sciendo | National University of Political Studies and Public Administration
Faculty of Management

Mexican Researchers' Contributions to the World Scientific Publications

Santos LOPEZ-LEYVA
Autonomous University of Baja California, Calzada Universidad, 14418. Parque Industrial Internacional Tijuana, 22390, MX; sanlop1947@gmail.com; slleyva@uabc.edu.mx.

Abstract: This paper highlights the importance of Mexican researchers' scientific publications in journals that are listed in Scopus and Web of Sciences (WoS). This research found that 98% of these publications were written by members of the National System of Researchers (SNI, by its acronym in Spanish), hence the importance of strengthening this organization. The paper also analyses the evolution of the funds that have been invested in science and technology; financing represented only 0.40% of the GDP (Gross Domestic Product) from 2000 to 2017. Therefore, it is concluded that such a variable is not determining enhancing scientific production among Mexican researchers. It is stated that per capita income growth within a country could improve the conditions for scientific production; however, in Mexico, this indicator was barely 0.8% annually; therefore, it is not a significant variable regarding the growth of Mexican publications. Mexico has gained importance in world science, explained by a growth in the number of researchers and their willingness to participate in the production of knowledge.

Keywords: scientific articles; scientific research; researchers; scientific publications; National System of Researchers (SNI); scientists.

Introduction

This paper analyses two variables and their influence on the number of scientific publications produced by Mexican researchers. The information is obtained from two of the most known data banks regarding journals and scientific information around the world: Scopus and the Web of Science (WoS). The two variables to be analyzed are 1) the growth rate in the number of researchers, and 2) the impact of financing, and their relation to the growth rate in the number of publications; for this regard, we observe the evolution of the funds that have been invested in science and technology.

First, from the analysis of the relationship between the number of researchers that are part of the SNI (National System of Researchers in Mexico) and the number of publications that were produced in the international context during the period 2000-2017, it was found that the coefficient of correlation was 0.99, and the coefficient of determination was equal to 0.98, which means that the members of this system produced 98% of the scientific publications.

Second, for the same period, we analyzed the impact of financing science and technology considering two indicators: 1) the federal funds invested in science and technology (CPI=2010) and, 2) the percentage of the GDP invested in such activities. Through this analysis we want to know the impact of financing on the level of productivity of Mexican researchers, what is the behavior that these researchers manifest with respect to the support received. Additionally, the information presented by international organisms regarding the importance of financing research in Mexico is analyzed

The research questions are the following:

1. What is the existing relationship between the growth of SNI and the growth of scientific production in Mexico (measured by the number of published papers)
2. What is the impact of financing science and technology on the publication of scientific research?

How to cite
Lopez-Leyva, S. (2021). Mexican Researchers' Contributions to the World Scientific Publications. *Management Dynamics in the Knowledge Economy. 9*(1), 50-64, DOI 10.2478/mdke-2021-0004
ISSN: 2392-8042 (online)
www.managementdynamics.ro
https://content.sciendo.com/view/journals/mdke/mdke-overview.xml

Vol.9 (2021) no.1, pp.50-64; DOI 10.2478/mdke-2021-0004

Based on the two questions set out above, the objective of this work is to reveal the influence of the growth in the number of researchers registered in the SNI in Mexico and the financing of science and technology as explanatory variables of the number of international publications made by the academics of this country. It seeks to demonstrate the following hypothesis: International scientific publications are mainly produced by Mexican researchers that are members of the SNI; hence their importance for science development within the country; these researchers are also internationally recognized, and their productivity is high, which justifies the use of financial resources for their researching activities

The number of scientific publications produced by Mexican researchers, listed on the main banks of information worldwide has increased at an average rate of 7.5% annually for the period 2000-2017. With information from Scopus, we found that Mexico increased its participation in the production of science in the world from 0.51% to 0.81%, for the period 2000-2017.

Considering the circumstances presented above, in this work, using different theoretical and methodological elements, the relationship between the growth of the SNI and the financing of science and technology is exposed as explanatory variables of the number of scientific publications made by Mexican researchers

Theories and contextualization

Scientific Research became an essential activity in universities as part of the changes that happened during the first academic revolution at the end of the XIX century. Etzkowitz and Webster's (1998) work mention that during this revolution, the state needed scientific research that would contribute to the development of agriculture, medicine, and military programs, hence the role of the universities and higher education institutions completely changed. The production of knowledge was assumed as an essential activity, and the formation of doctorates and disseminating science through the publication of scientific journals were promoted.

The second occurrence of an academic revolution in the XX century happened in the 1980s, and knowledge became more important for economics. Stephan (2011) states that: a) science was then considered to explain economic growth and development in the countries, b) scientific research and publications became public goods, and c) science and research became essentials for the new conceptualizations, theories, and policies of endogenous development. Romer (1989) thinks that even when science could be considered exogenous because it can be developed in any part of the world, this fact does not mean that science should be considered as an exogenous factor in the design of economic models that explain economic growth from a neoclassical perspective. Science is universal, but it keeps its endogenous value for the benefits it brings to the local economies and society in general; therefore, it is considered as an important factor in what is known as "the new economy" or "based-knowledge economy".

On the other hand, the dissemination of science and knowledge is an activity that has its origins in the Dialogues of Plato, particularly in his work "The Theaetetus", written around 369 BC (Burnyeat, 1990). Twenty centuries later, the first two scientific magazines were produced in Europe: 1) the French magazine "Le Journal des Savants", which after the French Revolution changed to "Le Journal des Savants" and its first edition was on January 5th, 1665. 2) the journal "Philosophical Transactions of Royal Society" published in London, on March 6th, 1665. Since then to this date, the number of journals that have been published had increased formidably, so much that by the end of 2016, Scopus listed 22,600 active publications. Another example is Ulrich that in 2013 listed 340,354 publications, from which 98,853 were categorized as technical-scientific magazines and 57,426 were reviewed by peers; what explains such a great increase in scientific publications? (Baiget & Torres-Salinas, 2013).

One first explanation is the great advances in science and the necessity to share the scientific research findings; the dissemination of science is a very dynamic activity, and the technological advances have contributed to shorter publishing times; hence, it is valid to question, why do the researchers need to disseminate the results of their scientific research?

Through their publications, researchers share the results of their investigations with colleagues, strengthen society's knowledge, receive an acknowledgment by the academic community, encourage young students to participate in scientific activities, help in the definition of policies regarding science and technology, create research groups, and delimit the frontiers of science, among others (Cargill & O'Connor, 2009; Claudio, 2016; Debnath & Venkatesh, 2015). Journals are the main mechanism to publish scientific articles, and that is because they require a peer evaluation process; the authors have the opportunity to give and receive feedback about the works that are published; it is possible to create citation indicators, compare the impact of the journals in the international context, and increase the availability of knowledge; they work as training mechanisms for referees, editors, authors and promote and strengthen their disciplines (Lopez-Leyva et al., 2018; Cargill & O'Connor, 2009).

Research papers must comply with certain requirements to be published in a journal; for example, APA (2010) establishes that articles must present research products that have not been published before, and they must be peer-reviewed; then they become part of a data bank that is used by researchers. Scientific articles are one of the main means by which the researchers communicate and spread the product of their research with other specialists. Information banks and electronic libraries that index scientific publications have been created as mechanisms to facilitate the availability, use, and control of scientific works. The most known is Scopus and Web of Science. SciELO (Scientific Electronic Library Online) and Redalyc (Network of Scientific Journals in Latin-America and the Caribbean, Spain, and Portugal) are the two most important electronic libraries in Latin America. Article 35 from SNI's regulations states that scientific papers must be subjected to a rigorous process of arbitration by prestigious editorial academic committees, for the researchers to be considered for accreditation.

Mexican researchers have increased their productivity through the number of articles they have published in Scopus and WoS; that is mainly explained by the greater number of researchers and the financial support that has been given to science and technology activities (Conacyt, 2018). Economic growth and endogenous development theories support the creation of teams to produce knowledge; this is because, theoretically, human capital is an explanatory variable of economic phenomena (Hanushek & Woessmann, 2015). This variable includes aspects like education and scientific talent; both are correlated with the growth rate of per capita income and the resources that are invested in the production of capital.

The literacy rate is another variable that could impact investment, therefore affects income growth rates (Romer, 1989). Lucas (1988) made a great contribution regarding human capital studies; he reviewed previous works from Schultz, Becker, Uzawa, and Arrow and established the existence of two types of capital: 1) produced capital (physical assets), which is traditionally used in the neoclassical growth models, and 2) human capital, which improves labor productivity and contributes to creating more physical assets. Without the investment of human capital that could lead to innovation, there would not be economic growth or development.

Data analysis

This research includes the analysis of three main aspects:

1. Human Resources: Data about enrollment in Ph.D. programs and the growth rate of SNI members, by levels and areas of knowledge.

2. Financial resources allocated to science and technology: Federal expenditure and GDP percentage invested in such activities.
3. The number of publications produced by Mexican researchers listed by Scopus and WoS.

Postgraduate studies in Mexico

One of the weaknesses of the Mexican Education System is that undergraduate programs do not consider researching as important; such activity consolidates in upper levels as doctorate programs, although there are master's degree programs where the students are required to do some research and work in a thesis; but professionalizing studies do not require dissertations.

As of January 2020, the number of professionalizing programs inscribed in the National Program of Quality Graduate Studies (PNPC, by its initials in Spanish) supported by the National Council of Science and Technology (CONACyT, by its initials in Spanish) was 850, which represented 38% of the total, 400 were specialties, 440 were master's degrees, and 10 were doctorates.

Table 1. Doctorate programs enrolment and growth rates (2000-2017)

Year	Ph.D. programs enrolment	Absolute change	Growth rate	% Doctorates/ Total of Graduate studies	Total of Graduate Programs	% Increases
2000	8,407			7.1	118,099	
2001	9,133	726	8.6	7.1	127,751	8.2
2002	9,910	777	8.5	7.5	132,421	3.6
2003	10,825	915	9.2	7.7	139,669	5.4
2004	11,822	997	9.2	8.3	142,480	2.0
2005	13,081	1,259	10.6	8.6	150,852	5.8
2006	13,454	373	2.8	8.7	153,903	2
2007	15,135	1,681	12.5	9.3	162,003	5.2
2008	16,698	1,563	10.3	9.6	174,282	7.5
2009	18,530	1,832	10.9	10	185,516	6.4
2010	23,122	4,592	24.8	11	208,225	12.2
2011	30,239	7,117	30.8	10.9	276,281	32.7
2012	32,012	1,773	5.8	11.3	283,287	2.5
2013	36,086	4,074	12.7	12.2	294,584	4.0
2014	39,139	3,053	8.4	12.4	313,997	6.5
2015	38,770	-369	-0.9	11.8	328,430	4.5
2016	39,448	678	1.7	11.8	334,109	1.7
2017	43,744	4,296	10.9	12.4	351,932	5.3

Source: Association of Universities and Higher Education Institutions (ANUIES, by its initials in Spanish) Retrieved from:
http://www.anuies.mx/informacion-y-servicios/informacion-estadistica-de-educacion-superior/anuario-estadistico-de-educacion-superior

Table 1 shows an average growth annual rate of 6.6% for graduate programs, with a significant increase of 32.7% in 2011; there were not negative fluctuations. Regarding the Ph.D. programs, they grew at a 10.2% annual rate, with an important increase of 30.8% in 2011, however with a decrease in 2015. On average, doctorate programs represent 10% of the total graduate programs, with an increasing rate of 5.6% for the period. As of 2020, the PNPC included 2,240 postgraduate programs, from which 400 were professionalizing specialties, 1,210 were master's degrees, only 770 were research-oriented, and 630 were Ph.D. programs, from which 620 were research-oriented. (Information retrieved from http://svrtmp.main.conacyt.mx/ConsultasPNPC/consulta-lgac.php February 10th, 2020).

CONACyT has implemented policies to assure and promote the quality of postgraduate programs, although some evaluations are difficult to perform because 60% of the total students are enrolled in private institutions, and this type of institution is not subject to evaluations. Hence, only 2% of the postgraduate programs offered by private institutions are considered qualitative.

The National System of Researchers (SNI)

This program originated in Mexico in 1984, as an alternative to improve the wage levels of researchers, therefore encouraging them to stay in the country and discourage brain drain. To be part of this system, it is required to hold a doctorate, have produced publications that are acknowledged by the academic community, and have tutored graduate students. The 2018 General Report of Science, Technology and Innovation presented by CONACyT (Conacyt, 2018) mentions that the activities that are evaluated for a researcher to join this system are: 1) the quantity and quality of scientific production; 2) the generation of research groups and networks; 3) teaching activities; 4) linking research with the public and private sectors, and 5) training new scientists and technologists.

As this program has consolidated, the salaries of the researchers have improved. Moreover, this program offers better opportunities, benefits, and professional satisfaction to the researchers. Table 2 shows the composition of the SNI for the period 2000-2017

From table 2, we made the following observations:

- SNI membership grew at an 8.1% annual rate;
- The category of candidates represented an average of 18% of the total, although there were years like 2002 when the participation went down to 14%. The average annual growth rate was 9.4%;
- The majority of the SNI members belong to the category known as national researcher level I. For the period, they represented 55.8% of the total, even though in four years it was over 58%. Their annual average growth was 7.7%;
- The second category, known as national researcher level II shows more erratic behavior. For the period, they represented 17.9% of the total, with an average annual growth rate of 8.8%. In 2003, there was an unusual increase of 49%, although there were two years where numbers decreased (2002 and 2010).
- Researchers level III are the smallest group since they only represent 8.5% of the total membership. The annual average growth rate for this group is 8.9%.

Table 3 shows the number of SNI members by areas of knowledge. From the analysis we observe that Area V (Social Sciences) shows the highest growth (11% annual average), while Area I (Physics-Mathematics and Earth Sciences) shows the smallest increase, even though this area has the higher representation from the total (17.5% average); area III (Medicine and Health Sciences) has the smallest number of members (10.4% average) from the total.

In its 2018 report, the CONACYT mentions that the SNI has never stopped growing and that in 2011 it included 17,639 researchers, going to 28,633 researchers in 2018, which corresponds to an increase of 62%. Women are 37%, and more than 40% of its members are located in Mexico City, the State of Mexico, and Jalisco.

Vol.9 (2021) no.1, pp.50-64; DOI 10.2478/mdke-2021-0004

Table 2. SNI members by levels, 2000-2017

			Researchers								
Year	Candidate		Level I		Level II		Level III		Total		
	Absolute	Relative	Absolute	Relative	Absolute	Relative	Absolute	Relative	Abs.	Increase	% increase
2000	1,318	0.18	4,191	0.58	1,159	0.16	584	0.08	7252		
2001	1,220	0.16	4,345	0.58	1,279	0.17	622	0.08	7466	214	2.9
2002	1,128	0.14	4,682	0.58	1,156	0.14	652	0.08	8018	552	7.3
2003	1,324	0.14	5,384	0.58	1,728	0.19	762	0.08	9199	1181	14.7
2004	1,634	0.16	5,782	0.57	1,827	0.18	876	0.09	10119	990	10.7
2005	1,876	0.17	5,981	0.55	2,076	0.19	971	0.09	10904	715	7.0
2006	2,190	0.17	6,558	0.54	2,306	0.19	1,123	0.09	12096	1192	11.0
2007	2,386	0.18	7,567	0.56	2,429	0.18	1,103	0.08	13485	1389	11.5
2008	2,589	0.18	8,165	0.56	2,814	0.19	1,113	0.08	14681	1196	8.8
2009	2,706	0.17	8,567	0.56	3,057	0.20	1,235	0.08	15565	884	6.0
2010	3,052	0.18	8,970	0.54	3,172	0.19	1,406	0.08	16600	1035	6.6
2011	3,390	0.19	9,577	0.54	3,135	0.18	1,537	0.09	17639	1039	6.2
2012	3,604	0.19	10,059	0.54	3,311	0.18	1,581	0.09	18555	916	5.2
2013	3,712	0.19	10,758	0.54	3,576	0.18	1,701	0.09	19747	1192	6.4
2014	3,991	0.19	11,673	0.585	3,852	0.18	1,842	0.09	21358	1611	8.1
2015	4,575	0.20	12,775	0.55	3,964	0.17	2,002	0.09	23316	1958	9.1
2016	5,044	0.20	13,710	0.55	4,221	0.16	2,097	0.08	25072	1756	7.5
2017	5,818	0.23	14,662	0.58	4,452	0.18	2,454	0.1	25186	2114	8.4

Source: National Council of Science and Technology. 2016 General Report about Science, Technology, and Innovation. Data from 2016 and 2017
http://www.siicyt.gob.mx/imdex.php/s191-sistema-nacional-de-investigadores-sni/2-uncategorised/220-bases-de-datos-abiertas-s191

Vol.9 (2021) no.1, pp.53-67; DOI 10.2478/mdke-2021-0004

Table 3. SNI composition by areas of knowledge (2000-2017)

Year	Area I		Area II		Area III		Area IV		Area V		Area VI		Area VII		TOTAL
	Absolute	%	Absolute	%	Absolute	%	Absolute	%	Absolute	%	Absolute	%	Absolute	%	
2000	1621	22	1435	20	721	10	1266	17	738	10	642	9	829	11	7252
2001	1569	21	1435	19	765	10	1269	17	810	11	700	9	918	12	7466
2002	1612	20	1436	18	846	10	1362	17	920	11	856	11	986	12	8018
2003	1770	19	1661	18	926	10	1582	17	1097	12	1011	11	1182	13	9199
2004	1878	18	1767	17	1043	10	1700	17	1233	12	1131	11	1437	14	10189
2005	1968	18	1776	16	1168	11	1798	16	1369	13	1257	12	1568	14	10904
2006	2074	17	1891	16	1343	11	1964	16	1608	13	1441	12	1775	15	12096
2007	2277	17	2179	16	1429	10	2169	16	1864	14	1586	12	1991	15	13485
2008	2478	17	2443	17	1445	10	2326	16	2187	15	1711	12	2091	14	14681
2009	2600	17	2704	17	1440	9	2394	15	2469	16	1720	11	2238	14	15565
2010	2708	16	2905	17	1592	9	2465	15	2616	16	1866	11	2248	14	16600
2011	2844	16	3084	17	1758	10	2622	15	2687	15	1993	11	2641	15	17639
2012	3004	16	3162	17	1914	10	2773	15	2747	15	2177	12	2778	15	18555
2013	3203	16	3360	17	2035	10	2918	15	2996	15	2326	12	2909	15	19747
2014	3458	16	3696	17	2233	10	3121	15	3336	16	2442	11	3072	14	21358
2015	3782	16	3993	17	2511	11	3380	14	3672	16	2612	11	3366	14	23316
2016	3995	16	4080	16	2844	11	3735	15	3990	16	2840	11	3588	14	25072
2017	4243	16	4263	16	3245	12	4033	15	4308	16	3162	12	3932	14	27186

Source: National Council of Science and Technology (various years). General report of the state of Science, Technology, and Innovation. Mexico. Contacyt.
Contacyt Areas: I. Physics and Mathematics, and Earth Sciences; II. Biology and Chemistry; III. Medicine and Health Sciences; IV. Humanities and behavior Science; V. Social Sciences; VI. Biotechnology and Agricultural Sciences; VII. Engineering

Financing science and technology

Table 4 presents indicators that reflect the evolution of financing science and technology in Mexico. Expenditure made by the federal government in science and technology from 2000 to 2017 (CPI=2010) was very erratic; the average annual growth rate was 3.95%. But, for example, in 2014, this indicator showed an increase of 17.5% compared to the previous year, and in 2017 the growth rate was negative (-4.35%).

On the other hand, the percentage of GDP that has been invested in these activities has been inferior; the annual average rate was around 0.40%, which is very low for a country like Mexico. When considering the percentage of the GDP that was particularly dedicated to R&D (research and development), the performance was also poor. In years like 2006 and 2007, the indicator was less than 0.40%, while the highest investment happened in 2014 (0.54% of the GDP).

Lastly, we analyzed the annual growth rate of the country per capita income, since this reflects the general economic situation of the population income. Column 6 shows the erratic behavior of the indicator, and some years were even negative. The average annual growth rate of one Mexican's income was 0.8% from 2000 to 2017.

Table 4. Financing Science and Technology activities (numbers in millions of Mexican pesos) 2010=100.
Percentage of the GDP invested in Science and Technology. Growth rate per capita income (CPI=2010)

Year	Federal Expenditure in Science and Technology 2010=100	Annual growth rate	% GDP invested in Science and Technology	% GDP invested in Research & Development	Annual growth rate of the per capita income
2000	35640.25		0.42	0.40	3.441
2001	35738.50	0.25	0.41	0.40	-1.993
2002	34333.90	-3.9	0.39	0.40	-1.403
2003	39722.85	15.69	0.43	0.41	0.07
2004	36014.25	-9.3	0.36	0.40	2.495
2005	39075.85	8.5	0.37	0.41	0.87
2006	39293.70	0.55	0.36	0.38	2.984
2007	40862.40	3.9	0.31	0.37	0.783
2008	47515.90	16.28	0.36	0.42	-0.358
2009	48121.70	1.27	0.38	0.44	-6.674
2010	54576.75	13.41	0.41	0.54	3.617
2011	56793.27	4.06	0.40	0.51	2.22
2012	54436.70	2.89	0.40	0.49	2.34
2013	61266.45	4.84	0.42	0.50	0.02
2014	71990.10	17.5	0.48	0.54	1.49
2015	71842.20	-0.2	0.47	0.53	2.01
2016	68713.20	-4.35	0.44	0.51	1.69
2017	65906.30	-4.08	0.42	0.48	0.88

Source: National Council of Science and Technology (several years). General Report of the state of Science, Technology, and Innovation. Mexico. Conacyt.
The information regarding per capita income was retrieved from the World Bank database: GDP per capita growth rate for Mexico

Production of scientific articles

From our calculations, the coefficient of correlation between the number of articles published by Mexican researchers and the growth of the SNI membership is 0.99. Therefore, it shows the importance of analyzing the contributions Mexican researchers made within Latin America and around the world.

Table 5. Scientific publications produced by Mexican researchers (Information from Scopus and WoS)

Year	Indexed articles listed (Scopus)	% Participation in the global science (Scopus)	% Participation in Latin America (Scopus)	Indexed articles listed by WoS	Contribution to science around the world according to WoS
2000	6570	0.51	19.22	4861	0.64
2001	7011	0.51	19.38	5209	0.68
2002	7663	0.53	18.87	5514	0.71
2003	8808	0.58	19.84	6234	0.73
2004	9571	0.59	19.58	6399	0.77
2005	10975	0.6	20.07	7357	0.77
2006	12253	0.64	19.62	7225	0.75
2007	12592	0.62	19.38	7471	0.60
2008	13759	0.65	18.67	8636	0.61
2009	14556	0.66	18.36	8758	0.59
2010	15205	0.66	16.86	9263	0.59
2011	16223	0.66	16.58	10011	0.59
2012	17304	0.68	16.33	10907	0.61
2013	18233	0.7	16.48	11615	0.61
2014	19689	0.74	16.54	12147	0.61
2015	19922	0.75	16.36	13025	0.62
2016	21115	0.78	16.29	13383	0.63
2017	22302	0.81	16.33	14480	0.66

Source: Information from Scopus found in Scimago. Country Rank 2018.
https://www.scimagojr.com/countrysearch.php?country=mx
Information from WoSis found in the General Report of the state of Science, Technology, and Innovation. Conacyt. Mexico

Table 5 shows the number of international publications produced by Mexican researchers according to information retrieved from Scimago with information from Scopus. From column 2, it is found that the publications grew at a 7.5% annual rate from 2000 to 2017. Then, from column 3, we observe a slow but steady increase in the percentage of participation in global production; by 2017, the participation was 0.81%.

On the other hand, the participation of Mexican researchers in the Latin American region has been smaller through the years; in 2000 their participation was 19.22%, but it diminished to 16.33% by 2017; this decrease is explained by the higher participation of Brazil. Columns 5 and 6 show information from WoS. It is observable that the participation annual growth rate is 6.9%, which is smaller than the one obtained with information from Scopus.

Vol.9 (2021) no.1, pp.50-64; DOI 10.2478/mdke-2021-0004

Analysis of the results

The following are the main conclusions we have arrived at after observing the data that is shown in table 6.

1) The enrolment in Ph.D. programs showed the highest growth, with an average annual rate of 10.2%, even higher by 2 points than the growth shown by the SNI membership. These numbers make sense if we consider that not all the students that get enrolled in a Ph.D. program achieved their doctorate; some drop the courses almost by the end and others do not present their thesis. Moreover, not all the students that achieve a doctorate become part of the SNI. It is also well known that the system has been greatly benefited by researchers that have achieved their degrees in foreign universities.
2) SNI membership did not show any negative numbers during the period. But the variable enrolment in Ph.D. programs was negative in 2015.
3) The volatility of these two variables differs, as the enrolment in Ph.D. is high but for the SNI variable is low; the difference between the smallest and the highest values in the first of these variables was 31.7 points. For the second one, the difference was 11.8 points.
4) The standard deviation for these two variables also differs. The first one shows an SD of 13 309 and the second one 5 981 (See table 6); However, since both variables showed a similar trend and growth rate, the correlation between those was 0.97.

Table 6: Annual growth rate of the main variables under analysis (2000-2017)

Year	Growth rate of Graduate	Growth rate of Ph.D.	SNI membership growth rate	The growth rate of the expenditure in Science and Technology	The growth rate of per capita income	The growth rate of publications in Scopus	The growth rate of publications in WoS
2000	--	--	--	--	--	--	--
2001	8.2	8.6	2.7	0.25	3.441	6.7	7.9
2002	3.6	8.5	7.3	-3.9	-1.993	9.2	4.2
2003	5.4	9.2	14.7	15.69	-1.403	14.9	12.4
2004	2	9.2	10.7	-9.3	0.07	8.6	4.4
2005	5.8	10.6	7	8.5	2.495	14.6	15.3
2006	2	2.8	11	0.55	0.87	11.6	3.8
2007	5.2	12.5	11.5	3.9	2.984	2.7	13.6
2008	7.5	10.3	8.8	16.3	0.783	9.2	7.8
2009	6.4	10.9	6	1.27	-0.358	5.8	1.4
2010	12.2	24.8	6.6	13.41	-6.674	4.4	5.7
2011	32.7	30.8	6.2	4.06	3.617	6.7	8
2012	2.5	5.8	5.2	2.89	2.22	6.6	8.9
2013	4	12.7	6.4	4.84	2.34	5.3	6.5
2014	6.5	8.4	8.1	17.5	1.49	7.9	4.5
2015	4.5	-0.9	9.1	-0.2	2.01	1.1	7.2
2016	1.7	1.7	7.5	-4.35	1.69	5.9	6.5
2017	5.3	10.9	8.4	-4.08	0.88	5.6	3.7
Mean	6.6	10.2	8.1	3.95	0.8	7.5	6.9

Source: Own elaboration

The SNI membership grew at an average annual rate of 8.1%. According to information from WoS, the area of knowledge with the highest growth was Social Sciences, which grew at a rate of a little over 11% annually. On the contrary, the area with the smallest increase was Physics and Mathematics, with 5.8% annually, but the productivity of this area was high, 24.1% of the total; the only area that surpassed such level of productivity was Biology and Chemistry with 37.9%. The areas with the lowest production were Humanities and Behavioral Science with a 4% of participation, and Social Sciences with a 5.3% of participation, even when the researchers from these last two areas have more editorial options to publish their articles.

In March 2020, the Conacyt System of Classification of Mexican Journals listed 261 magazines, from which 99 were in the Social Science field (38%), and 44 were about humanities and behavioral sciences, which is 17% of the total. The two scientific disciplines together reached 55% corresponding to 143 journals.

The growth rate of publications was higher according to the information retrieved from Scopus (7.5%) than from WoS (6.9%). Moreover, the researchers' productivity was higher, according to Scopus: 0.92 documents per researcher. In 2005 and 2006, productivity was equal to 1, which means that each researcher was publishing one article per year. Whereas, with information from WoS, the publishing rate was only 0.59 articles per researcher. The highest correlation (0.99) happened between the SNI growth rate and the Scopus publication growth rate.

From table 4, it is observable that the funds invested in science and technology have not increased, and that only 0.4% of the GDP was dedicated to these activities. Even though the government has been announcing their goal to invest at least 1% of the GDP it has never happened; as a matter of fact, the federal government plan expenditure for the period 1994-2000 clearly stated such a goal; moreover, in 2004 the Mexican Law of Science and Technology started in its 9bis article that local and federal governments would be obliged to invest 1% of their GDP in activities related to science and technology; yet, Special Program for Science and Technology (PECITI), in its strategy 3.5.1 considered to "Promote national investment on scientific research and technological development, so that the percentage of the GDP that is destined to such activities grow annually until it reaches 1%". In other words, this has been an unaccomplished goal, since investments have not grown and there are not clear actions that would change such a trend in the short term.

When analyzing the relationship among all the variables and the number of scientific publications listed by Scopus, the findings are: 1) SNI members' collaborations grew at an annual rate of 8.1%, even though the publications increased 7.5%; this is explained by the fact that not all the SNI members write for magazines that are recognized or listed by Scopus, but the existent correlation between those two variables is almost perfect R=0.99 and R^2 = 0.983; this means that 98.3% of the scientific publications in Mexico are produced by SNI members. These results confirm the premises and the idea we already had about the importance of SNI in the progress of science in Mexico.

Regarding the financial resources that have been invested in science and technology, it is found that Mexico should have had spent 1.42% of its GDP to finance the publications that were produced in 2017(Conacyt, 2018). Instead, this indicator oscillated between 0.4% and 0.5% for the period; this fact needs to be considered when evaluating the productivity of Mexican researchers in the world. Another way to analyze the productivity of Mexican researchers is by observing the evolution of the resources that have been used to support their activities. For example, in 2017, 22,302 articles were produced with an investment of 65,906.30 million pesos (prices of 2010) (Tables 4 and 5); if the financial productivity of 2000 were maintained, applying the growth rate of the article production, then the resources needed to produce the same number of articles would have been 121,893 million pesos.

Therefore, using the growth rates or the average cost by article, it is found that with 65,906.30 million pesos of 2017, it would only have been possible to produce 12,694 articles; the difference between the actual and the prospected number of publications is 9,608 articles, which can be considered as an extraordinary contribution of the researchers, that only could be explained by the efforts made by the members of the SNI to produce science; their contribution surpassed in 50%, the governmental economic support they received.

Considering the facts described above, if we try to explain the high productivity of Mexican researchers due to financial support, we might not see the correlation. Therefore, their scientific contributions must be explained by other factors such as the researchers' high commitment and attitude toward their responsibilities, plus the institutional evaluation mechanisms that promote and support research.

Furthermore, the importance of giving financial funding to researchers is supported by international facts and studies. For example, the World Economic Forum (WEF) elaborates the global competitiveness indicator and evaluates different factors from each country in the world. In 2017, Mexico was ranked in position 56 out of 136 countries, regarding the concept of innovation (pillar number 12 according to WEF's methodology) from which the indicators in best positions were: a) the quality of research institutions, in place 46 and qualification of 4.3, (where the maximum is seven and the minimum is one), and b) the availability of scientists in place 53, with a qualification of 4.2 (WEF, 2017, pp. 202-203).

In 2018, the structure of the WEF indices changed. They included the H-index. This indicator is an author-level metric that measures both the productivity and citation impact of the publications of a scientist or scholar (WEF, 2018, pp. 391-393). The index is based on the set of the scientist's most cited papers and the number of citations that they have received in other publications. Regarding this index, Mexico was in place 35 out of 140 countries, with a H=360.7; this index improved Mexico's position in the global ranks, placing the country in position 22, thanks to the quality of its researching institutions, despite the insufficient financial resources that have been allocated to this field.

In the 2018 Scimago Report, Mexico was in place 28thby the number of articles that were published around the world (from 1996 to 2018); the citation index was 11.82 per article, and the H-index was 411. It should be noted that some countries with fewer publications have a higher H-index because they have a higher citation index. For example, Greece was in place 29 with 16.34 cites per article, and an H-index = 466; Norway was ranked 30, with 29.76 cites per article and an H-index = 580; Singapore was in place 32 with 19.34 cites and an H-index = 535. Although, it is important to emphasize that these three countries invested a higher percentage of their GDP in science and technology than Mexico. The 27 countries that show a higher production of articles than Mexico spend an average of 2.19% of their GDP in science and technology. Iran is the only country that invested less than Mexico.

The National Science Board Report for 2018 presents information regarding the GDP percentage that is invested in R&D by 68 countries. Mexico was positioned in 54th place with the participation of 0.5%. If the information presented was organized by quartiles, Mexico would be in the fourth quartile among the countries with the smallest percentage allocated to R&D activities. On the other hand, Mexico was ranked 25th regarding scientific production in the global context, with a growth rate of 4.5% between 2006 and 2016. This information confirmed the importance of Mexican researchers and their scientific production; therefore, their productivity can be measured by the gap between the position the country has regarding financing (54) and the position it has achieved for its productivity (25), which is 29 positions.

Mexico should increase the GDP percentage that is invested in science and technology, which seems difficult since the average growth rate of the per capita income during 2000-2017 was barely 0.8%, and there were years with negative increases, for example in 2010 when the rate was -6.674%. The erratic behavior of the per capita income reflects the lack of sustainable growth of the Mexican economy, and such a situation makes it harder to comply with the law that requires an investment in science and technology, of at least, 1% of the GDP. Nevertheless, it is urgent to take actions that promote the long-term growth of the Mexican economy and its development, together with public policies that encourage solid competitiveness, sustained in the production and application of knowledge.

Based on the information above and compared with other countries, it is valid to say that Mexican researchers have made great contributions to the national production of science; moreover, they have been recognized by international organisms. Therefore, researchers should be supported to promote an endogenous model of development based on solid competitiveness. It is necessary to invest a higher amount of financial resources in science and technology. Even though Mexican researchers' productivity cannot only be explained by the theories of mobility and availability of resources, because as is stated by Melucci (1995), these theories only focused on the visible and organized forms of collective actions, but they underestimate other actions that are more profound or significant, which are practiced by Mexican researchers.

Supporting scientific research because it is a factor that could positively impact a country, is not new; from the mid of the XIX century, there was the idea to promote groups that would become the productive elite of a country; since 1856, List (cited by Selwyn, 2014) proposed the formation of a "productive power", which was understood as a group that would foster the production and would achieve social cohesion, therefore promote a better organized and productive system; scientists were considered in such group. This idea was included in the Latin American economic literature, particularly in Fajnzylber (1983) works, where he proposed that Latin American countries should create an articulated and technologically strong "endogenous group", with the capacity to penetrate the international markets and foster real competitiveness within the countries.

The United Nations Economic Commission for Latin America and the Caribbean acknowledges the aforementioned assumptions and proposals in their document "Education and knowledge: the axis of a productive transformation with equity" on CEPAL (1998), by encouraging the countries to support the professionalization and importance of educators, considering this sector as strategic in the design and implementation of policies that promote economic growth and development.

Freeman (1987) explains Japan's economic growth and development through the structure of a national innovation system based on four factors, where at least two, have to do with knowledge: 1) the importance of science, technology, and innovation sector, giving value to knowledge and all its participants, and 2) the formation of human capital; an innovation system cannot be implemented without people; they must-have skills, abilities, and availability to participate proactively in the innovation system. The national innovation system should have inclusive institutions that promote the motors of prosperity: science, technology, and education (Acemoglu & Robinson, 2013).

Lastly, considering Moreno-Brid and Ruiz-Napoles (2010), investment is a fundamental principle for economic growth in Latin American countries, and the application of science and technology is meant to modernize the productive processes in the region through the expansion of innovative systems and the improvement of science infrastructure, the availability of researchers and highly qualified staff, a functional and effective relationship between researching centers and productive enterprises.

Conclusions

Mexico has consolidated important groups of scientific researchers that are productive and are internationally recognized. These groups are part of the National System of Researchers (SNI), and their publications represent almost 100% of the Mexican scientific production, which is also recognized by the main banks of information as Scopus and WoS. The SNI is an important productive institution of science in Mexico. For this reason, it is necessary to implement policies to increase its strength.

The growth of scientific production in México cannot be explained only by the perspective of tangible variables, due to the increase in the number of researchers, but through the analysis of intangible aspects such as the responsibility, commitment, and hardworking values of academics. That is, by improving the quality and capacity of researchers.

Mexico stands out in the global scientific production and has been acknowledged by international organizations, such as the World Economic Forum, Scimago, and the National Science Foundation, among others. The Scimago group places Mexico in 28th position in the world ranking of scientific production; in Latin America is in second place, only behind Brazil, if our country wishes to improve its position in this ranking, it should increase the financial resources dedicated to research and increase the number of researchers.

Publications produced by Mexican researchers have grown with a better and higher dynamism than the growth of the financial resources that had been allocated for science and technology within the country. This can be explained by the commitment of Mexican researchers. The scientific production of a country is a very important variable to promote economic development, but this variable cannot be sustained with only the willingness and goodwill of researchers; it is necessary to improve their working conditions and provide financial support for all activities related to science and technology.

According to the new theories of endogenous economic growth, Mexico should consolidate and support groups of scientists and researchers, since they are vital for the country's development. It is also necessary to design and implement strategies that promote competitiveness in the long term.

References

Acemoglu, D., & Robinson, J. A. (2013). *Why Nations Fail. The origins of power, prosperity, and poverty*. Currency.

American Psychological Association. (2010). *Publication Manual of the American Psychological Association* (6th ed.).

Baiget, T., & Torres-Salinas, D. (2013). *Informe APEI sobre publicaciones en revistas científicas [APEI report on publications in scientific journals]*. Professional Association of Information Specialists. http://www.apei.es/

Burnyeat, M. (1990). *The Theaetetus of Plato*. Translation by M. J. Levett. Hackett Publishing Company.

Cargill, M., & O'Connor, P. (2009). *Writing scientific research articles. Strategy and steps*. Wiley-Blackwell.

CEPAL (1998). *Educación y conocimiento: ejes de la transformación productiva con equidad. En CEPAL [Education and knowledge: axes of productive transformation with equity. In ECLAC]*. Ciencuenta Años del pensamiento de la CEPAL (pp.877-886). Fondo de Cultura Económica.

Claudio, L. (2016). *How to write and publish a scientific paper. The step-by-step guide*. Write science now publishing Co.

National Council of Science and Technology. (2018). *General report on the state of science, technology and innovation*. https://www.conacyt.gob.mx/Informaci%C3%B3n-de-Ciencia-y-Tecnolog%C3%ADa.html

Debnath, J., & Venkatesh, M. D. (2015). Writing and publishing a scientific paper: facts, myths and realities. *Medical Journal Armed Forces India (MJAFI*), *72*(2), 107-111. https://doi.org/ 10.1016/j.mjafi.2015.02.009

Etzkowitz, H., & Webster, A. (1988). Entrepreneurial science: The second academic revolution. In *Capitalizing knowledge. New intersections of industry and academia* (pp. 21-46). New York State University.

Fajnzylber, F. (1983). *La industrialización trunca de América Latina [The incomplete industrialization of Latin America].* Nueva Imagen editorial.

Freeman, C. (1993). *Technology policy and economic performance. Lessons from Japan*. Frances Printer Publishers.

Hanushek, E. A., & Woessmann, L. (2015). *The knowledge capital of nations: education and the economic growth*. The MIT Press.

Lopez-Leyva, S., Alvarado- Borrego, A., & Mungaray- Moctezuma, A. B. (2018). La difusión de la ciencia en México a través de artículos científicos. Condiciones y contextos [The dissemination of science in Mexico through scientific articles. Conditions and contexts]. *Revista de la Educación Superior*, *47*(188), 157-176. http://resu.anuies.mx/ojs/index.php/resu/article/view/513/273

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, *22*, 3-42. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=227120

Melucci, A. (1995). El conflicto y la regla: movimientos sociales y sistemas políticos [Conflict and rule: social movements and political systems]. *Sociológica*, *28*(10), 10-25. https://scholar.google.com/scholar?hl=es&as_sdt=0%2C3&q=El+conflicto+y+la+regla%3A+movimientos+sociales+y+sistemas+pol%C3%ADticos&btnG=

Moreno-Brid, J. C., &Ruíz- Nápoles, P. (2010). La educación superior y el desarrollo económico [Higher education and economic development]. *Revista Iberoamericana de Educación Superior*, *1*(1), 171-188. http://www.scielo.org.mx/scielo.php?pid=S2007-28722010000100013&script=sci_arttext

National Science Board (2018). *Science and Engineering Indicators*, Alexandria VA, National Science Foundation. https://www.nsf.gov/statistics/2018/nsb20181/digest/sections/preface

Romer, P. M. (1989). *Human capital and growth theory evidence*. NBER working paper no. 3173. National Bureau of Economic Research. https://www.nber.org/papers/w3173

Scimago (2018). *Scimago Journal & Country Rank.* https://www.scimagojr.com/countryrank.php

Selwyn, B. (2014). *The global development crisis*. Polity

Stephan, P. (2011). The economics of science. In *Handbook of Economics. Economics of Innovation*, Vol. 1, Chapter 5, (pp. 217-273). Elsevier-NH.

World Economic Forum. (2017). *Global Competitiveness Index 2017*. https://www.weforum.org/reports/the-global-competitiveness-report-2017-2018

World Economic Forum. (2018). *Global Competitiveness Index 2018*. https://www.weforum.org/reports/the-global-competitveness-report-2018

Received: December 23, 2020
Accepted: February 15, 2021