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Inventors' mobility in Mexico in the context of globalization

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Abstract Talent, technology, and the presence of supportive environments are key factors in producing knowledge and innovation. In this era of globalization, the knowledge economy is supported by knowledge mobility. Migration, brain drain, brain circulation, diasporas are frameworks to analyze knowledge mobility. Previous studies have shown that globalization has been accompanied by an important rise in the mobility of highly skilled human capital. This paper explores inventors' mobility through an analysis of patents. In Mexico, the number of granted patents to Mexican residents at the United States Patents and Trademark Office (USPTO) has been diminishing, in absolute and relative terms, and the number of Mexican inventors in USPTO patents granted to non-Mexican assignees has been greatly increasing. The aim of this paper is to describe the mobility of Mexican inventors from 1976 until 2016. This exploratory and descriptive study is organized in two phases: firstly, the integration of a database of Mexican inventors in granted patents whose assignees are non-Mexicans, and secondly the identification of prolific Mexican inventors (with more than five granted patents) as well as inventors with recently issued patents. Preliminary findings show that after 1994, when Mexico joined NAFTA, the flow of Mexican inventors to multinational companies has increased.

Keywords Inventors mobility · Globalization · Granted patents · USPTO · Mexican inventors

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Introduction

The rise in mobility of highly skilled human capital is associated with a globalized economy. Docquier and Rapoport (2012) describe the growth of migration within the OECD countries at the same rate as trade, and see high-skilled migration as a major aspect of globalization. The movement of scientists and other highly skilled professionals is not the same amongst different countries. Nowadays, there is a marked flow of professionals from developing countries to advanced economies (Mountford and Rapoport 2011). Within Mexico, there is a substantial brain drain of professionals, particularly towards the United States (Johnson 2015), mainly because there are much better resources for research and development (R&D) within institutions, and higher salaries. According to the Institute of Mexicans Abroad (Instituto de Mexicanos en el Exterior) and the National Association of Universities and Institutions of Higher Education (Asociación Nacional de Universidades e Instituciones de Educación Superior ANUIES), there are more than a million Mexicans working in R&D in at least 20 countries (Dolores 2016).

Between 2005 and 2007, Mexicans represented 3.8% of the population of the United States and 30% of new immigrants going into that country (Rodríguez 2009). In 2014, there were more than 14,000 Mexican students in the United States, which makes Mexico 9th of countries with students at US universities and colleges. Although this itself is good, the main problem is that many of these professionals chose to stay in the US. Currently, more than 73,000 PhDs are working in academia, 20,000 of them are working in the USA (Baker 2015). In 2010, the Mexican Ministry of Education estimated that annually, around 20,000 academics educated with the state's resources, abandon national institutions and move abroad. According to Tuirán and Ávila (2013), the number of highly skilled Mexican citizens living in the US more than doubled between 2000 and 2012, going from 411,000 to more than a million. Of this group of immigrants, more than 150,000 have a graduate degree.

In Mexico, the migration of highly skilled human capital is very diverse and includes: students, engineers, scientists, academics and senior managers, who cannot integrate in the national labor market for various reasons (Tuirán and Ávila 2013; Alba 2013). Although this phenomenon has not been studied much within academia, it has become a topic of debate amongst politicians and an issue of controversy in public policies (Didou-Aupetit 2004, 2006). The complexity of this phenomenon and its different manifestations makes it quite difficult to quantify its impact. Amongst the direct consequences are the loss of knowledge and the weakening of academic networks. This will have adverse effects on local innovation (Agrawal et al. 2011).

Highly skilled human capital mobility and knowledge flows are asymmetrical. Developed countries are receiving professionals from developing countries but not the other way around. This migration seems to be related to commercial and economic flows (Solimano 2009). The Mexican Ministry of Education has presented several economic estimations on this one-way migration of highly skilled human capital:

> The exodus of Mexican talent – which rises to 575 thousand professionals – has cost the country more than 100 billion pesos. This amount is more than four times the budget of the whole Universidad Nacional Autónoma de México (National Autonomous University of Mexico) and is 25% of the total budget of the Ministry of Education (Tuirán 2009).

The Ministry adds that highly skilled professional migration is increasing. Every year around 20,000 Mexicans from the highest levels of education are leaving the country.

There are various reasons: lack of opportunities, unemployment, inadequate infrastructure for R&D, few positions at public universities and on the other hand, much better salaries and professional opportunities in other countries (Tuirán 2009).

The exploration of the mobility of Mexican inventors through patent analysis is a way to identify the integration of Mexican inventors in Mexican and non-Mexican companies, universities, R&D institutes, etc. What are the characteristics of Mexican inventor's mobility? Is there a change since the implementation of globalization policies? Latin America and the Caribbean is the region with the biggest relative growth in highly skilled human capital. This kind of migration grew 155% from 1990 to 2007 (Tuirán and Ávila 2013). Mexico is one of the major contributors to this this trend, particularly since NAFTA.

Mexican patent studies have described different aspects of the problem. Marmolejo-Leyva et al. (2015: 11) found that international migration and the mobility of human capital strengthens the scientific capacity of the source countries because mobility does not diminish local collaboration. On the other hand, Milan Quintero and Meza Rodríguez (2015) describe the low participation of Mexican researchers who are part of the national research system in patent production. These researchers participate in 23.95% of the patents granted in Mexico by the national office. Some of these patents were produced through collaborations with local institutions and 6.25% of them were international patent applications. Other studies have explored the Mexican participation in patents granted through the Patent Cooperation Treaty from 1995 to 2015. There were more than 3000 patent applications with at least one Mexican inventor. It is also relevant to know who are the inventors and for whom are they working. The patterns of invention change when the inventors' mobility is analyzed through USPTO.

The objective of this paper is to explore inventors' trajectories through patent analysis, primarily looking at the mobility of Mexican inventors working at global corporations from 1976 to 2016. We will look mainly into US patents that had Mexicans listed as inventors. Though our primary focus is on American patents, we also took into account patents associated with Mexican inventors in other similarly developed countries. The main questions that drive this analysis are: To what degree are Mexican inventors integrated into USPTO patents with Mexican and non-Mexican assignees? What are the main characteristics of the integration of Mexican inventors to patents of non-Mexican assignees? What are the institutions that integrate these Mexican inventors? Has the mobility pattern changed after globalization? The present exploration quantifies the Mexican inventors related with patents owned by non-Mexican companies. This research has provided us with evidence about the flow of Mexican inventors towards highly advanced economies, particularly the USA.

Globalization and knowledge mobility

This section provides an analytical framework, which allows us to look into the trajectory of Mexican inventors in the USA within 1976 and 2016. Previous studies (Aboites and Soria 2008, Aboites and Díaz 2012; Díaz and Alarcón 2014) show an exponential growth in the number of Mexican inventors working in foreign companies since the signing of NAFTA. With the purpose of analyzing this phenomenon, there are two relevant points in the literature: (1) Mobility of human capital in globalization, and (2) Mobility as a brain drain or flow of talents.

Human capital mobility in globalization

The mobility of human capital has considerably grown since the post-war period. The number of Mexican undergraduates that have had short or long stays in international universities has increased. This has generated a major flow of highly skilled individuals out of the country (Sieglin and Zúñiga 2010). Thus, understanding this phenomenon is of importance to developing countries since it directly impacts their scientific potential as well as how this relates to the consolidation of their higher education system. Since the knowledge-based economies are highly connected, this affects multinational companies as well, and ultimately, the economic development of entire countries. It has been noted before, that the problems that arise with this type of flow are more troubling to underdeveloped countries, since the more developed economies are an attractor for this kind of professional.

The globalization of world economies is related to R&D internationalization and the intensification of flows of knowledge. The role multinational companies play in shaping the way innovation works, as well as the appropriation of the mechanisms that countries use to innovate, is a fascinating field of study in this context (Criscuolo and Patel 2007). Another important research focus has been the way the inequality of knowledge flows increases the gap that currently exists between emerging and advanced economies (Mountford and Rapoport 2011). The analysis of knowledge mobility and its causes require an understanding of how mobility impacts countries economic development, and how resources allocated by governments to R&D can be wasted because of this. Davies (2007) proposes that the development of these flows is the consequence of the changing patterns of human flows in a globalized economy. The knowledge flow is a fundamental characteristic of knowledge-based economies (David and Foray 2002).

It is worth noting that patents filed at the USPTO[1] is an important indicator when it comes to the mobility patterns of highly skilled professionals in Mexico working in foreign institutions. This group of professionals is part of the international networks of innovators. They also belong to leading multinational companies that are involved in highly competitive environments where technology development is a primary activity. The generation of new products, processes, and services worldwide requires the most talented human capital in specific technological fields (Patel and Pavitt 2000).

The last theoretical reflection throws light onto the reasons, which influence the way knowledge moves out of Mexico and the way the mobility of human capital impacts the economy. Additionally, the country finds itself looking for highly skilled individuals who in turn leave Mexico because of the lack of opportunities within their field of specialization. Although evidence is not conclusive, we suspect there is a strong link between those academics educated abroad (particularly in the USA) who later migrate to the US or who go to work for global companies that take advantage of that knowledge. This topic, in particular is part of our future research agenda.

This scenario means that developing countries, such as Mexico, are behind in many fields, even though there is plenty of human capital. According to Aboites and Soria (2008), the numbers of Mexican inventors associated with patents filed at the USPTO

[1] The USPTO is one of the most important patent authorities. Each year, more than 100,000 patents are granted to companies, universities (called academic patents) and R & D institutions around the world. In the last decade, half of the patents granted have been issued to companies, universities, government agencies and R & D institutions in the United States. The other half is given to the same type of agents but from different countries. Mexico participates with less than half a percentage point of the total.

belonging to global corporations have grown considerably, especially since the implementation of NAFTA. This phenomenon raises different questions. Is this a systematic migration of highly qualified human capital towards the US, or a diaspora of creators in this new era of globalization?

Migration, brain drain or brain circulation

The mobility of inventors and the resulting knowledge flows are key factors when it comes to the creation of knowledge. Highly skilled human capital mobility is not a recent phenomenon. In their infancy, many European universities experienced the so-called "scientific nomadism", which entailed the movement of intellectuals and scientists within the European continent. Scientific nomadism became the beginning of scientific mobility and the cross-fertilization of knowledge between various groups of scientists and intellectuals (García de Fanelli 2008).

During the eighties, this phenomenon was called the brain drain. Sylvie Didou Aupetit (2004) defines the brain drain as a long-term stay in a foreign country for professional reasons. The brain drain is also the migration of highly qualified professionals from developing to developed countries (Baker 2015). Peña-Cid (2008) explains the departure of researchers and professionals from one country, looking for better work and living conditions, as a brain drain. The optimistic perspective on these processes calls this brain circulation, brain exchange or diaspora. According to this definition, and taking into account the increasingly globalized economy, there is a constant flow of human capital across borders, driven by those looking for improved professional opportunities and also, by companies seeking the best people to innovate (Saxenian 1999). This migration of human capital between developing and developed countries in both directions spreads knowledge and innovation everywhere.

Some of the most representative studies on highly skilled human capital migration are: (1) Statistical studies of large migration flows, which analyze the place of origin and destination, some of which consider the impact on the economic development of both countries (Di Maria and Stryszowski 2009; Dustmann et al. 2011; Docquier and Rapoport 2012). (2) Those which describe the factors that make highly qualified individuals leave the country and search for environments in which they can grow professionally (Sieglin and Zúñiga 2010; Peña Cid 2008; Tuirán 2009) (3) The diaspora perspective, which analyses the links that immigrants keep with their country of origin, and how this has generated a significant cross-over of knowledge between borders (Davies 2007; Rodriguez Gómez 2009; Marmolejo-Leyva et al. 2015). (4) Studies oriented to explain the causes of the brain drain and the brain circulation (Commander et al. 2004; Li et al. 2017; Licea de Arenas et al. 2001; Agrawal et al. 2011; Peña-Cid 2008).

Studies in the field note that there is a range of various public policies in Mexico associated with mobility. Some of these policies could foster the movement of students to other countries through scholarships (Sieglin and Zúñiga 2010). Globalization and NAFTA regulations opened frontiers and made the flow of Mexican professionals and the establishment of global companies in Mexico easier (Aboites and Soria 2008; Aboites and Díaz 2012). The quality certification of Mexican university programs, established to facilitate students and professor exchanges, plays a similar role (Didou-Aupetit 2004, 2008). Also, there are explicit policies in developed countries to attract and appropriate highly qualified labor from developing countries (Gascón-Muro and Cepeda-Dovala 2009). Other studies established that the brain drain in Mexico has been the result of ambiguous policies and limited absorption capabilities of Mexican institutions (Licea de Arenas et al. 2001). Other issues, which explain the expulsion of professionals from their home countries are poor living conditions and a difficult research environment. On the other hand, inventors are attracted to developed countries because of higher salaries, better infrastructure, and better opportunities to conduct research (Johnson 2015).

The migration of talent does not equal a brain drain in itself. Ideal measures would construct a win–win scenario between different countries, institutions and researchers, where both sides have a balanced flow of human capital and knowledge, benefiting, more or less equally, from the creation of new knowledge (Baker 2015). Other authors identify positive as well as negative consequences. For example, Agrawal et al. (2011) point to the fact that this migration of talent debilitates local knowledge networks, while still allowing innovators to access knowledge accumulated in other countries. This phenomenon is called brain bank. The so-called brain bank can be positive only when the innovators return to their country of origin, bringing back knowledge. An Indian study through patent citations shows that the net effect of migration damages the access to knowledge in the country. However, the access to the knowledge associated with the diaspora of Indian inventors around the world is highly valuable for the creation of new inventions (Agrawal et al. 2011).

Several studies present similar evidence. Saxenian notes that in 2000, a third of the highly skilled workforce in Silicon Valley came from outside the US, particularly from Asia. The role this group of immigrants had in the growth of opportunities was crucial and facilitated the development of information technology industries in their countries of origin, such as China and India (Saxenian 2005). However, in a different study, Chen (2008) notes that the research conducted by Saxenian is only valid for Silicon Valley and the results are not valid for other environments. In Taiwan, the government established very aggressive policies, mainly by the support of start-ups, to attract Taiwanese professionals working in other countries. During the seventies and eighties, one of the countries most affected by this type of brain drain was India. Lately though, there has been a reversal of migration patterns and the country is currently experiencing a brain gain. The study proved that even in developing countries, if the government is creating new business opportunities, providing better social and physical infrastructure for this type of professional, many of them are returning to their home country. These policies are particularly relevant in cities such as Hyderabad and Bangalore (Chacko 2007). Other studies have looked at the negative consequences these flows generate in poorly developed countries. For example, Mountford and Rapoport (2011) described the growth in inequality. These differences point to the fact that there are no conclusive studies when it comes to the consequences of the flow of highly qualified human capital.

Methods

This study is an exploratory analysis of secondary data. The goal of this analysis is to describe the mobility tendencies within Mexican inventors in foreign or Mexican companies, having patents with at least one Mexican as an inventor. The period analyzed comprises the years between the beginning of 1976 and the end of 2016. The year of 1994 is considered an inflection point because of Mexico's integration to globalization with the entry to NAFTA, as well as the implementation of other policies aimed at market liberalization, such as the Trade Related Aspects of Intellectual Property Rights from World Trade Organization. The Intellectual Property Rights regulation establishes that worldwide commerce must comply with intellectual property rules. With this in mind, a search of patents registered in the USPTO was conducted; we were particularly interested in patents with at least one Mexican inventor enrolled in non-Mexican companies. Search queries according to USPTO specifications were designed.

The queries used to build the database were:

1. The first one to identify the total number of patents with at least one Mexican inventor without considering the assignee for the studied period (1976–2016), icn/mx and isd/years$
   Where: Icn: Inventor Country, mx: Mexico, isd: Issue Date
2. The second one to determine the total number of patents with at least one Mexican inventor including the assignee country for the studied period (1976–2016), icn/mx and acn/mx and isd/years$
   Icn: Inventor Country, mx: Mexico, acn: Assignee Country, isd: Issue Date

The difference between the result of the first query and the second one is the total of USPTO patents with non-Mexican assignees.

A database with the following variables was developed: year of patent's application, year in which patent was granted, name of company, nationality of company, address and country of origin of the patent assignee, the name of the inventors and the citizenship of the inventors. For comparative purposes, a search with the same variables was conducted for inventors of Brazilian and Argentinian origin, with the goal of better understanding the mobility of Mexican inventors in a Latin American context. It is important to mention that (1) this study does not include Brazil and Argentina. Information about the flows of knowledge through patenting is included in the database to explore if there are some patterns related to globalization. (1) Brazil and Argentina, along with Mexico, are relevant since they integrate almost three-quarters of the Latin American economic output. The criteria used to define the nationality of the patent include the citizenship of the patent assignees and the nationality of the patent inventor. It is possible for a patent to have both a Mexican assignee and a Mexican inventor.

The analysis includes, in the case of Mexico, the identification of prolific inventors that had patents granted recently (2010–2016). These prolific inventors are the ones, which will allow us to describe the knowledge flows. For this purpose, an open search on the Internet was conducted, mainly to obtain academic and professional information about the inventors, as well as to obtain the contact information of Mexican inventors. The classification of prolific inventors was adapted from the criteria established by Gay et al. (2005), which is to have a history of at least five granted patents. We also considered the typology of Göktepe-Hultén (2008) that defines a serial inventor as one who has three or more granted patents. However, for this study we consider a prolific inventor to have at least five granted patents.

The questions that guide the analysis are the following: How many Mexican inventors are in USPTO granted patents between 1976 and 2016? What are the variations in Mexican inventors' involvement in USPTO patents before and after NAFTA? What is the degree of participation of Mexican inventors in Mexican versus non-Mexican USPTO granted patents of non-Mexican assignees? What are the most significant changes regarding mobility registered before and after 1994? Which companies have Mexican prolific inventors?

Results

The US patent analysis shows: (a) a total of 4538 patents with at least one Mexican listed as an inventor from 1976 to 2016 (b) 3351 patents with at least one Mexican inventor but a non-Mexican assignee, (c) 1187 patents with at least one Mexican inventor and a Mexican assignee. Also, 62 prolific Mexican inventors working for foreign organizations that participate in 445 US patents owned by non-Mexican assignees were found. With this data, the descriptive analysis, which follows, was conducted.

Figure 1 describes the participation of Mexican inventors in USPTO patents granted to non-Mexican and Mexican assignees in the period previous to and after NAFTA (1976–1994 and 1995–2016). The gap between the integration of Mexican inventors to Mexican and non-Mexican assignees has been growing considerably. The last period has registered an exponential increase. This difference shows that non-Mexican assignees (companies, universities and R&D institutes) have been incorporating highly-skilled Mexican human capital to produce new knowledge. Meanwhile the participation of Mexican inventors in patents owned by Mexican organizations has been growing but not at the same pace and intensity. The horizontal axis describes the number of USPTO granted patents of Mexican assignees. This is an indicator of Mexican inventive activity. The upper line of Fig. 1 represents the number of USPTO granted patents to non-Mexican assignees with Mexican inventors, describing the growth of Mexican inventors in US organizations.

The behavior of these two variables shows, on the one hand, the extent to which companies, foreign universities, and non-Mexican R&D institutions are increasingly integrating Mexican inventors. On the other hand, these variables describe the extent to which Mexican companies hire Mexican inventors to produce new patentable technological know-how. In 2016, the number of patents granted to Mexican assignees was 79 and the patents granted to non-Mexican assignees were 300, almost 400% more. This gap could suggest that after NAFTA the improved conditions and regulations increased the participation of Mexican workers in non-Mexican companies.

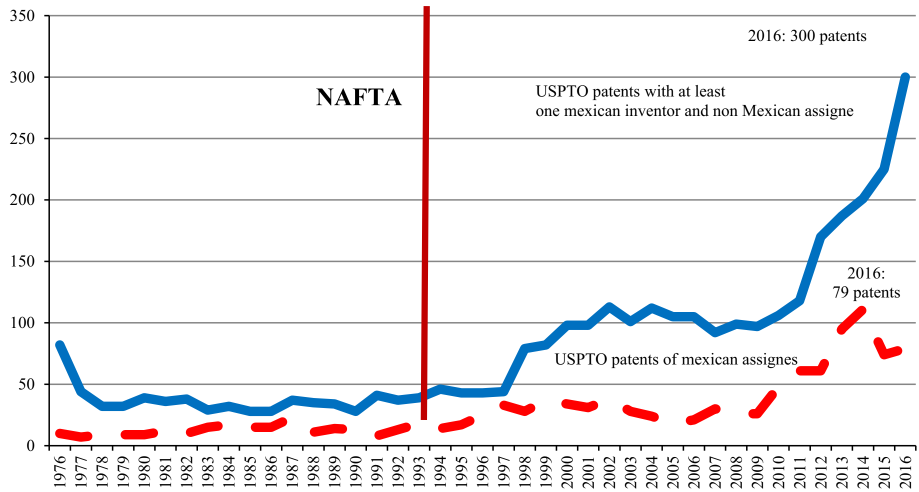


Fig. 1 USPTO Patents with at least one Mexican Inventor and non Mexican and Mexican Assignees NAFTA Period 1976–2016. *Source*: USPTO 2016

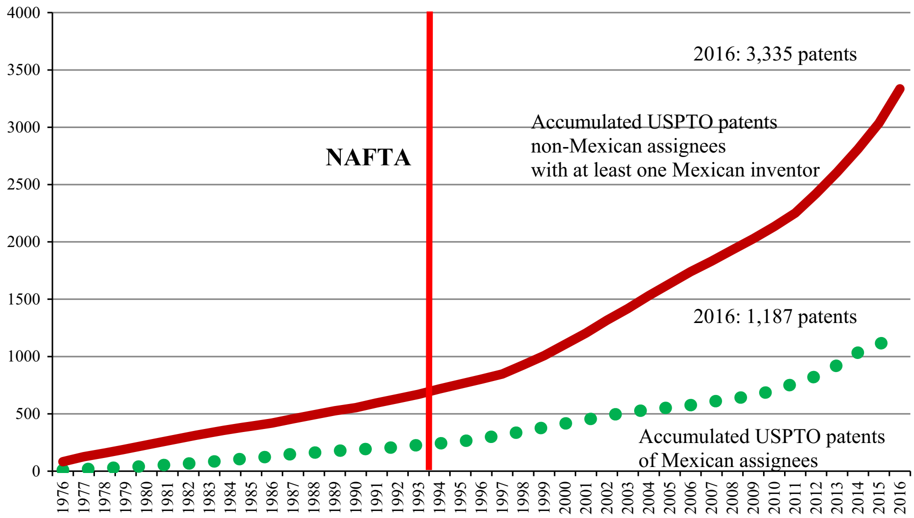
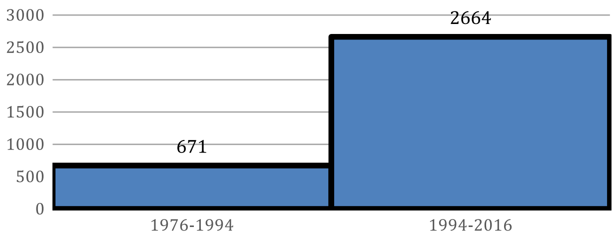


Fig. 2 USPTO Patents with at least one Mexican Inventor and Mexican and non-Mexican Assignees 1976–2016. *Source*: USPTO 2016

Fig. 3 Before and After NAFTA: Mexican Inventors in USPTO Patents of Non-Mexican Assignees 1979–2016. *Source*: USPTO 2016



Figures 2 and 3 show the cumulative form of the same data as Fig. 1. Cumulative data give another perspective of Mexican participation in USPTO granted patents to non-Mexican assignees. There were around 700 Mexican inventors from 1976 to 1994. In the same period, Mexican R&D centers, companies, and universities had only 280 Mexican inventors. Mexican entrepreneurs had hired less than half what multinational corporations and other non-Mexican organizations had. However, at the end of the studied period (2016), the number of Mexican inventors assimilated in global organizations had multiplied almost threefold (3335 Mexican inventors) while Mexican organizations had only assimilated 1187. What does the different behavior of these indicators mean? One possible answer considering the data is that those non-Mexican organizations have superior human capital absorption capabilities than Mexican organizations. Another explanation could be related to poor salaries and a lack of economic resources for R&D. However, there could be many other factors.

An examination of the Mexican participants in non-Mexican organizations in this period shows the following types of mobility: (1) Mexican professionals who live in Mexico and work for multinational companies such as Hewlett-Packard, Delphi Technologies, ADC Telecommunications, (2) Mexican inventors who used to live in Mexico and work as part of Mexican business, then went to the USA as a part of these companies, universities or R&D institutions, and (3) Mexican inventors whose inventive trajectories have been with

Table 1 Patent of Mexican inventor with non-Mexican Assignee (José J. Galicia)
Source: USPTO, 2016

US patent number	9,377,000
Date field	December 13, 2012
Date issue	June 28, 2016
Assignee	Delphi Technologies, Inc. (Troy, MI)
Inventors	
Skinner; Albert A.	Waterford, MI
Levers; Harry O.	Clarkston, MI
Scaff; Andre V.	Lake Orion, MI
Galicia; José J.	**Ciudad Juárez, MX**

non-Mexican organizations in other countries such as Germany, France, Japan, Sweden. This paper addresses mainly the first type of mobility.

The inventors' trajectories have some features of the brain drain phenomenon, but also some characteristics of diaspora if the inventors have a close relationship with their birthplace. Also, it could be brain circulation, if there is some kind of return and participation in producing knowledge in their home country. The US patent exploration also shows the case of Mexican inventors who live in Mexico and work at multinational companies there. In some cases, these highly skilled workers stay in Mexico while in others, they are promoted to another country. In either case, this phenomenon could be seen as knowledge mobility from a developing country to a developed country, because the owners of knowledge are non-Mexican companies and institutions. Likewise, it could be called one direction mobility, cut-off mobility, or virtual mobility. But it could be a brain circulation phenomenon as characterized by Saxenian (1999), where the Mexican inventors have the opportunity to disseminate their knowledge and foster learning processes at their workplace in American multinational companies, in their origin communities. This would be a spillover phenomenon. We do not have conclusive data. Figures 2 and 3 suggest that brain drain is the most likely explanation because of the enormous growth in Mexican inventors in USPTO granted patents to non-Mexican assignees.

Table 1 shows an example of a Mexican inventor, José J. Galicia, from Ciudad Juárez, Chihuahua, a border state in Mexico. José is one of the inventors of USPTO patent 9,377,000, whose assignee is Delphi Technologies Inc in Michigan, USA. This American company has one of the largest numbers of Mexican inventors. In Table 2, Alberto Aguilar Armendariz from Veracruz, Mexico worked for Tenaris Connections Limited from St. Vincent & the Grenadines. He is part of the inventor team of USPTO patent 9,375,798 granted in 2016. The USPTO patent database exploration let us identify 3335 patents with at least one Mexican inventor and non-Mexican assignee. The number of Mexicans registered as inventors in these patents is 3849. In some cases, the group of inventors is international, in others it is only Mexicans.

Table 3 describes the trajectory of a prolific Mexican inventor at USPTO. This inventor is also the CEO and founder of NEOLOGY Inc.,[2] now located in San Diego California. Table 3 shows the number of USPTO granted patents where this inventor participated. In just one case, the team of inventors is composed entirely of Mexicans. This company was opened in 2000, and its goal is the production of chips for identification through

[2] See http://www2.esmas.com/emprendedor/caso-de-exito/perfiles/090458/neology/consulted on February 12, 2017. This article published in August 2009 by Endeavor reports that the company has 26 Patents, 200 more in process and has 150 employees. It also notes that half of the patents have been produced in Mexico.

Table 2 Patent of Mexican Inventor with non-Mexican Assignee (Alberto Aguilar Armendariz) *Source*: USPTO, 2016

US patent number	9,375,798
Date field	January 17, 2014
Date issue	June 28, 2016
Assignee	Tenaris Connections Limited (Kingstown, St. Vincent & the Grenadines)
Inventors	
Mazzaferro; Gaston Mauro	Buenos Aires, AR
Coppola; Tommaso	Rome, IT
Amato; Stefano	Rome, IT
Armendariz; Alberto Aguilar	**Veracruz, MX**

radiofrequency, allowing the user to track products, persons, and vehicles. The inventor is Francisco de Velasco Cotina. The place of residence of the company between 2006 and 2012 is Mexico City. However, from 2012 to 2016, the place of residence is California. This finding requires an interview to gain more accurate information. Other sources show that R&D activities of NEOLOGYs take place in Mexico City and San Diego, California. Is this company an example of brain drain, gain brain, or diaspora? There is insufficient evidence to answer this question. The highly skilled migration includes: students, university professors, researchers, professionals, CEOs, and technicians, among others (Tuirán and Ávila 2013). This exploration identifies that Mexican inventors are part of different mobility trajectories, but one of the more common seems to be virtual mobility and a trajectory from the inventors' home country towards the company location in the USA.

Table 4 describes USPTO granted patents to non-Mexican assignees with at least one prolific Mexican inventor. The USPTO database gives a total of 445 patents with at least one prolific Mexican inventor with a non-Mexican assignee. In general, these inventors work for American companies and also universities and R&D centers. There are 62 prolific Mexican inventors (their production as inventors is between 5 and 20 patents). In this sub-group, there were 39 knowledge assignees, 98% of the assignees are American companies, and just 2% are American universities and R&D centers: Yale University has eight, Columbia University one, The Public Health Research Institute one, and MIT one. There were six patents in collaboration between Mexico and USA inventors. The assignees were the Instituto Nacional de Ciencias Médicas and Nutrición Salvador Zubirán (National Institute of Medical Science and Nutrition Salvador Zubiran) in Mexico City, the General Hospital Corporation in Boston, Massachusetts and the Childrens' Hospital Medical Center in Cincinnati, Ohio. The latter is an example of an international research network (inventors and assignees). However, these patents were excluded from the total because this is a co-ownership case. The sub-group analysis also reported 20 patents held by the French company Saint-Gobain Glass France, of Courbevoie, but the French inventor lives in Mexico, therefore these patents were excluded from the total number generated by prolific Mexican inventors.

Table 4 describes the fifteen companies with most USPTO granted patents. Possibly, globalization and economic liberalization are related to inventors' participation in American companies. The three American companies with the greatest number of USPTO

Table 3 Trajectory of a Prolific Mexican Inventor at USPTO Granted Patents (Francisco Martínez de Velasco Cotina) *Source* USPTO, 2016 and own research

No. of patents	USPTO patents number	Patent filed date	Patent issued date	Assignee's country of origin	Assignee name	Total number of inventors	Mexican or international group	Position among inventors	Co inventors' country of origin
1	7,034,688	09/04/2002	25/04/2006	Mexico city	Neology, Inc., San Diego, CA (US)	2	GI	P2	Rietzler; Manfred (Marktoberdorf, **DE**)
2	7081819	09/07/2003	25/07/2006	Mexico city	Neology, Inc., San Diego, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
3	7091860	08/08/2003	15/08/2006	Mexico city	Neology, Inc., San Diego, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
4	7091862	24/11/2003	15/08/2006	Mexico city	Neology, Inc., San Diego, CA (US)	1	GMX	–	–
5	7463154	30/04/2002	09/12/2008	Mexico city	Neology, Inc., San Diego, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
6	7671746	17/04/2006	02/03/2010	Mexico city	Neology, Inc., San Diego, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
7	8004410	15/01/2010	23/08/2011	Mexico city	Neology, Inc., San Diego, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)

Table 3 continued

No. of patents	USPTO patents number	Patent filed date	Patent issued date	Assignee's country of origin	Assignee name	Total number of inventors	Mexican or international group	Position among inventors	Co inventors' country of origin
8	8237568	01/07/2011	07/08/2012	Mexico city	Neology, Inc., San Diego, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
9	8325044	04/05/2012	04/12/2012	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
10	8350673	02/02/2009	08/01/2013	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	3	GI	P3	Nyalamadugu; Sheshidher (San Diego, CA); Liu; Jun (San Diego, CA)
11	8587436	13/01/2012	19/11/2013	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
12	8710960	08/01/2013	29/04/2014	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	3	GI	P3	Nyalamadugu; Sheshidher (San Diego, CA); Liu; Jun (San Diego, CA)
13	8766772	09/09/2013	01/07/2014	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
14	8847763	18/01/2013	30/09/2014	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)

Table 3 continued

No. of patents	USPTO patents number	Patent filed date	Patent issued date	Assignee's country of origin	Assignee name	Total number of inventors	Mexican or international group	Position among inventors	Co inventors' country of origin
15	8933807	16/09/2013	13/01/2015	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
16	9098790	28.03.2014	04/08/2015	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	3	GI	P3	Nyalamadugu; Sheshidher (San Diego, CA); Liu; Jun (San Diego, CA)
17	9342719	30.09.2014	17/05/2016	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	2	GI	P1	Rietzler; Manfred (Marktoberdorf, **DE**)
18	9355398	13.08.2014	31/05/2016	La Jolla, CA, USTED	Neology, Inc., Poway, CA (US)	5	GI	P1	Mullis; Joe (San Diego, CA), Rietzler; Manfred (San Diego, CA), Nyalamadugu; Sheshi (San Diego, CA), Monsalvo; Rodolfo (San Diego, CA)

Table 4 Non-Mexican Assignees and at least one Prolific Mexican Inventor in USPTO Granted Patents 1976–2016 *Source*: USPTO, 2017

Position	Knowledge ownership	Number of patents
1	Hewlett Packard Development Company and Hewlett Packard Company (Palo Alto, CA and Houston, Texas)	85
2	DELPHI Technologies, Inc. (Troy, Minnesota)	76
3	ADC Telecommunications, Inc. (Eden Prairie, MN)	42
4	Zodiac Seats US LLC (Gainesville, TX)	31
5	Carrier Corporation (Syracuse, NY)	19
6	Neology, Inc., Poway, CA (US)	18
7	Vitro Global, S.A. (Givisiez, CH)	16
8	Goody Products, Inc. (Freeport, IL) Goody Products, Inc. (Atlanta, GA)	15
9	Allergan, Inc. (Irvine, CA)	15
10	Lamkin Corporation (San Diego, CA)	14
11	Ansell Healthcare Products LLC (Red Bank, NJ);	14
12	GES Technologies IP GmbH (Basel, CH)	10
13	Ecolab Inc. (St. Paul, MN)	8
14	Yale University (New Haven, CT);	8
15	Nature Sweet, Ltd. (San Antonio, TX)	6

granted patents with at least one Mexican prolific inventor are Hewlett-Packard, Delphi Technologies Inc. and ADC Telecommunications.

Figure 4 presents the annual growth rate of patents in Brazil, Mexico, and Argentina for the same period (1976–2016), before and after globalization and liberalization policies, particularly the Trade Related Aspects of Intellectual Property Rights (TRIPS). This analysis is useful to explore changes related to liberalization policies in the three most developed economies in Latin America. It helps us to understand if Mexican inventors' mobility is an isolated phenomenon or is part of a wider tendency induced by globalization.

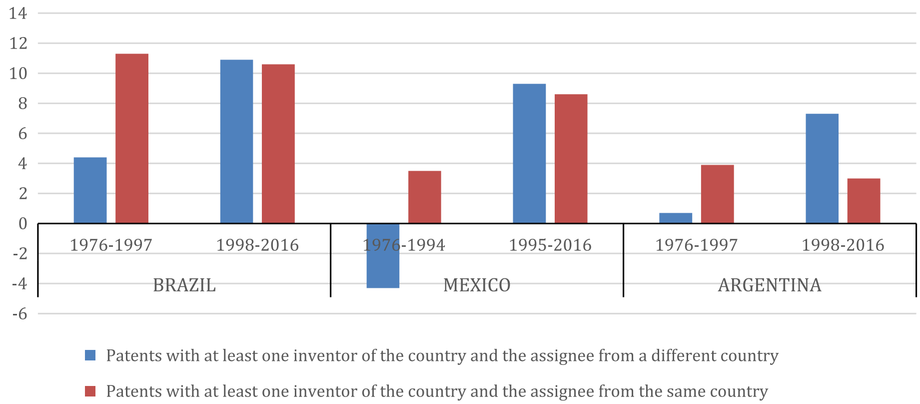


Fig. 4 Annual Growth Rate of Patents in Brazil, Mexico and Argentina 1976–2016 (Before and after TRIPS). *Source*: USPTO 2017

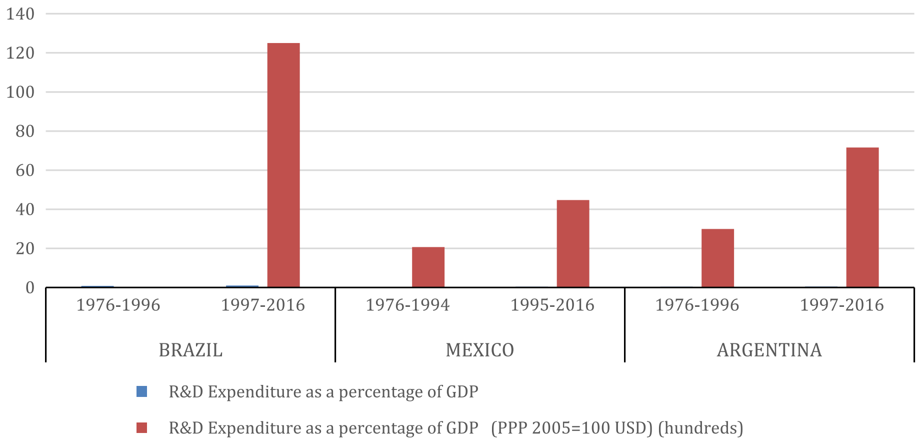


Fig. 5 Average R&D Expenditure as a Percentage of GDP. *Source*: UNESCO database (Institute for Statistics) http://data.uis.unesco.org/Index.aspx. Network of Ibero-American and Inter-American Science and Technology Indicators (Red de Indicadores de Ciencia y Tecnología Iberoamericana e Interamericana RICYT) http://db.ricyt.org/ui/v1.0/index.html). World Bank, World Development Indicators Series. Cragnolini, Alider. Scientific and Technological Policy Issues. Second Seminar Jorge Sabato ("Cuestiones de Política Científica y Tecnológica. Segundo Seminario Jorge Sabato."), Madrid, España, 1986. Ed. Consejo Superior de Investigaciones Científicas

Figure 4 shows that there were important changes in inventors' mobility from Brazil, Mexico and Argentina, respectively. The participation of inventors from these countries has also been increasing in groups, international networks, and foreign organizations. After TRIPs, the involvement of Brazilian inventors in USPTO granted patents to international assignees grew from 4.4 to 10.9, Mexico increased from − 4.3 to 9.3 and Argentina from 0.7 to 7.3. However, the patents with at least one inventor of the country and with an assignee from the same country have a similar rate of growth in Brazil and Argentina. Only Mexico registered an increase of more than twice. Mexico has the highest inventors mobility and it was the first Latin American country to adopt liberalization policies (TRIPs). The comparison shows that Mexico has been very affected by globalization, understood as economic liberalization and knowledge mobility.

Figure 5 describes the average R&D expenditure as a percentage of GDP for Brazil, Mexico, and Argentina for 1976–2016. The first indicator is R&D expenditure as a share of GDP. Mexico is the country that allocates the least amount of economic resources to R&D activities. No significant growth before or after globalization is seen for the three countries. The second indicator is R&D expenditure per capita. Even though we do not have data for the first period in Brazil, the information shows again that Mexico is the country with the least expenditure per capita for the period. Eventually, this could be another factor explaining mobility of Mexican inventors.

Discussion

This article presents an exploration of the mobility of Mexican inventors, mainly towards global companies, universities and R&D centers through USPTO granted-patents. The analysis of this group of highly-skilled human resources shows that American companies are those with the greater absorption capabilities than Mexican companies, universities, and R&D centers. These inventors are usually part of an international team. The patent analysis shows how Mexicans are part of global networks that produce industrial knowledge and inventions. This pattern applies particularly to prolific Mexican inventors.

Various reasons related to this mobility are reported (Johnson 2015; Tuirán 2009l Díaz 2014): (1) higher salaries in the USA than Mexico, (2) R&D centers, universities and companies do not have the proper infrastructure, resources, administrative procedures and environment to develop R&D activities. (3) Mexican companies do not require highly-skilled human resources. (4) and recently, crime has become a factor encouraging inventors to move.

Previous research establishes that at institutional level globalization, education, and science and technology (S&T) policies foster students' and professor' international mobility. These policies operate as incentives through scholarships, certification, and recognition of studies and grades obtained in other countries. These incentives are encouraging highly skilled human capital to leave Mexico (Didou-Aupetit 2004). The exploration introduced in this article confirms the mobility growth of Mexican inventors, particularly towards American companies, although more research needs to be done. Moreover, studies in Mexico have also found that the lack of the demand for technology by Mexican companies makes it difficult for young inventors to find a place to work (Díaz 2014).

There are more critical perspectives that claim that highly-skilled human capital migration related to globalization is producing exclusion and inequalities (Davies 2007). These studies also confirm that migration could increase long-term inequality in income distribution between developing and developed countries (Mountford and Rapoport 2011). More optimistic perspectives are explaining diasporas, brain gain, brain circulation, exchanges and knowledge spillovers (Saxenian 1999, 2005; Marmolejo-Leyva et al. 2015). The understanding of the phenomenon requires further studies of the different factors and processes. Is this a brain drain related to a lack of absorption capabilities in developing countries like Mexico? Could it be characterized as virtual mobility of inventors through the channels opened by information and telecommunication technologies? Are knowledge spillovers produced by the integration of Mexican inventors in American companies in Mexico? Or is the knowledge trapped inside the multinational companies? These are some of the questions that require future research.

This anecdotal evidence suggests that it is not enough to characterize the mobility pattern of knowledge produced by Mexican professionals towards developed countries through patenting trajectories. It is necessary to go further and prepare interviews with inventors to know directly some cases of the people who decided to migrate, work and create their professional life in foreign companies, R&D centers, and universities, particularly from the USA. This way, it will be possible to document in a more accurate way the complexity of the phenomenon.

Conclusion

There has been a growth in the mobility of Mexican inventors incorporated in foreign companies, universities, and R&D institutes, particularly American companies. Since 1994 the increase of Mexican inventors with US patents granted to non-Mexican assignees has been great. Prolific Mexican inventors are working for American companies in Mexico and the USA. Comparing data to the mobility of Brazilian and Argentinian inventors sheds light on the amount of Mexican mobility, showing that more Mexican inventors are part of foreign organizations than inventors from Brazil or Argentina. Future research has also to look into geographic factors as Mexico shares a long border with the United States. The magnitude of trade flows and the settlement of American companies in Mexico must also be considered. Another issue related with the growth in mobility of Mexican inventors could be the small R&D expenditure in Mexico. A further possible cause could be that the Mexican production system and the national innovation system do not have the capacity to absorb the number of highly qualified Mexican inventors. More research needs to be done to answer these questions.

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