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Measuring the incidence of social factors on scientific research: A socio-scientometrics analysis of strategic countries

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Artículo de investigación

Abstract

Throughout scientific literature, some studies have examined the positive impact of research in society. However, this paper is oriented in the opposite direction analyzing how social factors could be influencing scientific results. The research sample comprises Mexico and its 18 strategic partners in science and technology and a 17-year temporary window. The results are divided into three parts, the first one shows the relation among population, government investment in tertiary education, gross domestic expenditure on R&D (GERD) (as a percentage of Gross Domestic Product (GDP)) number of researchers with scientific production and citations received. The second part is focused on the relationship between researcher mobility (sedentary or migratory:

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inflow, outflow, transitory) and scientific collaboration. The third part analyses whether the countries research preferences (measured through the Relative Activity Index in subject areas) have a repercussion on scientific production. This study facilitates a better understanding of social contributions to the scientific and socioeconomic development of countries and it is valuable for governments and policy makers for taking into account the importance of these social variables in leading countries towards excellence in science.

Keywords: Scientific Production; Social Factors; Science Policy; Bibliometrics

Midiendo la influencia de los factores sociales en la investigación científica: un análisis sociocienciométrico de países estratégicos

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Resumen

En la literatura científica algunos estudios han examinado el impacto positivo que tiene la investigación en la sociedad. Sin embargo, este trabajo analiza cómo los factores sociales pueden influir en los resultados científicos. La muestra de investigación estudia a México y sus socios estratégicos en ciencia y tecnología. Los resultados se dividen en tres partes, la primera muestra la relación entre población, inversión pública en educación superior, gasto interno bruto en I+D (GERD) (como porcentaje del Producto Interno Bruto (PIB)), número de investigadores y los resultados científicos (producción científica y citas recibidas). La segunda parte se centra en la relación entre la movilidad del investigador (sedentario o migratorio (flujos de entrada y salida, estancias transitorias)) y la producción en colaboración. La tercera parte analiza si las preferencias en investigación de los países tienen una repercusión en el conjunto total de la producción científica. Este estudio facilita una mejor comprensión de las contribuciones sociales al desarrollo científico y socioeconómico de los países y es útil para que los gobiernos y los responsables políticos tengan en cuenta la importancia de estas variables sociales y, como resultado, conducir a los países hacia la excelencia en ciencia.

Palabras clave: Producción Científica; Factores Sociales; Política Científica; Bibliometría

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Introduction

Research plays a fundamental and essential role in our society. This has proportioned enormous benefits to population such as facing its own challenges, improving the quality of people's lives, innovating or discovering new tools to make a world healthier, eliminating or fighting powerful diseases and reaching unimaginable scientific processes. For all these reasons, scientific results generate a considerable and significant impact on our society (Bornmann, 2012).

The National Science Foundation (NSF) created the Broader Impacts to evaluate not only the intellectual significance of a planned research, but also the potential societal benefits of this research contributing to reach the desired societal outcomes. According to an official document from National Science Board (NSB) the criteria for reviewing research proposals should include not only quality requirements of scientific outputs but also measure the broadest contribution to reach global social challenges (NSB, 2011).

Some authors have analyzed the social effects of science (Spaapen and van Drooge, 2011; Owen, Macnaghten, and Stilgoe, 2012; Marmolejo-Leyva, Perez-Angon, and Russell, 2015; Samuel and Derrick, 2015; Derrick and Samuel, 2016; Hill, 2016; Bozeman and Youtie, 2017). Many countries have worked under the principle "science is the genie that keeps the country competitive, but the genie needs to be fed" (Stephan, 2012: 10; Bornmann, 2013). Moreover some studies have revealed a significant relationship between scientific results and global economy (Inglesi-Lotz, Chang, and Gupta, 2015; Kumar, Stauvermann, and Patel, 2016).

Apart from the recognized positive effects that science provides to society some authors have assessed the effects that social factors are causing on research. They have stated the positive relationship between inputs (i.e., economic funding, political efforts, human resources in R&D) and outputs (i.e., generated scientific results) (Moya-Anegon and Herrero-Solana, 1999; Gonzalez-Brambila et al., 2016).

Although social components have a close relationship with the economy they refer to a broader structure composed by all factors that interfere in society. This structure is composed about factors such as population density, specific characteristics, cultural identity, composition, migratory movements and other elements that involve a society in general.

After contextualizing the present study, our intention is to measure the influence of some social dimensions together on research results. For this, we chose a representative sample that attended to different social characteristics and a wide time-window. For this reason, we chose a closed sample of 19

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strategic countries (Mexico and its strategic partners) where there is a country representation from each world region. We decided to study this sample because it is mixture of countries with cultural diversity (Lancho-Barrantes and Cantú-Ortiz, 2019).

In this paper, we measure the relationship that exists between the social variables and research results: population of the country, gross domestic expenditure on R&D (GERD) and economic investment in tertiary education as a percentage of GDP, researchers, researcher's migratory movements, social networks and collaboration, publication in academic disciplines, scientific production and citations as a measure of the research representation. The results of this work can assist countries to redesign their policies in science to achieve a greater scientific productivity.

We formulate the following research questions based on the above mentioned:

> Which kind of correlations exist among population, expenditure in research, investment in tertiary education, researchers, and scientific production and citations in all countries? Which countries produce more documents per researcher? Do the different types of researcher's mobility have any relationship with scientific collaboration? How is the country's contribution to different scientific disciplines? Is there any kind of relation among all these results?

The main hypothesis in this study is that social dimensions (expenditure in research, investment in tertiary education, researchers, researcher's mobility, scientific collaboration, disciplines patterns) have a correlation with scientific results. Therefore, social variables are interconnected and have an influence on research.

Materials and Methods

In order to develop this study, we have selected a closed sample of countries with cultural, social, geographic, linguistic, and economic differences to give a wide-ranging spectrum from worldwide sources. For this reason, we chose Mexico and its strategic partners because this is a diverse sample of 19 countries all very different from each other.

The selected countries are the following: Argentina, Brazil, Canada, Chile, China, Colombia, France, Germany, India, Israel, Japan, Russian Federation, South Africa, South Korea, Spain, Turkey, United Kingdom and United States considered strategic in Science, Technology and Innovation for Mexico (Conacyt, 2016).

We used data from UNESCO Institute for Statistics (UIS) as a main data source because it provides a wide range of indicators (http://uis.unesco.org/, 2018).

With the purpose of extracting data of different patterns of researcher' mobility we used *World of Research 2015. Revealing patterns and archetypes in scientific research*. The book contains over 70 national profiles and comprises general statistics and graphs along with analyses and interpretations (Elsevier Analytical Services, 2015).

In order to extract the countries' scientific production, we used Scopus database because it represents the overall structure of world science at a global scale. Furthermore, we used SciVal to extract the total number of citations received.

The time window for our study comprise 17 years. Data from 1996 to 2012 for: investment on tertiary education, gross domestic expenditure on R&D (GERD) as a percentage of GDP and researchers (FTE). The time frame for scientific production and citations cover from 1999 to 2015. We displaced the data by three years because the economic and social effect on scientific results are not materialized immediately. For instance, the effect of GERD/GDP investment on scientific production takes at least three years to manifest. We determined the three-year displacement period by experimenting with several time windows.

We downloaded data from Scopus, SciVal, and UNESCO in March 10, 2017. The variables extracted from UNESCO are:

- *Gross domestic expenditure on R&D (GERD) as a percentage of GDP* is the total intramural expenditure on R&D performed in the national territory during a specific reference period expressed as a percentage of GDP of the national territory.
- *Government expenditure on tertiary education as a percentage of GDP*: Total general (local, regional and central) government expenditure on tertiary education (current, capital, and transfers), expressed as a percentage of GDP. It includes expenditure funded by transfers from international sources to government.
- *Total population by country*: Estimated midyear population from each country.
- *Researchers (FTE)*: Number of professionals engaged in the conception or creation of new knowledge during a given year at full-time equivalent (FTE).

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From Scopus database and SciVal we have extracted:

- *Scientific production*: Total number of documents produced by the countries (from 1999 to 2015).
- *Scientific production of different subject areas*: Number of documents produced each year from the temporary window (from 1999 to 2015) by the countries in the 27 Scopus subject areas.

In order to know the relative effort that a country of analysis devotes to a specific field measured in publications we applied *RAI (Relative Activity Index)*. We decided to use relative indicators that may prove rather useful in the comparative assessment of scientists, groups, institutions or countries (Schubert and Braun, 1986).

RAI (Relative Activity Index) is calculated by dividing the share of a country's output in a particular field relative to the share of the world's output in that same field. It therefore represents how concentrated a country's output is in a particular area relative to the world average and can be used to estimate specialization in a particular field. A value of 1.0 indicates that a country's research activity in a field corresponds exactly with the global activity in that field; higher than 1.0 implies a greater emphasis while lower than 1.0 suggests a lesser focus.

- Citations: Number of citations by the documents published during the source year, –i.e. citations in years X, X+1, X+2, X+3... to documents published during year X.

We have divided the scientific production between the different types of scientific collaboration. A publication is considered collaborative when there is more than one author in the authorship byline in Scopus. The four types of scientific collaboration are (Leimu and Koricheva, 2005):

- *International collaboration*: Defined as at least two different countries listed in the authorship byline.
- *National collaboration*: Defined at least two different institutions listed in the authorship byline, all of which are from the same country.
- *Institutional collaboration*: Defined at least two authors listed in the authorship byline, all of which are affiliated with the same institution.
- *Single authorship*: These are technically not collaboration. This is defined as documents written by only one author listed in the authorship byline.

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We have downloaded researcher' mobility data from the book *World of Research 2015* (Elsevier Analytical Services, 2015):

Migratory
Outflow: Researchers whose Scopus author data indicates that they first published with an affiliation in Country X and have subsequently migrated from Country X to another country (or countries) for at least two years without returning to Country X.
Inflow: Researchers whose Scopus author data indicates that they migrated to Country X from another country (or countries) for at least two years without leaving Country X.

Transitory
Researchers whose Scopus author data indicates that they are based in Country X for less than two years at a time but are predominantly based in another country (or countries).

Sedentary
Researchers whose Scopus author data indicates that they have not published with an affiliation outside of Country X.

Results and Discussion

We have calculated correlations among expenditure in research, investment in tertiary education, researchers and scientific results. The second part is focused on migratory movements and collaboration and the last part dedicated to countries preferences in research.

As we can observe in *Table 1*, all the variables have a high correlation with the scientific production. The population (0.747), the researchers (0.793), the investment in education (0.529) and the investment in research (0.663).

The highest correlation is between researchers and scientific production. It seems that if the number of researchers increases, scientific production increases as well.

	Population	Researchers	Government expenditure on tertiary education as a percentage of GDP	Gross domestic expenditure on R&D (GERD) as a percentage of GDP	Scientific production	Citations
Population	1					
Researchers	0.786	1				
Government expenditure on tertiary education as a percentage of GDP	0.409	0.470	1			
Gross domestic expenditure on R&D (GERD) as a percentage of GDP	0.491	0.599	0.384	1		
Scientific production	0.747	0.793	0.529	0.663	1	
Citations	-0.121	-0.217	-0.502	-0.289	-0.330	1

Table 1. Correlation among social factors and scientific results for all countries in the 17-temporary frame

Researcher's mobility and scientific collaboration

In order to determine the relationship between researcher's mobility and scientific collaboration we show the *Table 2* with scientific production divided into four groups of collaboration. Additionally, with the different types of mobility: Migratory (Inflow, Outflow, Transitory) and Sedentary.

As we can observe, countries produce more in International collaboration and in Institutional collaboration than in National collaboration or even Single authorship. Chile, Colombia and France are the countries with the highest percentage of international collaboration for their production.

Furthermore, India, China and Turkey are the countries with the highest percentage of Institutional collaboration. However, there are countries that have almost equal the international and institutional percentages: Argentina, Japan, and Mexico.

Countries	International collaboration	National collaboration	Institutional collaboration	Single authorship	Inflow	Outflow	Sedentary	Transitory
Argentina	38.98	12.28	38.76	9.97	7	7.3	46	40
Brazil	25.3	25.0	43.3	6.4	4.8	3.8	63	29
Canada	39.51	10.24	35.45	14.78	11	13	29	48
Chile	51.7	11.2	25.3	11.7	11	8.6	30	50
China	15.53	18.06	61.39	5.02	4.1	2.7	79	15
Colombia	49.31	5.34	33.85	11.50	10	7.7	24	59
France	41.64	18.09	26.92	13.34	8.4	9.3	37	46
Germany	20.95	21.84	48.25	8.96	8.6	11	37	43
India	16.1	10.1	65.2	8.5	6.7	7.2	60	26
Israel	40.1	15.9	29.1	14.9	10	10	34	46
Japan	38.22	15.09	37.09	9.59	4.9	5.4	63	27
Mexico	38.22	15.09	37.09	9.59	7.8	5.6	45	41
Russian Federation	28.90	9.72	44.00	17.38	5.5	6	59	29
South Africa	40.2	8.1	30.8	21.0	9	8.2	35	48
South Korea	24.76	23.84	45.73	5.68	8.9	4.4	61	26
Spain	35.18	13.04	42.95	8.82	7.8	7	49	37
Turkey	17.47	17.23	53.37	11.91	4.6	2.2	71	22
United Kingdom	37.34	11.55	29.16	21.96	9.3	13	29	49
United States	24.62	18.33	37.31	19.78	7.7	9.1	49	34

Table 2. Average of International Collaboration, Institutional Collaboration, National Collaboration, Single authorship, Migratory (Inflow, Outflow, Transitory) and Sedentary

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Respect to the researcher's mobility relative to migratory movements (Inflow, Outflow, Transitory) or sedentary manners, the countries with the highest migration tendencies are Colombia, Canada, and the United Kingdom. In the case of Colombia, the transitory percentage is higher than the others.

On the contrary countries with the highest percentage of sedentary researchers are China, Turkey and Brazil. They are countries with a low percentage of International collaboration.

Canada has a high transitory pattern of researchers. We can observe that Canada has low correlation between researchers and investment in tertiary education possibly because many of them are not permanently resident in the country.

In order to know if there is some kind of correlation between the collaboration indicators and mobility patterns indicators, the Pearson correlation matrix is shown (*Table 3*).

Predictably, there is a high correlation between the Transitory indicator and the international scientific collaboration of $r = 0.821$ for all countries. The data of institutional collaboration has a correlation of 0.767 with the sedentary indicator. There is a correlation of 0.849 between the Inflow and Transitory data. Also, correlation of 0.766 between Inflow and Outflow.

The correlation between the Single authorship percentage and Outflow has a correlation of 0.596. And a correlation of 0.750 between Transitory and Outflow, the indicators most linked to the scientific diaspora.

This may indicate that the movements of the countries favor collaboration and therefore, thanks to this, the quality of the work and production increase remarkably. The countries that have a high percentage of international collaboration and that have high percentages of transitory researchers are the countries that publish more documents per researcher and which receive more citations per researcher.

Do countries specialize in particular research areas?

In this part of the work we focus on the contribution that countries make to scientific production by areas. First, we know the area where more documents are published, and then through the RAI (Relative Activity Index) we measure how is the country's contribution to the whole scientific production.

In the *Table 4*, we can observe the subject areas which produce the large number of documents in the range of years studied.

	International collaboration	National collaboration	Institutional collaboration	Single authorship	Inflow	Outflow	Sedentary	Transitory
International collaboration	1							
National collaboration	-0.530	1						
Institutional collaboration	-0.882	0.252	1					
Single authorship	0.332	-0.465	-0.556	1				
Inflow	0.659	-0.349	-0.650	0.371	1			
Outflow	0.453	-0.336	-0.555	0.596	0.766	1		
Sedentary	-0.769	0.470	0.767	-0.518	-0.900	-0.841	1	
Transitory	0.821	-0.493	-0.788	0.476	0.849	0.750	-0.985	1

Table 3. Pearson correlation matrix among the different kind of scientific collaborations

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Countries	Subject area with greatest production	Percentage from total production	Citations to subject area with greatest production	Percentage from total citations
Argentina	Medicine 37,492	25.09	673,303	29.34
Brazil	Medicine 184,130	28.17	2,556,404	33.05
Canada	Medicine 368,856	29.29	11,020,671	37.45
Chile	Medicine 23,447	23.71	366,423	23.97
China	Engineering 1,483,903	36.78	7,845,710	21.66
Colombia	Medicine 16,724	27.22	240,541	36.02
France	Medicine 424,972	27.45	9,808,600	31
Germany	Medicine 624,808	28.52	14,139,252	30.69
India	Medicine 224,432	20.82	2,115,344	19.16
Israel	Medicine 81,740	30.11	2,124,925	32.85
Japan	Medicine 525,662	26.19	9,230,700	28.54
Mexico	Medicine 48,952	21.95	719,973	25.72
Russian Federation	Physics and Astronomy 244,594	35.28	2,416,339	43.93
South Africa	Medicine 44,664	24.49	933,361	34.85
South Korea	Engineering 229,949	28.64	2,227,598	19.96
Spain	Medicine 299,511	30.15	5,426,788	30.25
Turkey	Medicine 178,098	42	1,595,810	35
United Kingdom	Medicine 780,372	31.60	21,180,242	36.78
United States	Medicine 2,705,199	31.15	77,768,163	34.95

Table 4. Scientific discipline with the highest production in each country in 1999 to 2015, with percentage of total production, citations received and percentage of total citations

Observing the *Table 4* Medicine is the area which has the highest production in all countries except China, South Korea and the Russian Federation.

Countries which produce the most documents in this area (in proportion to their total production) are: Turkey, United Kingdom, and United States. With regard to citations, the countries that receive more citations in the area of Medicine with respect to total citations are: Canada, United Kingdom, Colombia, Turkey, and United States.

Engineering is the chosen area for China to publish the majority of its works, however China does not receive as many citations to the documents in this area. The citation habits vary by different subject areas, for example Medicine receives far more citations than other disciplines.

The Russian Federation publishes most of its papers in Physics and Astronomy. However, Russia receives more citations in this area than other countries in Medicine. We must remember that the research in Physics in Russia is one of the most important in the world, in fact, Russia does not have Medicine among its first three disciplines to publish.

In South Korea as in China, the preferred area for its production is Engineering but it does not receive many citations in comparison with other areas.

Once we know which is the discipline chosen to publish by countries, we detect what the contribution of each country to total world production by disciplines. For this we apply RAI (Relative Activity Index) defined in methodology part (Elsevier Analytical Services, 2015).

The formula of this indicator is applied to the sample of production downloaded by 27 scientific disciplines for the 19 countries and in the 17-year time window. When the indicator is less than 1, the contribution made by the country is less than that of the discipline to total production, if the indicator is equal to 1 the contribution of that country is equal to that of the discipline and if it is greater than 1 this country contributes more to the discipline than what the discipline does in general.

Those countries that on average contribute with a higher value to all disciplines are the United States, United Kingdom and China. On the contrary with the lowest values are Colombia, Chile, and Argentina. The results show that the United States is the country with the greatest contribution in all disciplines except in Material Science where China is the highest contributor.

At first glance, countries contributions performed to disciplines are less than the contribution than the discipline performs to total production. Except in certain disciplines where the contribution of certain countries is very remarkable. For example, in the area of Engineering where only USA exceeds 1. China is near to 1 with 0.963. Medicine is the area chosen by almost all countries to publish. The most contributing countries in this area are United States, United Kingdom and Germany.

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INVESTIGACIÓN BIBLIOTECOLÓGICA, vol. 34, núm. 85, octubre/diciembre, 2020, México, ISSN: 2448-8321, pp. 61-80

	Agricultural and Biological Sciences	Arts and Humanities	Biochemistry, Genetics and Molecular Biology	Business, Management and Accounting	Chemical Engineering	Chemistry	Computer Science
United States	3.650	7.089	2.779	9.063	3.908	2.303	2.793
United Kingdom	1.037	2.974	0.668	3.341	0.920	0.631	0.664
China	1.132	0.241	0.766	2.281	3.684	2.024	1.439
Germany	0.850	0.755	0.646	1.367	1.243	0.933	0.681
Japan	0.804	0.235	0.732	0.532	1.403	1.047	0.693
Canada	0.692	0.954	0.366	1.101	0.620	0.336	0.436
France	0.686	0.818	0.452	0.750	0.838	0.641	0.531
India	0.615	0.139	0.270	0.898	0.977	0.708	0.288
Brazil	0.627	0.137	0.151	0.263	0.338	0.217	0.144
Spain	0.601	0.559	0.271	0.633	0.588	0.469	0.314
South Korea	0.237	0.083	0.223	0.352	0.844	0.414	0.342
Turkey	0.201	0.099	0.077	0.223	0.237	0.138	0.079
RussianFederation	0.210	0.109	0.153	0.169	0.522	0.539	0.139
Israel	0.118	0.253	0.086	0.198	0.139	0.079	0.112
Mexico	0.202	0.066	0.049	0.081	0.145	0.080	0.058
South Africa	0.188	0.191	0.034	0.167	0.071	0.049	0.027
Argentina	0.182	0.061	0.049	0.039	0.113	0.069	0.021
Chile	0.085	0.059	0.021	0.048	0.043	0.032	0.019
Colombia	0.047	0.027	0.011	0.048	0.036	0.015	0.012

Table 5. Relative Activity Index (RAI) for Mexico and its 18 strategic partners

	Decision Sciences	Dentistry	Earth and Planetary Sciences	Economics, Econometrics and Finance	Energy	Engineering	Environmental Science
United States	36.811	49.689	6.364	22.124	7.518	1.148	5.961
United Kingdom	10.422	14.916	1.946	7.681	1.670	0.241	1.631
China	12.954	3.597	3.325	1.368	6.423	0.963	2.142
Germany	6.824	8.341	1.806	3.311	1.834	0.252	1.326
Japan	3.540	12.721	1.088	1.326	2.527	0.361	0.890
Canada	6.441	4.593	1.130	2.694	1.145	0.152	1.093
France	6.138	2.793	1.422	2.710	1.218	0.183	0.862
India	3.534	6.176	0.653	0.952	1.165	0.146	0.940
Brazil	2.148	12.684	0.351	0.452	0.526	0.055	0.424
Spain	4.171	3.581	0.712	1.782	0.691	0.092	0.724
South Korea	2.737	3.003	0.283	0.701	0.924	0.166	0.357
Turkey	1.354	5.053	0.204	0.452	0.414	0.041	0.293
Russian Federation	0.974	0.069	1.033	0.330	1.306	0.106	0.320
Israel	1.697	1.967	0.146	0.582	0.121	0.026	0.116
Mexico	0.563	0.454	0.224	0.241	0.285	0.026	0.215
South Africa	0.558	0.467	0.226	0.561	0.138	0.013	0.202
Argentina	0.237	0.373	0.188	0.154	0.096	0.009	0.134
Chile	0.457	0.446	0.193	0.173	0.044	0.007	0.083
Colombia	0.154	0.308	0.029	0.105	0.066	0.006	0.032

Table 5. Relative Activity Index (RAI) for Mexico and its 18 strategic partners (continued)

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	Health Professions	Immunology and Microbiology	Materials Science	Mathematics	Medicine	Multidisciplinary	Neuroscience
United States	29.503	10.702	1.841	3.823	4.816	29.576	14.953
United Kingdom	6.988	3.145	0.465	1.022	1.394	6.925	4.033
China	1.854	2.461	1.920	2.207	0.893	14.669	1.814
Germany	4.993	2.560	0.751	1.279	1.090	4.685	3.671
Japan	3.069	2.345	0.967	0.827	1.018	3.484	2.862
Canada	4.091	1.351	0.244	0.641	0.633	2.381	2.374
France	3.209	2.077	0.512	1.131	0.758	3.268	2.056
India	0.829	1.064	0.435	0.455	0.359	5.300	0.515
Brazil	1.412	1.039	0.140	0.281	0.299	1.228	0.882
Spain	1.825	1.268	0.235	0.610	0.519	1.377	1.133
South Korea	1.511	1.077	0.451	0.441	0.248	1.032	0.706
Turkey	1.086	0.357	0.105	0.169	0.289	0.520	0.423
Russian Federation	0.424	0.465	0.410	0.578	0.074	1.957	0.320
Israel	0.661	0.350	0.057	0.247	0.152	0.784	0.541
Mexico	0.156	0.317	0.068	0.138	0.085	0.459	0.248
South Africa	0.341	0.299	0.030	0.062	0.074	0.280	0.087
Argentina	0.113	0.317	0.034	0.067	0.064	0.235	0.188
Chile	0.106	0.089	0.016	0.061	0.038	0.187	0.084
Colombia	0.096	0.088	0.011	0.026	0.025	0.130	0.031

Table 5. Relative Activity Index (RAI) for Mexico and its 18 strategic partners (continued)

	Nursing	Pharmacology, Toxicology and Pharmaceutics	Physics and Astronomy	Psychology	Social Sciences	Veterinary
United States	22.501	7.343	1.973	20.943	4.506	26.114
United Kingdom	6.687	1.893	0.523	5.324	1.547	9.373
China	0.760	2.793	1.254	0.430	0.355	2.877
Germany	1.630	1.592	0.805	2.769	0.446	5.840
Japan	0.908	2.217	0.821	0.873	0.187	4.210
Canada	2.710	0.844	0.241	2.949	0.573	4.077
France	2.104	1.065	0.560	1.700	0.373	4.125
India	0.392	2.177	0.310	0.203	0.161	6.738
Brazil	1.194	0.607	0.150	0.526	0.121	7.365
Spain	1.360	0.818	0.255	1.151	0.252	2.812
South Korea	0.794	0.725	0.305	0.251	0.091	1.605
Turkey	0.328	0.313	0.073	0.330	0.097	3.101
Russian Federation	0.082	0.276	0.515	0.227	0.073	0.118
Israel	0.310	0.166	0.088	0.697	0.129	0.560
Mexico	0.167	0.170	0.082	0.195	0.052	1.020
South Africa	0.219	0.111	0.029	0.271	0.123	0.984
Argentina	0.082	0.134	0.043	0.091	0.031	0.912
Chile	0.122	0.049	0.033	0.108	0.034	0.393
Colombia	0.059	0.036	0.014	0.077	0.018	0.354

Table 5. Relative Activity Index (RAI) for Mexico and its 18 strategic partners (continued)

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Conclusions

This study contributes to the analysis of the incidence of social variables into scientific research in a sample of countries of diverse nature. There are 18 countries defined as Mexico's strategic partners by National Science and Technology Council (Conacyt), the decentralized public agency of the federal public administration responsible for the development of science and technology policies in Mexico. These countries are designated in terms of cooperation, alliances, and common projects with Mexico (Conacyt, 2016).

It has been shown that on average there is a high correlation between social variables (population, researchers, investment in tertiary education, investment in research) and scientific production. In the case of citations, it is not possible to appreciate or demonstrate linearity with current data because of curvilinear function of citations. However, there are countries in which some social variables have little correlation with scientific production.

With respect to the mobility values of researchers, the sample is also divided into the countries with the highest percentage of Sedentary and the countries with the highest percentage of Migratory tendencies. China, Turkey and Brazil are the most sedentary. The countries (ranked) that are the most migratory are Colombia, Canada, and United Kingdom.

There is a high correlation between the values of Transitory and International Collaboration, and between Sedentary and Institutional Collaboration. There is also high correlation between Inflow and Outflow.

Scientific collaboration favors production and if there is a correlation between the researcher's international movements and scientific collaboration this has a positive effect on scientific production.

The scientific discipline where most researchers publish is Medicine. Except the case of China and South Korea in which is Engineering and the Russian Federation which is Physical Sciences. These disciplines are those that have a greater percentage of the production of the country and are those that increase production with its greater contribution.

The highest values of RAI average for all the areas are the United States, United Kingdom and China. The lowest ones correspond to Colombia, Chile, and Argentina. In all disciplines, the United States is the country that has the greatest contribution, except in Material Sciences, in which China is the first.

Finally, the main contribution of this study is the high relation of a selected set of social variables on the country's research production. Moreover, mobility patterns of researchers have a correlation with scientific collaboration, and therefore, this in turn on the increase of total production. The

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vocation of a country measured by priority areas also impacts on research through the contribution that each country establishes.

This study should help governments to be aware of how these social variables affect research and take part in this matter. An analysis of economic and scientific results relations can help the government of a country to promote research in their countries to strengthen their research ecosystems to give light to scientific policies.

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