

Mobility of the Members of the National System of Researchers of Mexico in their Academic Training in Latin America

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ABSTRACT

Mobility in academic scientist training has been central in the installation and consolidation of scientific and technological systems. These human resources are fundamental for the scientific development and technology of countries and their importance is reflected in the indications about scientific activities. The studies relating to academic mobility are not new, however, little quantitative studies exist due to the lack of access and availability of data about this type of mobility. This text presents a panorama of mobility during the formation of 1169 research members of the National System of Researchers (Sistema Nacional de Investigadores, SNI) of Mexico that have obtained at least a university diploma in Latin America or the Caribbean. Asymmetry in academic mobility is identified in terms of gender, areas of knowledge and the geographic distribution of centers of attraction and mobility. Finally, these results constitute a basis for generating new questions to better understand the dynamics that have shaped the current mobility structure in Latin America and the Caribbean in scientist training.

Keywords: Academic mobility, Scientific migration, Latin America and the Caribbean, Highly specialized human resource training.

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INTRODUCTION

The relationship of scientific and technological development with economic and social development have been thoroughly recognized.^[1,2] Throughout the 20th century we have witnessed scientific and technological advances in different socio-political and economic contexts. Advances that have given origin to diverse new technologies, which have modified the industry and are actually a part of daily life for the majority of the population. National and regional agencies for scientific and technological development, with the support of specialists from diverse disciplines, have proposed several indicators for measuring and evaluating the advances of scientific and technological activities. In the last decades, the scientific and technological advances have shown constant changes, which are related with the contexts where they occur. This represents important challenges for the proposals of the indicators, being that they lose validity facing rapid technological, social and economic challenges.^[3,4] Within these activities of the evaluation of science and technology, knowing the state of scientific and technological capacities

has been a central theme for the formulation of public politics in science and technology. In fact, different manuals exist for the production of indications around science and technology: Frascati, Oslo, Bogota, Lisboa, to mention a few. In general terms, these manuals indicate which are the inputs and outputs to measure for the evaluation of scientific and technological systems from different perspectives. However, the indicators and the metrics about scientific and technological activities are not limiting to the dictated patterns in these manuals.

On the other hand, scientific and technological capacities can distinguish material and human capacities. The first is up to the group of infrastructures that make up scientific and technological systems, like laboratories, research centers and other academic institutions and universities where they develop public research activities as much as private. Human capacities are human resources set aside for the development of these activities. Within the metrics that have developed in the field of bibliometrics and scientometrics, they have proposed metrics and indicators that are useful in categorizing the scientific and technological capacities. The results of these studies allow us to have panoramas of these scientific and technological systems from divers levels and dimensions.

The development of capacities in scientific and technological systems in Latin America have been accompanied by the initiatives that search to establish and consolidate these systems. These initiatives, under the form of regional and

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national politics and their programs in scientific development, have contributed to the creation and installation of material and human capacities in practically all areas of knowledge in the region. The importance of human resources in scientific development is thoroughly recognized and is reflected in the science and technology indicators.^[5,6] Additionally, in academic literature we find several studies centered in the development of human resources, where academic mobility has been central in the development of human resources in science and technology in Latin America.^[7] This mobility has been studied from the perspective of brain drain and brain gain, but few have been quantitative and comparative studies due to the lack of data for mapping and measuring mobility.^[8] This article is interested in analyzing the mobility in Latin America and the Caribbean from the research members of the National System of Researchers of Mexico (SNI) during their academic training. The results constitute a panorama that concerns a total of 1169 members of the SNI that have obtained at least a diploma in academic training in a country in this region and outside of Mexico. The results of this study are based in a descriptive statistical analysis and a social network analysis with the purpose of identifying trends and showing different elements of structure and dynamics in this mobility.

Academic mobility

Before explaining the methodology and results, it's pertinent to place the studies on academic mobility. When we observe academic mobility, themes and questions emerge that equally concern the highly qualified studies of migration of human resources and students, as well as knowledge of circulation, and collaboration networks, within others. Academic mobility has been studied from several perspectives and disciplines of social sciences. A dense reading exists about these themes, being that there is a current debate about theoretic approaches over academic mobility and migration.^[9-11] This scientific mobility and migration are not new social phenomena, throughout the history of humanity scientific mobility has taken place and generated questions over brain drain, knowledge circulation and confirmation of scientific communities,^[12] as well as over negative implications.^[13] The history of science has delivered us valuable work over the mobility of individuals, theories, texts, scientific artifacts and ideas that have allowed us to better understand the spatial dimension of science.^[14] Actually, mobility and migration have emphasized each other and taken new forms with globalization and internationalization of universities.^[15] In the last decades, studies over academic mobility and migration stood out in two main points, one where studies have been interested in negative aspects of mobility and academic migration (brain drain) and the other where interest has been concentrated over positive aspects (brain gain).

On the other hand, in a wider frame, academic mobility inserts itself in the analysis of spatial dimensions of science and technology. Additionally, studies already recalled in the previous paragraph, which in their majority are qualitative and have allowed advancement in the comprehension of this social phenomena. In the field of scientometrics have suggested various approaches addressing spatial dimension and labor mobility of scientists from quantitative approaches.^[16] As a matter of fact, it is known that the generation of indicators over academic mobility and migration are useful for the politics of science and technology. However, we confirm that few have been qualitative studies over academic mobility and migration during scientist training. This must be in part to the diversity and inconsistency of the information over this type of mobility and migration.^[8,13] Regarding studies in Latin America, studies have been carried out over internationalization of science,^[15] brain drain,^[17,18] and scientific diasporas.^[19] In the particular case of Mexico, they have explored questions over trajectories of researchers trained abroad and their repercussions over the scientific structures of the country,^[20] the correlations between places of training, networks of collaboration and scientific productivity^[17] and the characteristics of mobility in the physical field,^[21] among other studies. These studies contribute different elements to understanding academic mobility and migration in Mexico and the region of Latin America, just as their effects and implications in scientific systems and technologies. However, the lack of available data and its diversity constitute an important limit, because of what these studies have centered themselves in particular cases about universities and disciplines. Limits impede us in finding trends, obtaining national views and formulating ample conclusions about this phenomena. It is in this context that the present study proposes a view of academic mobility and the research members of the SNI in Mexico and the region of Latin America and the Caribbean.

METHODOLOGY

The methodology of this study rests on the analysis of the basis of data from the SNI active in the year 2019. The information for building this basis of data has been obtained from the National Council of Science and Technology of Mexico (Conacyt) throughout the platform of access to public information of the National Institute of Transparency, Access to Information and Protection of Personal Data. The public information over the SNI consists in several fields of data over the categories of classification of the researchers' specialization knowledge, the degrees of studies obtained throughout their profession, and the institutions and countries where they carry out their studies and the current affiliation institutions. The data were reviewed and compared with the public registry

of the SNI.¹ The data treatment consisted of verifying the cases where the information on obtaining academic diplomas was confusing. This review was carried out by consulting the personal sites, curriculum vitae, and sites of the researchers' affiliation institutions. With this data, a curated database was built whose structure allows us to query the data at different levels and to be able to preserve relational data to obtain adjacency and frequency tables for its analysis of social networks (visualizations) and descriptive. The visualizations have been carried out with the softwares Pajek and Vosviewer for network analysis, RAWGraphs (<https://rawgraphs.io/>) for the alluvial diagrams, and the proposed methodology by Leydesdorff and Person^[22] applied to the data of SNI for carrying out the cartographic mobility.

With the obtained information from Conacyt they have built a basis of data that concerns all the current researchers in the year 2019. From this data it was identified that 1169 researchers have obtained a bachelor's degree, master or doctorate outside of Mexico and in an institution in Latin America or the Caribbean. These researchers who have been trained in this region represent 3.82% of the total of the SNI register.² By level of studies in this region, a total of 860 researchers carried out their bachelor's degree, 346 researchers did a masters and 316 obtained a doctorate in a country in this region (excluding Mexico). It fits to mention that the research members of the SNI are not exclusively researchers born in Mexico. This system is comprised of researchers born outside of this country that have emigrated to Mexico for different reasons.

From the basis of resulting data, this study characterizes the academic mobility profile of information from mexican scientists with the following points: gender distribution, areas of knowledge and specialties of discipline of the researchers, countries of academic training and mobility in the region of Latin America and the Caribbean.

Profile of Academic Mobility of Scientist Training in Mexico

Before presenting the results it is pertinent to describe the SNI in Mexico. This system was created in the year 1984 with six objectives: 1. Promote scientific and technological development of the country, 2. Increase the number of researchers, 3. Stimulate efficiency and quality of the research, 4. Promote research that is carried out in the public sector agreed to the established priorities in the National Plan of

Development, 5. Promote research training groups and 6. Contribute to the integration of national systems of scientific and technological information by discipline.^[23] The number of researchers that make up this system has increased in an important way. In the year of its creation it started with 1,396 researchers and in the year 2019 a total of 30,548 researchers made up the SNI. To enter and maintain the affiliation to the SNI, the scie in six categories of knowledge that contemplate all fields and disciplines that are created in the academic institutions of the country. Not all university professors and researchers are members of the SNI, but the characteristics of this system and the number of researchers that make it up are sufficient representatives of the scientific and technological systems of the country. It is also worth mentioning that there have been important transformations in the SNI since its creation, such as passing an economic stimulus as a symbolic issue by hierarchizing the Mexican scientific elite,^[24] as well as asymmetry in the requirements of entry and permanence between the different affiliation areas.^[25] The data used in this work indeed concern this scientific elite in Mexico. The SNI database is not exhaustive of the entire scientific and technological system in the country, however, the volume of data is important and allows us to have a corpus of information that reflects a representative image of the science and technology system in this country.

The participation of women in science and technology is not a new theme and is still prevailing in the region of Latin America and the Caribbean.^[26-28] In Mexico, women have always been present in science and technology, and just like in other nations their recognition is very limited. The lack of data over the participation of women in science has been a barrier in developing studies about this theme in this country. However, discussions exist about the issues of gender in university institutions and in some studies it has shown the underrepresentation of women in certain areas of knowledge.^[29] Upon observing the areas of knowledge that concern research members of the SNI, by making gender distinctions, Table 1, we confirm that in the majority of areas of knowledge there is a masculine predominant. In previous studies it has already signaled these asymmetries in the representation of gender in science and technology in Mexico. Additionally, these asymmetries are emphasized in other areas of knowledge: for example, in the case of Physicist Mathematics and Earth Science, the participation of women in this area that have been trained in Latin America and the Caribbean is 20.98%, whereas the total of women in the SNI in this same area is 22.54%.³ On the other hand, in the

1. (Available on the website: <https://www.conacyt.gob.mx/Sistema-nacional-de-investigadores.html>)

2. Of the total number of researchers members of the SNI for the year 2019, 18,885 have obtained at least one diploma outside of Mexico during their academic training. This represents 61.82% of the Mexican scientific elite and confirms that academic mobility has been central in the formation of this scientific and technological system.

3. The participation of women in the seven areas of knowledge in the SNI in 2019 is as follows: Physicist Mathematics and Earth Sciences 22.54%; Biology and chemistry 42.94%; Medical and Health Sciences 49.52%; Humanities and Behavioral Sciences 49.52%; Social Sciences 40.93%; Biotechnology and Agricultural Sciences 36.93%; and Engineering 22.90%.

area of Engineering, the participation of trained women in the region increases five percentage units and in the area of Medical Science and Health it increases two percentage units.

With respect to the distribution of these trained researchers in Latin America and the Caribbean, making the distinction by gender, see column 2 and 3 of Table 1, a strong presence in the areas of Social Sciences is observed with 28.83% of the researchers having training in the region of Latin America and the Caribbean, which indicates that countries of the region pinpoint attraction poles for the academic training in this area. The areas with a non-negligent percentage in academic research training are Physicist Mathematics, Agricultural Science and Humanities and Behavioral Sciences.

In addition to mapping the areas of knowledge in academic training, it interests us to map the geographic distribution of this training. From the data that concerns the researchers that have obtained at least a diploma in the region, they identified a total of 89 countries from Latin America and the Caribbean and other regions, with a total of 46 countries for the cases that have received diplomas in other regions. These results indicate to us that an important mobility exists in this region. Additionally, not all members of the SNI are born in Mexico, a significant part of the researchers have emigrated to this country. In Table 2, it shows the 20 main countries where members of the SNI have been trained in each academic object level of this study. In the first columns of this table,

Table 1: Distribution of areas of knowledge and gender of SNI researchers trained in Latin America and the Caribbean.

Knowledge area	Researchers	% of 1169	Male	% of 704	Female	% of 465
Physicist Mathematics and Earth Sciences	205	17,54%	162	79,02%	43	20,98%
Biology and chemistry	130	11,12%	77	59,23%	53	40,77%
Medical and Health Sciences	77	6,59%	37	48,05%	40	51,95%
Humanities and Behavioral Sciences	210	17,96%	104	49,52%	106	50,48%
Social Sciences	337	28,83%	179	53,12%	158	46,88%
Biotechnology and Agricultural Sciences	108	9,24%	71	65,74%	37	34,26%
Engineering	102	8,73%	74	72,55%	28	27,45%

Table 2: Countries for obtaining university degrees.

Top	Bachelor	Researchers	% 884	Master	Researchers	% 525	Doctorate	Researchers	% 566
1	Colombia	236	26,70%	Cuba	87	16,57%	Cuba	119	21,02%
2	Cuba	179	20,25%	United States of America	66	12,57%	Brazil	79	13,96%
3	Argentina	138	15,61%	Colombia	53	10,10%	United States of America	78	13,78%
4	Venezuela	58	6,56%	Brazil	52	9,90%	Spain	63	11,13%
5	Peru	55	6,22%	Spain	46	8,76%	Argentina	43	7,60%
6	Chile	54	6,11%	Costa Rica	45	8,57%	Chile	24	4,24%
7	Brazil	31	3,51%	Chile	33	6,29%	France	21	3,71%
8	Uruguay	20	2,26%	Argentina	33	6,29%	United Kingdom	16	2,83%
9	Bolivia	17	1,92%	Venezuela	20	3,81%	Peru	15	2,65%
10	Guatemala	15	1,70%	France	11	2,10%	Canada	14	2,47%
11	Nicaragua	15	1,70%	United Kingdom	10	1,90%	Germany	11	1,94%
12	Costa Rica	10	1,13%	Peru	9	1,71%	Colombia	11	1,94%
13	Ecuador	10	1,13%	Canada	7	1,33%	Costa Rica	9	1,59%
14	Salvador	7	0,79%	Germany	6	1,14%	Venezuela	9	1,59%
15	Spain	6	0,68%	Belgium	5	0,95%	Russian Federation	8	1,41%
16	Dominican Republic	5	0,57%	Ecuador	5	0,95%	Italy	7	1,24%
17	Russian Federation	4	0,45%	Russian Federation	5	0,95%	Belgium	6	1,06%
18	Paraguay	4	0,45%	Japan	4	0,76%	Netherlands	6	1,06%
19	France	3	0,34%	Italy	3	0,57%	Japan	4	0,71%
20	Germany	2	0,23%	Guatemala	3	0,57%	Paraguay	3	0,53%

which correspond to a bachelor's degree, we observe that the main countries concern the region of Latin America and the Caribbean. In these cases it is about the origin of the researchers, which reflects an important academic migration towards Mexico. On the other hand, the results of these columns in the middle of the table show that the master's level, where importance is gained in European and North American countries, and the last columns (doctorate) we observe that the presence increases in these countries for academic training. This last one confirms that these industrialized countries are attraction poles in Latin American and Caribbean science training.

To better understand these changes that we observe in Table 2, taking to Colombia and Cuba, the trajectory of the researchers is traced from those that obtained their first university studies in both countries. In Figures 1 and 2, they show alluvial diagrams that represent the mobility in the 3 levels of studies that we analyze. For the case of Colombia, Figure 1, observes that the researchers that have carried out studies of a Master's in some country of Latin America continue their doctorate studies in the region, presenting a strong retention of postgraduates in Mexico. Additionally, an important mobility is appreciated towards Mexico for researchers of doctorate studies that have carried out their Master's in France, Spain, Brazil, Venezuela and the United States. For the case of

Cuba, Figure 2, the scenario is distinct, because they present trajectories that are more linear. The cases of researchers that carried out their Doctorate studies in the same countries where they received their Master's are notorious. In this same Figure, we appreciate that Mexico continues presenting an important retention between a Master's and a Doctorate, just as the pull towards a doctorate for Cubans. However, doctorates in Cuba equally seem to be attractive for Cubans that previously had emigrated to Mexico.

An interesting way of visualizing this mobility is throughout a cartography, with the goal of having better clarity in the shifts in Latin America and the Caribbean within research members of the SNI during academic training. In Figure 3, it shows the cartography of the mobility of these researchers throughout their academic training. The thickness of the lines is determined by basing the mobility frequencies of the researchers, and the blue color indicates the cases that leave from Mexico (this color is used to better distinguish the arrow and make the visualization more visible). On the one hand, it observes the mobility in the training of the researchers and, on the other hand, the academic migration. Over mobility, the importance of Brazil, Cuba and Costa Rica increases, as with Chile and Argentina in smaller amounts. It is evident

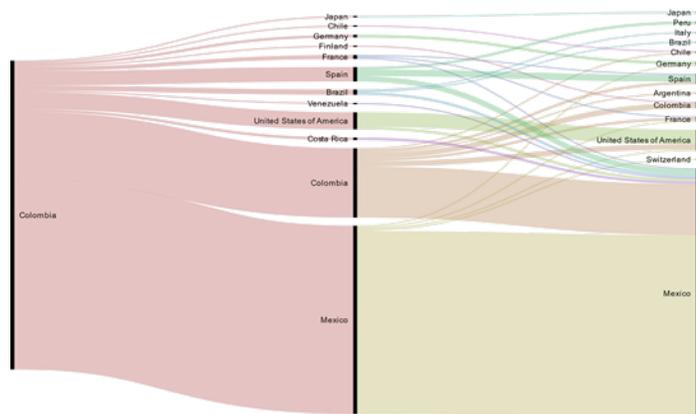


Figure 1: Academic career of Colombian researchers' members of the SNI.

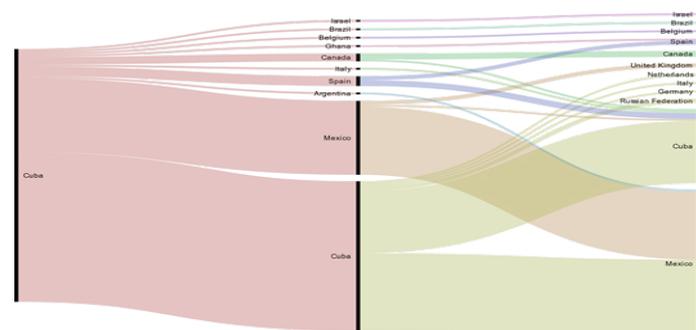


Figure 2: Academic trajectory of Cuban researchers' members of the SNI.



Figure 3: Academic mobility in Latin America and the Caribbean in training of SNI members.

that in this visualization, Mexico is the country that has the largest attraction in research training and being that it is already about data that comes from scientific and technology systems of this country. Additionally, a characteristic that stands out is that the majority of mobility is bilateral, where there are capacities of important retention in some cases, just as the above paragraphs have recalled. However, the mobility that concerns more than 2 countries is lightly present, in other terms, the training trajectories of researchers seems to be more linear than mobility terms.

We can also see some increased signs of academic migration to Mexico. It is pertinent to remember that the data concerns the members of the SNI in Mexico, who are researchers affiliated with Mexican academic and research organizations. In the cartography we observe an important mobility of researchers from Colombia and Cuba who have completed postgraduate studies in Mexico. In these stays of postgraduate studies, social relationships are established that last long after obtaining the diplomas, and are relationships that make up collaborative and interpersonal networks, which with consolidation of the lines of research, disciplines and areas of knowledge, they establish regional research communities.

CONCLUSION

In the presented results of this text, asymmetry is identified in the academic mobility in aspects of gender and areas of knowledge, as well as the geographic distribution of mobility in different academic levels. Likewise, the characterization of networks of mobility in institutions, shows us the centers of academic attraction for scientific training and also reflects important asymmetries. Finally, these results allow us to generate new questions to better understand the dynamics that have molded the real structure of mobility in Latin American and the Caribbean in scientist training.

The displayed panorama in this study has presented some elements of academic mobility in the region of Latin America and the Caribbean. The data used in this study concerns the National System of Research (SNI) relating to the information of 1169 administrative researchers aligned to an academic mexican organization that have obtained at least an university diploma in their academic training. This panorama should not be taken as exhaustive, but can be considered as a reflection of academic mobility and the capacities of human resource training in the region of Latin America and the Caribbean. The data and its analysis presented were selected to show a general panorama focusing on gender issues, areas of knowledge and mobility in the academic trajectories of researchers. It has also recalled some elements related to academic migration. All of these points in actuality are a part of the discussion about scientific and technological indicators that develop in literature and academic spaces in the region.

The main results are the asymmetry mentioned in this text. The distribution of gender and the asymmetries in the different areas of knowledge confirm the points already mentioned in other studies, and allow evaluating the progress of gender issues in the region. As regards geographic mobility and academic trajectories the results show other asymmetries in different countries of the region. These results show the capabilities of retention in scientific and technological systems of the region, just as in the case of Cuba and Mexico. The cartography equally shows important differences of mobility in the capacities of scientific and technological systems in the region for scientific training.

These results show us some elements that allow us to obtain a vision of academic mobility in Latin America and the Caribbean from a quantitative perspective, but is it necessary to go into depth with the inquiries from qualitative perspectives and other quantitative data. It relate to searching explanatory elements that allow us to realize social, economic, political and cultural dynamics that have shaped the structures of mobility presented in this study. This type of analysis is interesting for studies of science and technology, being that it allows us to have useful descriptions for subjects discussed in these areas of social sciences. Subjects of studies in gender and migration, as well as public politics, lack tools and data for their analysis. In order to deepen these studies it is required to formulate new questions and expose them in other disciplines of social sciences.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

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