

5.4 Results

5.4.1 Academic Institutions with PCT patent applications and at least one Mexican inventor

There has been a continuous increase in the number of academic patents in the period of study, as can be seen in Figure 5.1, although the number of academic patents is extremely low when compared with the total of patent applications filed in the same period (367 academic patent applications/3350 total patent applications). These applications correspond to Universities, research centers, national institutes that develop R&D activities, boards of trustees of different universities and public research foundations.

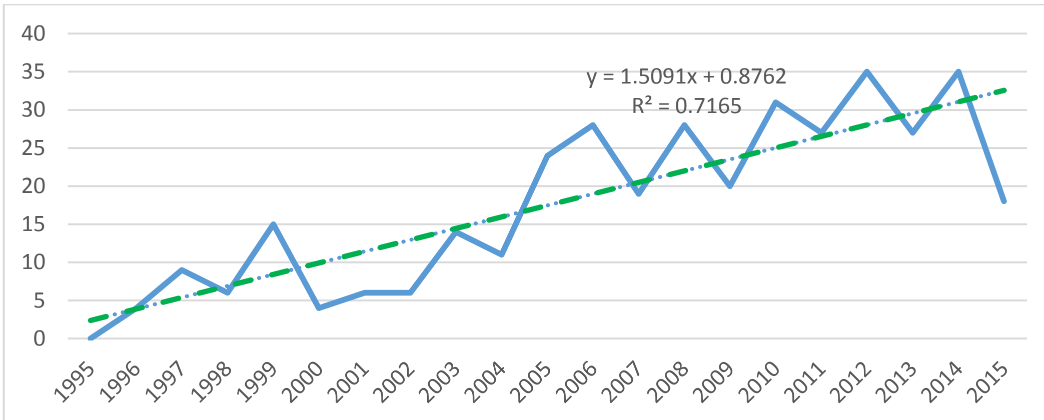


Figure 5.1. Academic patent applications from 1995 to 2015 with at least one Mexican inventor.

We found 134 institutions that correspond to this classification, where 37% are Mexican, 23% are based in United States of America, 12% are French and the remaining 28% are institutions from other countries around the globe. As stated, at least one of the inventors listed in the patent application is Mexican. There have been found some cases in which the patent applicant is a foreign institution, without any collaboration of Mexican PROs, but with participation of one or more Mexican inventors. This phenomena has implications such as the participation of Mexican students in foreign institutions' developments or scientific diaspora from our country to other places in the globe. There are studies that refer specifically to these cases (Castaños, 1998; Didou, 2008 /2011; Marmolejo-Leyva, Pérez-Angón and Russell, 2015).

The Mexican institutions holding the biggest number of patent applications in the period under study are shown in Table 5.1. The complete list of 50 Mexican institutions with patent applications found is shown on Appendix B.

INSTITUTION	NUMBER OF PCT PATENT APPLICATIONS
Universidad Nacional Autónoma de México (UNAM)	61
Instituto Tecnológico de Estudios Superiores de Monterrey (ITESM)	49
Centro de Investigación y Estudios Avanzados del Instituto Politécnico Nacional (CINVESTAV)	35
Universidad Autónoma Metropolitana (UAM)	25
Instituto Mexicano del Petróleo (IMP)	18
Instituto Politécnico Nacional (IPN)	12

Table 5.1. Top Mexican institutions with PCT patent applications (1995-2015)

The top foreign institutions holding academic patent applications with at least one Mexican inventor from 1995 to 2015 are shown in Table 5.2. The complete list of foreign academic institutions is found on Appendix C.

INSTITUTION	COUNTRY	NUMBER OF PCT PATENT APPLICATIONS
Centre National de la Recherche Scientifique (C.N.R.S)	France	9
The Regents of the University of California	U.S.A.	7
Children´s Hospital Medical Center	U.S.A.	5

Board of Regents the University of Texas system	U.S.A.	4

Table 5.2. Top Foreign institutions with PCT patent applications that include at least one Mexican inventor (1995-2015)

5.4.2 Collaboration between countries

Mexican academic institutions collaborate mostly with other Mexican institutions or companies. Collaboration with the rest of the world is shown in Figure 5.2. The number of collaborations is shown next to the connection between nodes. It is worth noting the strongest collaboration link is with the United States (16 cases), followed by France (7 cases). Countries which have patent applications filed by PROs with no collaboration with Mexican institutions but still have at least one Mexican inventor are pictured as outliers in the network.

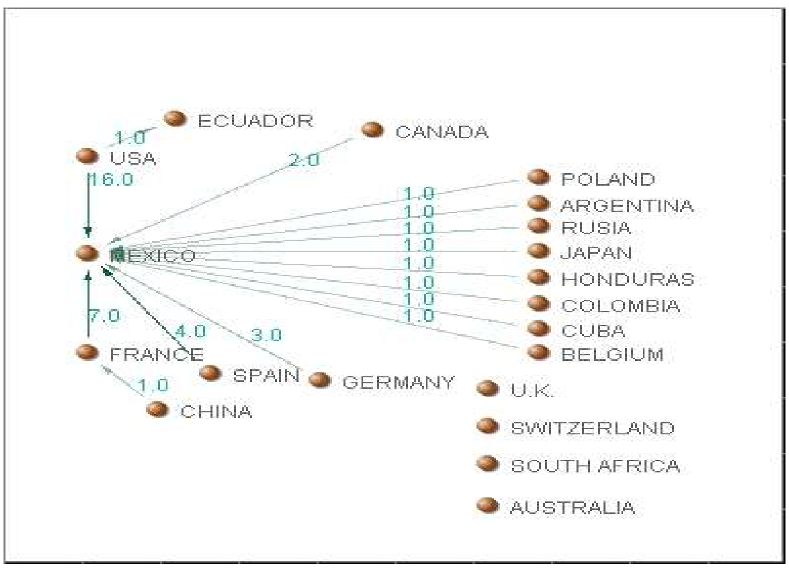


Figure 5.2. Collaboration between PROs according to their countries.

5.4.3 Academy-Industry collaboration

There are benefits that may be obtained through PROs interactions with industry. Firms might obtain a different perspective from which to solve their problems and perform product or process innovations, they also benefit from highly skilled research teams, new human resources, and access to different approaches to problem solving. On the other side, PROs might benefit from additional funding (when legislation permits it), and a way to guide their research to solving specific requirements.

Policy-makers have recently been particularly concerned about knowledge transfer through patents. Although, as said in the introduction, researchers in general have traditionally been reluctant to filing patents or to interact with industry. According to some authors, Latin American universities were traditionally disconnected or opposed to both government and industry (Arocena and Sutz, 2005). This has been changing in recent times (FCCT, 2015) and researchers, PROs managers and even policy makers are willing to establish interactions between al actors. There is a general perception that PROs interactions with industry in Latin America are weak (Cassiolato et al., 2003; Cimoli, 2000; Dutrénit et al., 2010; López, 2007). The results from our study are consistent with those studies. In figure 5.3, the collaboration network of Mexican PROs with foreign industries is pictured, while in table 5.3, we show the Mexican PROs with collaborations with industry either Mexican or foreign.

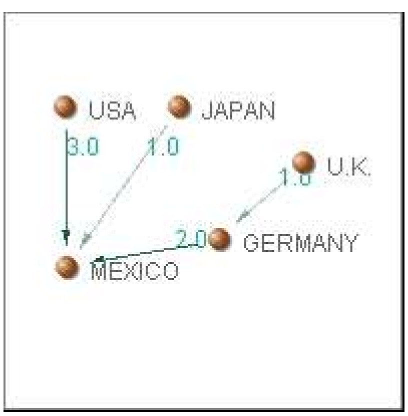


Figure 5.3. Collaboration between Mexican PROs and foreign industry.

INSTITUTION	# COLLABORATIONS WITH INDUSTRY
Instituto Tecnológico de Estudios Superiores de Monterrey (ITESM)	5
Universidad Nacional Autónoma de México (UNAM)	3
Universidad Autónoma Metropolitana (UAM)	3
Centro de Investigación en Química Aplicada (CIQA)	3
Centro de Investigación y Estudios Avanzados del Instituto Politécnico Nacional (CINVESTAV)	2
Universidad Autónoma de Guadalajara (UAG)	1
Universidad de Guanajuato (UG)	1
Instituto Politécnico Nacional (IPN)	1

Table 5.3. Collaborations with industry by institution.

As can be seen, Mexican institutions are characterized by weak interactions between the industrial and academic sectors, being our results coherent with the stated by AIHEPS (2005), Casas et al. (2000) and CONACYT (2006). There have been other studies analyzing particular cases of universities from one of the Mexican states (Villasana, 2011) that are consistent with our findings.

5.4.3 Patent filing collaboration between Public Research Organizations

In the period under study, we found a greater collaboration between PROs than the one with industry. A total of 54 over 367 academic patent applications were written in collaboration with other PROs either Mexican or foreign. In figure 4 collaborations between Mexican PROs are plotted according to the nationality of the counterpart PRO. The larger collaboration networks found were for UNAM and CINVESTAV-IPN both with 12 counterpart PROs, followed by UAM (11), Instituto Mexicano del Seguro Social (10), Instituto Nacional de Neurologia y Neurocirugia Manuel Velasco Suarez (8), and Instituto Nacional De Ciencias Médicas Y Nutrición 'Salvador Zubirán' (6). The collaboration networks for the PROs that according to our study have the biggest number of counterpart PROs are shown in figures 5.5a. 5.5b. and 5.5c.

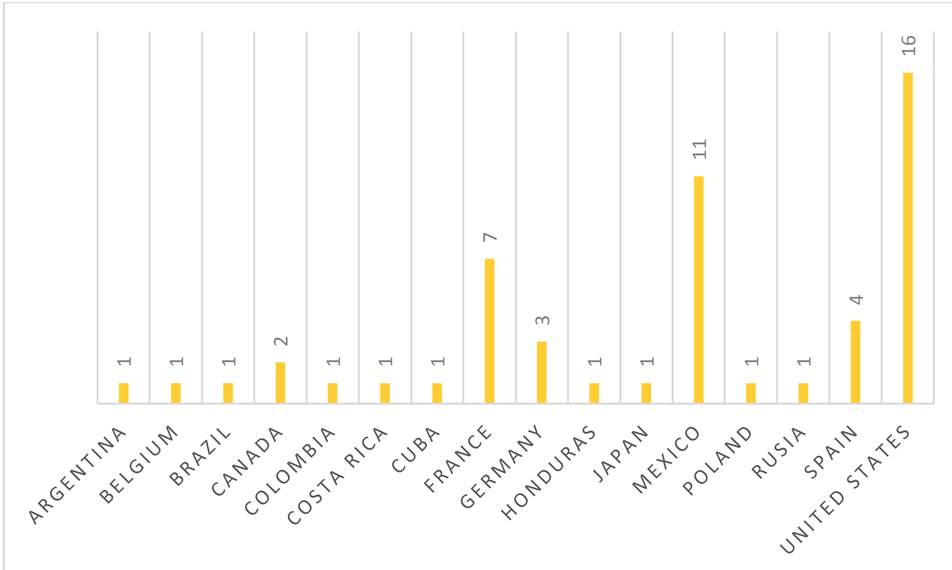


Figure 5.4. Collaboration of Mexican PROs with foreign and national institutions.

Figure 5.5a. CINVESTAV-IPN collaboration network

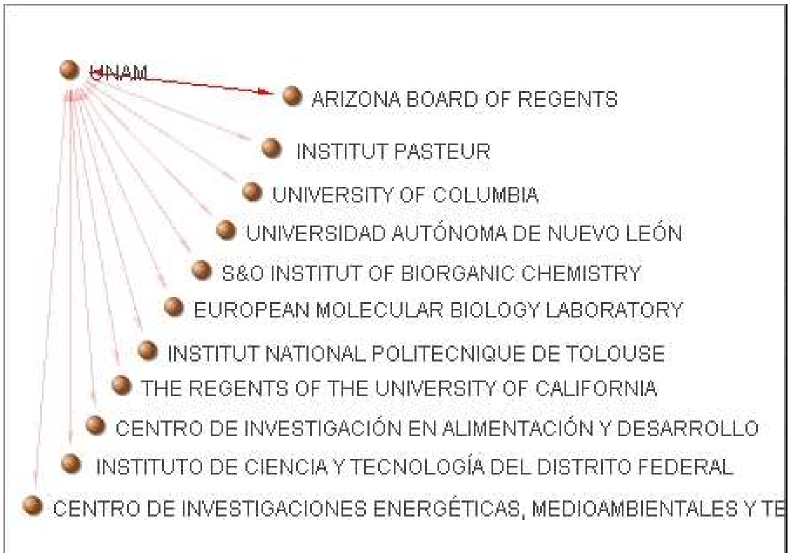


Figure 5.5b. UNAM collaboration network.

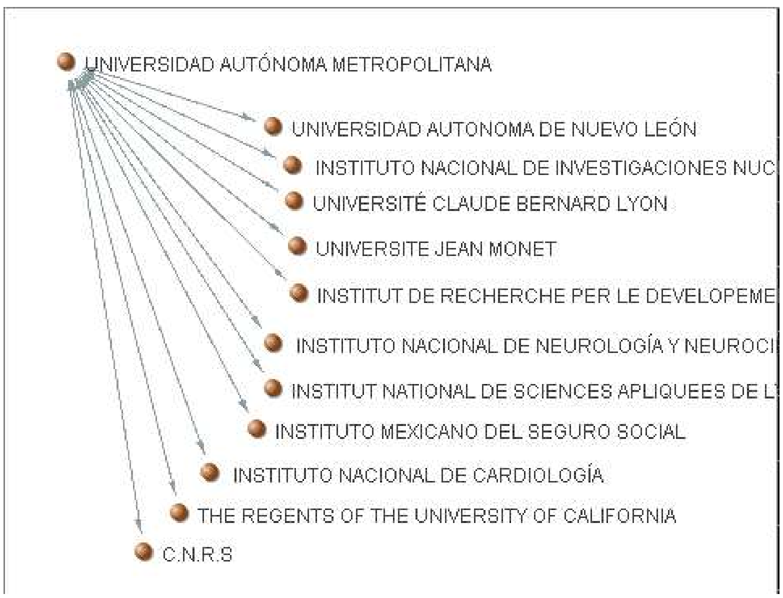


Figure 5.5c. UAM collaboration network.

5.4.4 Academic patents and International Patent Classification (IPC)

The International Patent Classification (IPC) described also in the WIPO page was used to identify the section the academic patent applications found relate to. The IPC proposed by the World Intellectual Property Organization (WIPO) was established by the Strasbourg Agreement in 1971. It consists in a hierarchical system of language independent symbols according to different areas of technology. The IPC version used is the one that came into force on January 1st 2015. The IPC serves as: (a) an instrument for the orderly arrangement of patent documents in order to facilitate access to the technological and legal information contained therein; (b) a basis for selective dissemination of information to all users of patent information; (c) a basis for investigating the state of the art in given fields of technology; (d) a basis for the preparation of industrial property statistics which in turn permit the assessment of technological development in various areas (Guide to the IPC 2014). For our purpose, IPC was used to determine growth of academic patent applications in each section, shown in table 5.4; and the incidence of patent applications for each IPC section shown in figures 5.6a and b.

	1995-2004	2005-2015	Increase (percentage)
A. Human necessities	16	79	79.75
B.Performing Operations/Transporting	3	28	89.29
C. Chemistry/Metallurgy	20	98	79.59
D. Textiles/Paper	0	0	0
E. Fixed Construction	0	3	100
F.Mechanical Engineering/Lighting/Heating/Weapons/Blasting	1	9	88.89
G. Physics	4	31	87.10
H. Electricity	0	9	100

Table 5.4. Number of Mexican academic patent applications and their increase between the first and second decade of our study.

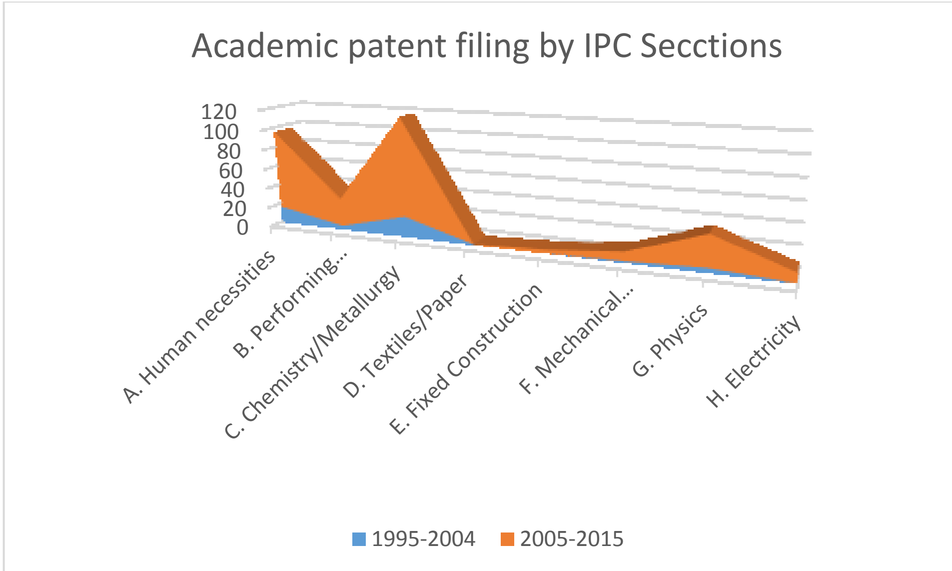


Figure 5.6a. Contribution from each period to the number of patent applications by IPC sections.

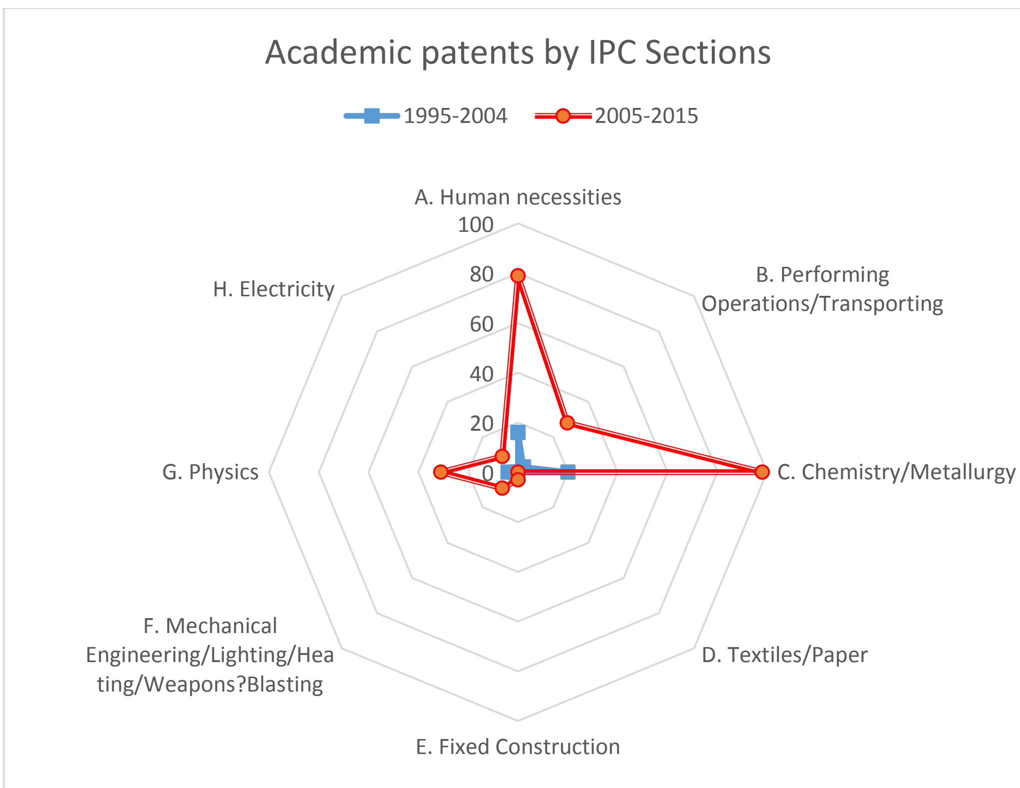


Figure 5.6b.

In relation to the applications filed in collaboration with other academic institutions the same phenomena is observed. The sections in which Mexican academy and its collaborators file the biggest number of patent applications are in first place Chemistry and Metallurgy followed by human necessities. Results are consistent with the general trend of academic patenting and with the Statistical Country Profile for Mexico provided by WIPO statistics database (2016).

idad	1995-2004	2005-2015	Increase (percentage)
A. Human necessities	2	18	88.88
B. Performing Operations/Transporting	0	1	100
C. Chemistry/Metallurgy	7	20	65
D. Textiles/Paper	0	0	0
E. Fixed Construction	0	0	0
F. Mechanical Engineering/Lighting/Heating/Weapons?Blasting	0	0	0
G. Physics	0	6	100
H. Electricity	0	2	100

Table 5.5. Increase of collaborations in patent applications.

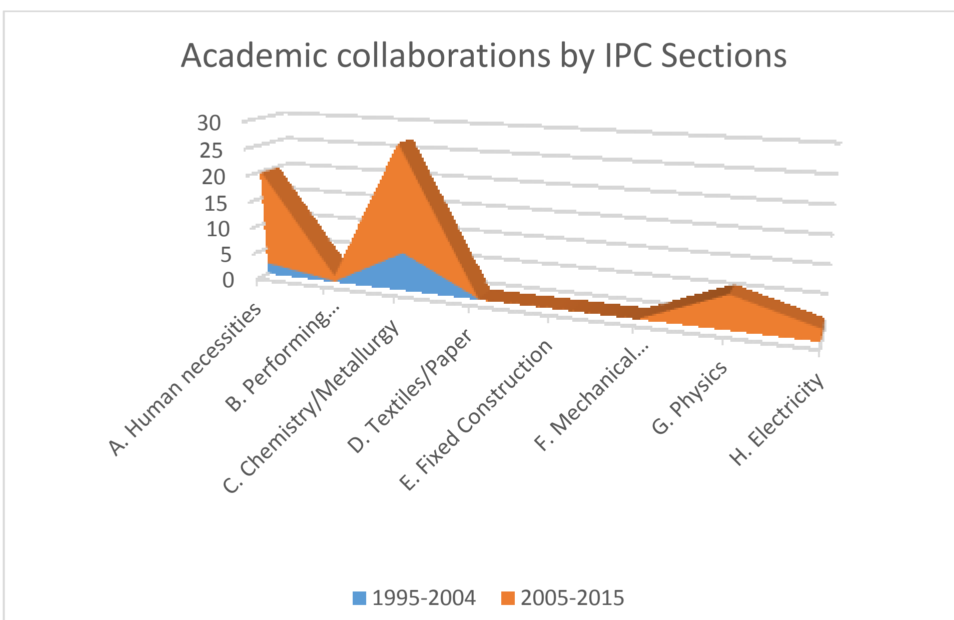


Figure 5.6. Academic collaborations by IPC sections.

In our analysis it is clear that Chemistry and Metallurgy areas this finding relates to the strong Chemistry school in Mexico that has been historically productive in publications and patents in all the branches of the discipline (Atlas 2014). However, other Sections have experienced a bigger increase, and some that had not been exploited by Mexican inventors within the academy are being explored.

5.4.5 Conclusions

Studying patent applications can provide with useful information regarding the way science is applied in benefit of society. As this is a general question and demand in our times, these studies are important and should be promoted as it has been made by OECD (1994) in national and international levels. We have explored PATENTSCOPE database (WIPO, 2015), as it contains all patent applications filed under the PCT regardless of the patent office in which the application has been filed. This is an advantage in comparison to studies made exclusively on particular databases such as the one held by the Mexican Patent Office (IMPI) as in Meza-Rodriguez et al. (2015), the United States patent office (USPTO) as in Guzmán (2012) or Sugimoto et al. (2015), or the European patent office (PATSTAT) as in Frietsch et al. (2009) and Toivanen and Suominen (2015).

Academic patents are of special interest as given the fact that there has been an effort to relate the actors of National Innovation Systems and analyze interactions between them (Dutrenit, 2010). In this study, we have found that in terms of patent filing, the relations between Public Research Organizations (PROs) that include universities, public research centers and institutes and industries are weak. The academic patents written in collaboration with industry account only 5.4% of the total academic patents and 0.6% of the total patent applications with at least one Mexican inventor count in the period under study.

Collaboration of PROs with other institutions on their same sector are better, although the percentage of academic patents written in collaboration with other PROs represents only 14.7% of academic patent applications and 1.6% of the total patent applications. The networks constructed around the academic patent applications found reveal that there are few PROs that have collaboration with other institutions on their own sector, and that only three of them (UNAM, CINVESTAV-IPN and UAM) have constructed a network bigger than 10 participants. This is directly related with their scientific relevance in the country and in further studies it would be interesting to find the correlation between collaboration in publishing and collaboration in patent filing.

The areas in which academic patent applications with Mexican inventors are found are concentrated on the Human necessities and Chemistry/Metallurgy IPC sections. Therefore these areas are considered the strongest in technological profile for our country. This is consistent with the statistic national profiles given by WIPO, although this site considers patent holders instead of inventors. We chose to study the inventors field to visualize the human factor involved in patent filing.

Further work might include the comparison of these percentages with other Latin American countries and the globe but there has not been found literature concerning this problem with the required specificity. Our results may well serve to complement other studies like the one of Brambila et al. (2016) that consider the scientific impact of developing countries, including Mexico and use resident patents (instead of academic patents) as an input for their analysis.

In terms of public policy, the National Science Council (CONACyT) has implemented some strategies that aim to promote interactions between actors that generate knowledge and the business part of the triple helix model. There are programs aimed at micro-, small and medium sized enterprises that require them to include a university in their project proposals in order to receive financing (CONACyT, 2015b). Recently, there have been changes in the Science and Technology Federal Law that will enable Mexican researchers to benefit from their work economically (FCCT, 2015) making thus even more important the knowledge and application of Intellectual Property (including patents).

It is important to highlight that patenting activities should be promoted at PROs under the assumption that only high quality patents, and the implementation of appropriate transfer mechanisms can indeed be beneficial for PROs themselves and the rest of the society. The assessment of social benefit of technological activities within PROs could be then objective and echo in public policy making.

Chapter 6. General conclusions

There are many activities that contribute to the development of a country. In the last decade, the importance given to Innovation in the whole world as a source and shaper of a nation´s development has grown. Innovation studies have taken relevance and are now a popular research topic. There are many angles to deal with innovation studies. One of them, the PCT patent applications is taken in this dissertation, and although there are some studies concerning patents in general, we have given a twist to the subject by concentrating our efforts in taking a close look to the human factor of the patent applications: the inventors.

We have established in Chapter 3 a relationship between public policy and patenting activities, analyzing the effects of the inclusion of Mexico to an international treaty (PCT) and comparing our country's panoramic with those of Chile and Brazil, other two Latin American countries with similar economic parameters, but different policies in science and technology culture, and that entered the same treaty in very different times of their history and the regulations' history.

As for Mexico and Chile, the inclusion to the PCT has proved beneficial, showing a sharp increase in patent filings following the TCP route that helped both countries follow international trends in this respect. A case to be noted is the Chilean, as they have a higher percentage of patent filing to the national phases via the PCT than the other countries compared, and even than the world's average. For Brazil the case is not the same, their early inclusion to the PCT showed no true effect on the number of patent filings; the behavior of this giant of South America corresponds to other factors such as their internal policy.

Another interesting but already known information about patenting activities of the three countries is their high percentage of patents applied by Non-residents. The three countries con be considered big markets for the firms and individuals filing those patents in our countries.

Given this conclusions, it would be important to analyze other public policies that have been changed or newly established and affect patenting activities especially in our country and that have the purpose of ascending to higher states of economic development based on Science and Technology.

Specifically, it would be interesting and necessary to address the parliamentary politics on Science, Technology and Innovation of the LXII legislature which has tried to build bridges between legislators, the organized scientific community, the young students and the firm directors.

The approval and implementation of a flexible legislation that promotes participation of scientists, institutions, research centers and other actors in the technology transfer and makes possible the creation of technology based enterprises by them would give an extraordinary impulse to social and economic development of the country.

In Chapter 5 we have analyzed the way that the academic sector collaborates with other national or international actors. The recent approved changes to the Science and Technology Law and the Administrative Responsibilities of Public Officials Law are oriented to have a vast preparation of human capital (with more postgraduate students) and redirection the scientific tasks to technology development, innovation and intellectual property.

"Encouraging universities to commercialize research results by granting them title to IP can be useful but it is not sufficient to get researchers to become inventors. The key is that institutions and individual researchers have incentives to disclose, protect and exploit their inventions. Incentives can be “sticks” such as legal or administrative requirements for researchers to disclose inventions. Such regulations are often lacking in many countries, even in those where institutions can claim patents." (Cervantes, WIPO documents)

Indeed, in 1980, the United States passed what is widely considered landmark legislation, the Bayh-Dole Act, which granted recipients of federal R&D funds the right to patent inventions and license them to firms. The main motivation for this legislation was to facilitate the exploitation of government-funded research results by transferring ownership from the government to universities and other contractors who could then license the IP to firms. Although patenting in US universities did occur prior to the passage of Bayh-Dole Act, it was far from systematic.

At the end of the 1990s, emulating the US policy change, many other OECD countries reformed research funding regulations and/or employment laws to allow research institutions to file, own and license the IP generated with government research funds. In Austria, Denmark, Germany and Japan, the main effect of these changes has been the abolishment of the so-called "professor's privilege" that granted academics the right to own patents. The right to ownership has now been transferred to the universities while academic inventors are given a share of royalty revenue in exchange. There has also been debate in Sweden on whether to follow a similar path and transfer ownership to institutions. For now at least, the status quo remains and policy efforts are focusing on developing the ability of universities to provide professors with support for patenting.

Mexico has a well constituted scientific community of researchers in (around 23,000) or out (not counted) the researchers national system (SNI as an Hispanic acronym for Sistema Nacional de Investigadores). Even when the proportion of 1.6 researchers for each 10 thousand inhabitants is far from optimum (compared with developed countries that have between 5 to 10 researchers for each thousand inhabitants) the capacity and quality of research made in Mexico is undeniable. Our country has a great economy, but there are few national firms that impulse innovation, the technological balance with the rest of the world is negative and both private and public inversion in competitiveness and patents is limited. It is thus imperative to have a national industry that "talks" to the academic sector to find solutions to national problems today are in the future.

Finally, to achieve this objectives, it is necessary to create a ground base information, with solid statistics that can give the picture of where are we standing in the present. This is the purpose of Chapter 4 of this dissertation in which gender desegregated research is made considering only one particular aspect of patenting activities at a national basis: where are the female inventors? This analysis would be important to promote or support public policies that attain gender equality in Science and Technology activities and monitoring them throughout the years.

Currently, international organizations such as the United Nations, WISET, UNESCO and PORTIA publish important studies inspired by scientific evidence of different countries. Many of these studies are comprised in the proceedings of the Gender Summits, in which part of this dissertation will be published.

It is clear that research and innovation outcomes are influenced by biological and social differences between females and males and thus the growing scientific consensus to integrate gender as a dimension of quality and impact in research gives support to our efforts to integrate this angle to the construction of the data here shown.

The United Nations and the 17 Sustainable Development Goals (SDGs) would raise the awareness of the importance of obtaining gender desegregated data and statistics. Although the scientific evidence available in other countries shows gender inequality issues can affect knowledge production, transference and application, there is no sufficient published work for the Mexican case. We could then continue with this important work in other innovation and gender related subjects.

We have also established the strongest technological fields in which Mexican inventors, both, male and female, participate: The Chemistry and Metallurgy field. An insight into this field now looking for firms and individual patent holders might be desirable as further work, and the technology surveillance on branches such as Bio and Nanotechnology, still not broadly developed would prove very interesting.

As can be seen, we have just opened a door, given a few steps into the understanding of patenting activities for Mexican inventors and found a lot of information that could be used to understand the nature of the activities and the actors themselves. Many more steps could be given, and many other dimensions studied. As typical as it can be said, this is just the beginning.

ANNEX A. The decentralization process of Mexican Physics

El proceso de descentralización de la física Mexicana

(In press Revista Mexicana de Física)

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Abstract

Statistical data supporting the relatively fast process associated to the decentralization of the research and graduate studies of the Mexican physical community is presented. The period under study goes from 1987 to 2013. We include information on the evolution of the number of researchers, their production and impact in mainstream journals. In particular, the graduate programs have matured enough in such a way that most of the active researchers in physics have been graduated in local institutions.

Resumen

Se presenta información estadística recabada en el periodo 1987-2013 que documenta el acelerado proceso de descentralización de la física mexicana: número de investigadores activos, miembros del SNI, producción científica e impacto en revistas de corriente principal. Además, los programas de doctorado mexicanos en el área de las ciencias físicas han evolucionado hacia una autosuficiencia en la formación de nuevos investigadores.

Introducción

La comunidad de físicos mexicanos es una de las más estudiadas en nuestro país. Cuando Jorge Flores tenía el cargo de subsecretario de educación superior universitaria a principios de la década de 1980, organizó un simposio sobre la situación de los programas de licenciatura y posgrado en nuestra especialidad.

Algunas de las contribuciones presentadas en ese simposio fueron publicadas en la revista del Conacyt "Ciencia y Desarrollo" [1,2]. Poco después, una vez que se instaló el Sistema Nacional de Investigadores (SNI) en 1984, Salvador Malo, como director del SNI, empezó a publicar una serie de artículos con información estadística sobre los diferentes gremios científicos representados en este sistema [3]. Por otra parte, en la Sociedad Mexicana de Física (SMF) se instaló en 1986 una nueva mesa directiva, encabezada por Rubén Barrera, que impulsó la renovación de sus diferentes reuniones académicas y de sus publicaciones, entre ellas la *Revista Mexicana de Física* [4]. Además, creó dos nuevas publicaciones que ayudaron a mejorar la comunicación entre los miembros de la SMF y a recabar información estadística sobre nuestra comunidad: el *Boletín de la Sociedad Mexicana de Física (BSMF)* [5] y el *Catálogo de Programas y Recursos Humanos en Física (CPRHF)* [6], que posteriormente se transformó en el *Catálogo Iberoamericano de Programas y Recursos Humanos en Física*. Estas publicaciones siguen vigentes y, en particular, el *BSMF* ha publicado una serie de análisis sobre diferentes aspectos de nuestra comunidad [7].

El presente artículo incluye información que hemos recabado en el *Atlas de la Ciencia Mexicana (ACM)* [8] sobre el proceso que ha experimentado el gremio de físicos mexicanos en los últimos treinta años y que se caracteriza principalmente por una profunda descentralización. La presentación estará dividida en tres partes: planta académica (capitulo 2), producción e impacto científicos registrados en revistas de corriente principal (capitulo 3) y el Sistema Nacional de Investigadores (capitulo 4). En el capítulo 5 se presentan algunas conclusiones.

Planta académica

A partir de 1987 empezamos a recabar información estadística sobre la planta de investigadores y profesores asociados a los diferentes programas de licenciatura y posgrado en el área de las ciencias físicas por medio del *Catálogo de Programas y Recursos Humanos en Física*. En la Tabla 1 se muestra el número de investigadores con doctorado registrados cada año a partir de 1987. Como se puede apreciar, el incremento de la planta académica fue del orden del 10% anual en los primeros años pero en años recientes este incremento es solo del orden del 5%. De paso también se puede observar que el porcentaje del género femenino no ha pasado del 15% en el transcurso de los años [8,9], y es el más bajo dentro de las 10 áreas del conocimiento que registra el *Atlas de la Ciencia Mexicana (ACM)* [8].

En la Tabla 2 se incluyen los indicadores sobre la planta académica que apuntan claramente hacia un proceso de descentralización de la física mexicana: porcentaje de investigadores con doctorado ubicados en la Ciudad de México, así como los investigadores adscritos a las dependencias de la UNAM. Además se incluye la evolución del número de investigadores activos que se han formado en los programas de doctorado de las instituciones mexicanas. Todo ello soporta la tendencia de un proceso de descentralización de los físicos mexicanos. Según los datos generados por el *Atlas del Ciencia Mexicana 2014*, solo los gremios de agrociencias e ingenierías tienen un proceso de descentralización más acentuado que el gremio de físicos mexicanos [8].

El número de programas de posgrado en física ubicados fuera del área metropolitana de la Ciudad de México también soporta esta tendencia descentralizadora: de los 30 programas de doctorado en esta área del conocimiento, solo 7 están ubicados en la CDMX [9] y, además, los miembros del SNI adscritos a instituciones fuera de la CDMX es del 63% [9]. Es interesante verificar que el número de programas de doctorado en física se estabilizó a partir de 2002 y solo 3 de los 35 programas se abrieron en años recientes: fisicoquímica de la Unidad Mérida del Cinvestav, nanociencias del CNyN-UNAM, y ciencia de materiales del IPICyT.

En la Tabla 3 se incluye la evolución del número de investigadores en física por disciplina a partir de 1987. Es interesante resaltar que las cuatro disciplinas más cultivadas en nuestro gremio (materia condensada, óptica, astronomía y fisicomatemática) cubren más del 50% de los 2000 físicos activos en investigación. En particular, sorprende que la óptica y la astronomía sean dos de las áreas más cultivadas en nuestro país. De acuerdo con la tendencia registrada en el ACM, esta circunstancia se debe al impulso que les han dado varios Centros Conacyt.

Producción y repercusión científicas

El gremio de los físicos mexicanos también es uno de los que profesionalizó más rápidamente la actividad de investigación en nuestro medio. Esta afirmación se puede documentar con un dato sobre la evolución de su producción científica en revistas de corriente principal: en 1980 los físicos publicábamos solo un tercio de la producción científica de los médicos y la mitad de los biólogos mexicanos, pero para 2010-2013 nuestra producción de artículos es similar a la producción de estos dos gremios [8].

En la Tabla 2 se puede observar también la evolución de la producción de artículos originales por parte de los físicos mexicanos entre 1987 y 2013. Se aprecia una clara tendencia de descentralización de esta producción. Además, el impacto (número de citas generadas por los artículos publicados) también ha tenido una clara tendencia hacia la descentralización. Podemos observar que los porcentajes de citas son mayores de los respectivos porcentajes de artículos debido a que el número de investigadores con el Nivel III del SNI es mayor en las instituciones de la CDMX que en los otros estados del país [8]. De manera natural, los investigadores con mayor antigüedad (Nivel III) acumulan un mayor número de citas que los investigadores más jóvenes.

Sistema Nacional de Investigadores (SNI)

Estudios recientes han confirmado que la creación del SNI fue un factor determinante en el incremento de la producción científica mexicana, y por supuesto también para la producción de los físicos mexicanos [10]. Cuando Jorge Flores propuso la creación del SNI como subsecretario de la SEP, tenía en mente detener la emigración de científicos mexicanos debido a la crisis por la atravesaba el país en la década de 1980. La idea funcionó y no solo detuvo el éxodo de científicos, sino que ayudó a atraer investigadores mexicanos radicados en el extranjero y también a un buen número de colegas extranjeros. Desgraciadamente, este proceso se ha detenido en años recientes y ahora podemos documentar una diáspora científica mexicana que tiene interés en incorporarse a las instituciones nacionales pero que no es posible por falta de recursos [11].

También se ha documentado que el SNI ha incorporado los investigadores mexicanos más activos [12] y que el porcentaje de físicos mexicanos activos en investigación con registro en el SNI rebasa el 90% [8]. Otro aspecto asociado a la descentralización de la física mexicana está identificado con el grado de consolidación de grupos de investigadores en varias entidades federativas; además de los grupos ubicados en la Ciudad de México (CDMX, con más de 700 investigadores), las siguientes entidades cuentan con grupos muy activos en investigación y en la formación de nuevos investigadores: Puebla (189), Guanajuato (140), Baja California (102), Morelos (82), Estado de México (65), Jalisco (61), Michoacán (58), San Luis Potosí (56) y Sonora (50).

Creemos que hay un aspecto donde la actividad de los miembros del SNI podría ser mejorada: la generación de patentes tanto en los registros nacionales como los internacionales. Estudios recientes sobre este tema indican que es muy bajo el porcentaje de miembros del SNI que han generado este tipo de patentes [14]. Los procesos de evaluación académica, tanto del SNI como de la mayoría de las instituciones mexicanas, valoran muy poco esta actividad y quizás sea el momento de darle mayor importancia.

Conclusiones

Además de sus actividades asociadas a la administración académica, Jorge Flores también ha tenido una actividad científica muy destacada. En el *ACM* hemos llevado un registro de los artículos de investigación original, publicados en revistas de corriente principal y por investigadores adscritos a instituciones mexicanas, que han recibido por lo menos cien citas en los índices internacionales. Jorge Flores tiene el mérito de haber publicado un artículo con más de 1,400 citas [13], lo cual es un fenómeno realmente extraordinario en nuestro medio [8].

La visión que tuvo Jorge Flores en 1983-1984 para convencer a nuestros políticos ubicados en la SEP y la Secretaria de Hacienda, ha rendido suficientes frutos tan solo con la creación del SNI. Pero también ha tenido una actividad determinante en la creación de nuevos grupos de investigación fuera de la CDMX y con ello ha contribuido al acelerado proceso de descentralización de la física mexicana. En perspectiva, quizás sería conveniente impulsar un proceso de descentralización similar para el SNI, con la incorporación de la evaluación académica en cada institución de manera que los estímulos económicos asociados a cada nivel académico fueran incorporados directamente a los tabuladores de cada institución. Este proceso podría influir en la aceleración de un proceso de jubilación razonable para muchos investigadores en los niveles II y III del SNI, lo que a su vez podría influir en la renovación de nuestra planta académica.

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Tabla A.1. Evolución de la planta de profesores e investigadores adscritos a las instituciones mexicanas entre 1987-2013 en el área de ciencias físicas. Entre paréntesis se indican los números correspondientes al género femenino. (ACM)

Año	Doctorado	Maestría	Licenciatura
1987	337	187	139
1988	390	218	248
1989	412	241	199
1990	462	259	185
1991	497	308	261
1992	591	329	278
1993	621	331	275
1994	732 (71; 9.6%)	373 (50; 13.4%)	345 (38; 11.0%)
1995	804 (89; 11.1%)	291 (53; 18.8%)	268 (39; 14.6%)
1996	889 (101; 11.4%)	279 (55; 19.7%)	176 (17; 9.7%)
1997	896 (103; 11.5%)	246 (49; 19.9%)	169 (20; 11.8%)
1998	920 (112; 12.2%)	208 (45; 21.6%)	142 (19; 13.4%)
1999	1024 (121; 11.8%)	198 (34; 17.2%)	151 (13; 8.6%)
2000	1041 (116; 11.1%)	165 (31; 18.8%)	159 (14; 8.8%)
2001	1109 (132; 11.9)%	211 (33; 15.6%)	145 (12; 8.3%)
2002	1213 (139; 11.5%)	255 (48; 18.8%)	147 (15; 10.28%)
2003	1236 (163; 13.2%)	188 (33; 17.5%)	118 (13;11%)
2004	1296 (157; 12.1%)	175 (24; 13.8%)	109 (6; 5.5%)
2005	1367 (169; 12.4%)	167 (24; 14.4%)	99 (7; 7.1%)
2007	1412 (200; 14.2%)	168 (31; 18.5%)	113 (9; 7.9%)
2009	1723 (217; 12.6%)	163 (28; 17.2%)	109 (8; 7.3%)
2013	2006 (298; 14.9%)	182 (34; 18.7%)	106 (7; 6.6%)

Tabla A.2. Indicadores sobre la descentralización de la física Mexicana (porcentajes, 1987-2013).

Indicador	1987	2004	2009	2013
Investigadores formados en México	30	45	51	58
Investigadores formados en la CDMX	70	41	35	35
Artículos por institución de la CDMX	74	55	49	42
Citas por institución de la CDMX	84	63	51	48
Investigadores en la UNAM	51	36	29	31
Investigadores experimentales	38	45	50	56

Tabla A.3. Distribución por especialidad de los investigadores con doctorado en el área de las Ciencias Físicas (2002-2013, ACM)

	2002	2009	2013
Materia condensada	247	367	378
Óptica	144	284	333
Fisicomatemática y gravitación	105	194	214
Astronomía y Astrofísica	119	181	204
Física estadística	96	147	167
Ciencia de materiales	105	155	160
Partículas y campos	80	130	138
Física nuclear	56	69	77
Física atómica y molecular	36	57	68
Fisicoquímica	--	50	66

Appendix B. Mexican academic PCT patent applications

INSTITUTION	TOTAL COUNT
UNAM	61
ITESM	49
CINVESTAV-IPN	35
UNIVERSIDAD AUTÓNOMA METROPOLITANA	25
INSTITUTO MEXICANO DEL PETROLEO	18
INSTITUTO POLITÉCNICO NACIONAL	12
CID CENTRO DE INVESTIGACION Y DESARROLLO TECNOLOGICO S.A. DE C.V.	11
UNIVERSIDAD AUTÓNOMA DE NUEVO LEÓN	10
INSTITUTO NACIONAL DE CIENCIAS MÉDICAS Y NUTRICIÓN 'SALVADOR ZUBIRÁN'	7
CENTRO DE INVESTIGACION EN ALIMENTACIÓN Y DESARROLLO, A.C. (CIAD)	6
INSTITUTO POTOSINO DE INVESTIGACION CIENTIFICA Y TECNOLOGICA, A.C.	6
CENTRO DE INVESTIGACIÓN EN QUÍMICA APLICADA (CIQA)	5
UNIVERSIDAD DE GUANAJUATO	5
CENTRO DE INVESTIGACIÓN Y ASISTENCIA EN TECHNOLOGÍA Y DISEÑO DEL ESTADO DE JALISCO, A.C.	4
INSTITUTO MEXICANO DEL SEGURO SOCIAL	4
INSTITUTO NACIONAL DE ASTROFÍSICA, ÓPTICA Y ELECTRÓNICA	4
CENTRO NACIONAL DE NEUROLOGÍA Y NEUROCIRURGÍA MANUEL VELASCO SUÁREZ	3
INSTITUTO DE CIENCIA Y TECNOLOGÍA DEL DISTRITO FEDERAL	3
INSTITUTO DE ECOLOGIA, A.C.	3
INSTITUTO DE INVESTIGACION EN QUIMICA APLICADA S.C	3
INSTITUTO NACIONAL DE INVESTIGACIONES NUCLEARES	3
INSTITUTO NACIONAL DE NEUROLOGIA Y NEUROCIRUGIA MANUEL VELASCO SUAREZ	3
CENTRO DE INVESTIGACIÓN CIENTÍFICA Y DE EDUCACIÓN SUPERIOR DE ENSENADA, BAJA CALIFORNIA	2
CENTRO DE INVESTIGACIONES EN ÓPTICA, AC	2

COLEGIO DE POSGRADUADOS	2
INSTITUTO DE INVESTIGACIONES ELÉCTRICAS	2
INSTITUTO NACIONAL DE PSIQUIATRÍA RAMÓN DE LA FUENTE MUÑIZ	2
UNIVERSIDAD AUTÓNOMA DE GUADALAJARA, A.C.	2
UNIVERSIDAD AUTÓNOMA DE LA CIUDAD DE MÉXICO	2
UNIVERSIDAD AUTÓNOMA DEL ESTADO DE MORELOS	2
CENTRO DE INVESTIGACION EN MATERIALES AVANZADOS, S.C.	1
CIATEQ, A.C.	1
CIMMYT	1
COLEGIO DE LA FRONTERA SUR	1
EMORY UNIVERSITY	1
ESCUELA NACIONAL DE CIENCIAS BIOLÓGICAS-IPN	1
FONDO DE INFORMACIÓN Y DOCUMENTACIÓN PARA LA INDUSTRIA INFOTEC	1
INSTITUTO MEXICANO DE TECNOLOGIA DEL AGUA	1
INSTITUTO NACIONAL DE CARDIOLOGÍA IGNACIO CHÁVEZ	1
INSTITUTO NACIONAL DE INVESTIGACIONES FORESTALES AGRÍCOLAS Y PECUARÍAS	1
INSTITUTO NACIONAL DE MEDICINA GENÓMICA	1
SOCIEDAD INTERNACIONAL PARA LA TERAPIA CELULAR CON CELULAS MADRE, MEDICINA REGENERATIVA Y EL ANTIENVEJECIMIENTO, S.C.	1
UNIVERSIDAD AUTÓNOMA DE QUERÉTARO	1
UNIVERSIDAD AUTÓNOMA DE YUCATÁN	1
UNIVERSIDAD AUTÓNOMA DEL ESTADO DE HIDALGO	1
UNIVERSIDAD AUTÓNOMA DEL ESTADO DE MÉXICO	1
UNIVERSIDAD DE LA SALLE BAJIO, A.C.	1
UNIVERSIDAD IBEROAMERICANA	1
UNIVERSIDAD JUAREZ AUTONOMA DE TABASCO	1
UNIVERSIDAD POPULAR AUTÓNOMA DEL ESTADO DE PUEBLA, A. C.	1

Appendix C. Foreign institutions with academic PCT patent applications between 1995 and 2015.

INSTITUTION	TOTAL COUNT	COUNTRY
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (C.N.R.S.)	9	France
THE REGENTS OF THE UNIVERSITY OF CALIFORNIA	7	USA
CHILDREN'S HOSPITAL MEDICAL CENTER	5	USA
BOARD OF REGENTS, THE UNIVERSITY OF TEXAS SYSTEM	4	USA
THE GENERAL HOSPITAL CORPORATION	4	USA
THE UNIVERSITY OF BRITISH COLUMBIA	3	Canada
INSTITUT PASTEUR	3	France
UNIVERSITE CLAUDE BERNARD LYON I	3	France
RESEARCH DEVELOPMENT FOUNDATION	3	Pakistan
DUKE UNIVERSITY	3	USA
UNIVERSITY OF COLUMBIA	3	USA
MAX-PLANCK-GESELLSCHAFT ZUR FÖRDERUNG DER WISSENSCHAFT E.V.	2	Germany
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS (CSIC)	2	Spain
ECOLE POLYTECHNIQUE	2	France
INSTITUT NATIONAL DE LA RECHERCHE AGRONOMIQUE	2	France
INSTITUT NATIONAL DES SCIENCES APPLIQUEES DE LYON	2	France
UNIVERSITE JOSEPH FOURIER - GRENOBLE 1	2	France
BETH ISRAEL DEACONESS MEDICAL CENTER	2	Israel
ARIZONA BOARD OF REGENTS ON BEHALF OF THE UNIVERSITY OF ARIZONA	2	USA
CENTER FOR BLOOD RESEARCH	2	USA
SANFORD SCIENTIFIC INC	2	USA
THE GOVERNMENT OF THE UNITED STATES OF AMERICA, AS REPRESENTED BY THE SECRETARY, DEPARTMENT OF HEALTH AND HUMAN SERVICES	2	USA
THE TEXAS A&M UNIVERSITY SYSTEM	2	USA
ASOCIACIÓN CIVIL DE ESTUDIOS SUPERIORES	1	Argentina

CONSEJO NACIONAL DE INVESTIGACIONES CIENTÍFICAS Y TÉCNICAS	1	Argentina
UNIVERSIDAD NACIONAL DE LA PLATA	1	Argentina
AUSTRALIAN NATIONAL UNIVERSITY	1	Australia
FUNDACIÓN DE LA UNIVERSIDAD DE BRASILIA	1	Brasil
THE ROYAL INSTITUTION FOR THE ADVANCEMENT OF LEARNING / MCGILL UNIVERSITY	1	Canada
UNIVERSITE LAVAL	1	Canada
JILIN UNIVERSITY	1	Chile
UNIVERSIDAD PONTIFICIA BOLIVARIANA	1	Colombia
UNIVERSIDAD DE COSTA RICA	1	Costa Rica
CENTRO DE INVESTIGACIÓN Y DESARROLLO DE MEDICAMENTOS	1	Cuba
CENTRO NACIONAL DE INVESTIGACIONES CIENTÍFICAS	1	Cuba
INSTITUTO FINLAY. CENTRO DE INVESTIGACIÓN-PRODUCCIÓN DE VACUNAS Y SUEROS	1	Cuba
EUROPEAN MOLECULAR BIOLOGY LABORATORY	1	Germany
K.U. LEUVEN RESEARCH & DEVELOPMENT	1	Germany
TECHNISCHE UNIVERSITÄT MÜNCHEN	1	Germany
UNIVERSIDAD TECNICA PARTICULAR DE LOJA	1	Ecuador
CENTRO DE INVESTIGACIONES ENERGETICAS, MEDIOAMBIENTALES Y TECNOLOGICAS	1	Spain
UNIVERSIDAD DE SALAMANCA	1	Spain
UNIVERSIDAD DE VIGO	1	Spain
UNIVERSIDAD PÚBLICA DE NAVARRA	1	Spain
UNIVERSITAT POLITÉCNICA DE CATALUNYA	1	Spain
AGENCE FRANCAISE DE SECURITE SANITAIRE DES ALIMENTS	1	France
ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS (ARMINES)	1	France
INSTITUT DE RECHERCHE POUR LE DEVELOPEMENT	1	France
INSTITUT NATIONAL POLYTECHNIQUE DE TOULOUSE	1	France
UNIVERSITÉ BLAISE PASCAL - CLERMONT II	1	France
UNIVERSITE CATHOLIQUE DE LOUVAIN	1	France
UNIVERSITE DE BORDEAUX I	1	France
UNIVERSITE JEAN MONNET	1	France
UNIVERSITE RENE DESCARTES	1	France
UNIVERSIDAD NACIONAL AUTONOMA DE HONDURAS	1	Honduras
RIKEN (THE INSTITUTE OF PHYSICAL AND CHEMICAL RESEARCH)	1	Japan
POLISH ACADEMY OF SCIENCES	1	Poland

SHEMYAKIN AND OVCHINNIKOV INSTITUTE OF BIOORGANIC CHEMISTRY	1	Rusia
UNIVERSITE DE GENEVE	1	Switzerland
UNIVERSITE DE GENEVE LABORATOIRE DE PHARMACIE GALENIQUE	1	Switzerland
THE UNIVERSITY OF BIRMINGHAM	1	UK
THE UNIVERSITY OF BRISTOL	1	UK
CORNELL UNIVERSITY	1	USA
DANA-FARBER CANCER INSTITUTE, INC.	1	USA
MASSACHUSSETS INSTITUTE OF TECHNOLOGY	1	USA
NATIONAL INSTITUTES OF HEALTH	1	USA
NEW ENGLAND MEDICAL CENTER HOSPITALS	1	USA
THE ADMINISTRATORS OF THE TULANE EDUCATIONAL FUND	1	USA
THE BROAD INSTITUTE, INC.	1	USA
THE FLORIDA INTERNATIONAL UNIVERSITY BOARD OF TRUSTEES	1	USA
THE ROCKEFELLER UNIVERSITY	1	USA
TRUSTEES OF BOSTON UNIVERSITY	1	USA
UNIVERSITY OF CHICAGO	1	USA
UNIVERSITY OF GEORGIA RESEARCH FOUNDATION, INC.	1	USA
UNIVERSITY OF MASSACHUSETTS	1	USA
UNIVERSITY OF NEW MEXICO	1	USA
UNIVERSITY OF PITTSBURGH-OF THE COMMONWEALTH SYSTEM OF HIGHER EDUCATION	1	USA
VANDERBILT UNIVERSITY	1	USA
WILLIAM MARSH RICE UNIVERSITY	1	USA
WORLD HEALTH ORGANIZATION	1	USA
YALE UNIVERSITY	1	USA
RAND AFRIKAANS UNIVERSITY	1	South Africa
UNIVERSITY OF JOHANNESBURG	1	South Africa
THE BOARD OF TRUSTEES OF THE UNIVERSITY OF ARKANSAS	1	USA

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