EVALUATION OF SCIENTIFIC PRODUCTION IN MEXICAN STATE PUBLIC UNIVERSITIES (2007-2011) USING PRINCIPAL COMPONENT ANALYSIS

Evaluación de la producción científica en universidades públicas estatales mexicanas (2007-2011) usando análisis de componentes principales

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Abstract

This article focuses on the application of the principal component analysis (PCA) method to evaluate the competitiveness of scientific production in Mexican universities, based on the identification and classification of a set of indicators, grouped into seven dimensions and 18 criteria. Specifically, the method was performed in the educational institutions included in the category of state public universities (33 in total), over a period of five years (2007-2011), and ultimately identified only seven

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criteria as principal components, resulting in a scale of positions that indicate the index of relative potential (IPR in Spanish). Thus, the levels of opportunity for each university in relation to their group are defined, and the university that showed the highest competitiveness is identified and it in turn becomes a quality parameter.

Keywords

Scientific production; Principal component analysis (PCA); Institutional competitiveness; Index of relative potential; State public universities; Mexico.

Resumen

Se aplica el método de análisis de componentes principales (ACP) para evaluar la competitividad en producción científica de universidades mexicanas, partiendo de la identificación y clasificación de un conjunto de indicadores, agrupados en 7 dimensiones y 18 criterios. De forma específica, el método se llevó a cabo en las entidades educativas incluidas dentro del rubro de universidades públicas estatales (33 en total), en un período de cinco años (2007-2011). Con ello se determina, que por su comportamiento significativo, sólo se identifican 7 criterios como componentes principales, dando como resultado una escala de posiciones que indican el índice de potencialidad relativa (IPR), definiéndose así los niveles de oportunidad de cada entidad participante en relación con su grupo, además de reconocer a la institución que mostró mayor competitividad y que se convierte a su vez, en un parámetro de calidad.

Palabras clave

Producción científica; Análisis de componentes principales (ACP); Competitividad institucional; Índice de potencialidad relativa; Universidades públicas estatales; México.

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1. Introduction

The Mexican government is allocating financial resources to Higher Education Institutions (HEIs) based on a set of indicators. As a result, Mexican professors, researchers, and higher education institutions (HEIs) are under mounting pressure to generate, increase, and record their individual and collective academic and scientific production. However, there is no clear method for tracking, measuring, and evaluating this output.

Though the definitions of scientific production in Mexican universities are vague, it is easy to identify the products, actions, and environments that are of greater value, which is necessary if researchers want to maintain an individual and institutional status of quality. In order of relevance, the government guidelines for instructors and researchers are integrated into four action axes: generation and communication of knowledge, teaching, student tutoring (formation of human resources through thesis dissertation development, especially in graduate studies), and institutional management.

Although these fields of action can be disaggregated to the most specific level, it is the first level that determines the individual scientific production capacity, which is based on non-specific guidelines and is identified through two measurement approaches: the first related to the amount of products generated (especially scientific articles); and the second, related to quality, measured through visibility and impact indexes. Though the conceptualization of scientific production is defined as a process by which scientists interact creating new knowledge, and whose results are disseminated through informal, semiformal, and formal media (**Romanos-de-Tiratel**, 2009; **Campos-Rosa**, 2000), it is clear that only the latter are considered feasible in order to affect measurement processes.

Academic and scientific communities are well aware of the different means to disseminate knowledge, which includes scientific articles, thesis dissertations, books, and book chapters (**Braga-Ferreira**; **Malerbo**; **Silva**, 2003); they also know that in order to make science it is necessary to write it down and publish it (**Campos-Rosa**, 2000); and competitiveness in educational institutions is created whenever their scientific research processes are constant and systematic (**Shults**, 2005).

The great majority of academics in Mexican universities were hired for teaching; however, current demands in higher education lean towards strengthening the research profile, and as a result it is necessary for faculty to develop knowledge generation processes as their jobs become more multidimensional (**Gorbea-Portal**, 2010). Such trends show that the Mexican university system needs to respond timely to world challenges, steering strategies towards the identification of scientific production potentialities for the development of intellectual and social capital (**Modrego**, 2002).

The measurement of scientific competitiveness requires the recording of behaviors through time and not as isolated facts (**Bonzi**, 1992), including also the consideration of the teacher's academic status in relation to his type of work relation, gender, work field, citation patterns, and above all the need of pondering the academic and research environments that are characteristic of HEIs. Mexican universities

really need to define their order of priorities, since in the observation of **Manjarin**; **Cutri**; **Torres**; **Noguerol**; **Ossorio**; **Durán**; **Ferrero** (2009), it is common for Mexican academics to participate frequently in easier activities (such as lectures in congresses) and not in apparently complex substantial actions, such as publishing academic articles, which has become a priority in the government's measurements.

2. Research objectives

This study presents the following objectives:

a) To define and classify the evaluation dimensions and criteria for scientific production in Mexican universities.

b) To demonstrate the applicability of the PCA model in the identification of institutional competitiveness in scientific production, using the results observed in Mexican state public universities.

c) To identify institutional rankings according to scientific production by using the IPR; results will help guide decision making for the development of the evaluated educational organizations.

> "The definition of scientific production is often vague, though it is easy to identify which products, actions, and environments acquire value in the individual and institutional status of quality"

3. Methodology of the study

This work is divided in four analysis phases: identification of data starting from Access to scientific observatories; creation of a dimension and criteria identification matrix; evaluation of variables using the principal component analysis (PCA) as a central model; and creation of the IPR to compare institutional positions. The analyzed results cover every contribution to scientific production of the evaluated universities out of the total of scholars in the institution, regularly with the following denominations: professors (instructors), professors-researchers, and researchers, which have a full-time, part-time, and hourly-rate work relation.

3.1. Identification of data in scientific observatory

As the source of information for data collection we identified the scientific observatory developed by Mexico's *National Autonomous University* (*UNAM*, 2011, 2012) called *Comparative Study of Mexican Universities* (*ECUM* in Spanish), a project that systematizes, measures, and compares the performance of Mexican universities and other higher-education institutions (approx. 2,800 entities), in which the information can be segmented into different categories (in this case by type of university).

Data collection corresponded to the period 2007-2011 (five years), because these years were available at the time of the study. Though the scientific observatory allows for multiple ways of displaying data, for this study they were sorted into two alternative combinations: by type of university (federal public institutions, state public institutions, private institutions, federal technological institutes, state technological institutes, technological universities, polytechnic universities, intercultural universities, and other public universities) and multiannual selection (the years that correspond to the evaluation period).

Since it is a descriptive study, the data collected from the observatory were designed over the possibility of establishing a relevant type and level of comparison, for that we obtained unweighted data without indicators of behavior comparisons, in a way that the study, starting from the application of the PCA model, would establish relations in the study's criteria and construct indicators from the model's own needs and perspectives of analysis.

3.2. Creation of a dimension and criteria matrix

Once the general data collection was carried out and according to their disposition, we identified 18 evaluation criteria that are related to scientific production and two more that complemented the information: number of students, and instructors. Such criteria were grouped according to their affinity in six dimensions related to scientific production, and one more group that integrated the complementary data mentioned before (see Attachment).

3.3. Application of the PCA model for data analysis

For the data analysis and the definition of the level of competitiveness of the evaluated universities we used the PCA, which is a statistical algebraic model with the purpose of reducing the size and giving structure to information in a wide data matrix. The process consists in approving the matrix in a vector area, trying to find the axis linear combination of the variables entering, the objective of which is to reduce as much as possible the dimension of variables entered or original variables (**Lozares-Colina**; **López-Roldán**, 1991; **González-Martín**; **Díaz-de-Pascual**; **Torres-Lezama**; **Garnica-Olmos**,1994), in a way that when it is possible to identify smaller variables that have a differentiated behavior (similarities and differences) out of a group of interrelated variables called principal variables, these are considered for the analysis.

The new variables (principal components) are weighted obtaining a decreasing order of relevance according to their variance percentage, thus the PCA allowed for the identification of the causes for variability of a set of data, and sorting them by relevance, using descriptive statistical multivariable techniques, which variables were measured on each of the subjects (universities) obtaining data matrices (**Terrádez-Gurrea**, 2012; **Pla**, 1986).

The analysis compared the behavior of the variables and in a dual form, in the area of the subjects (universities), to later plot such results in a graph, in a way that both in the table as in the graphical representation the data with the greater original variability ration are observed (**Manly**, 2004).

3.4. Identification of the IPR

The incorporation of this concept by the authors refers to the comparison of the scientific production levels of a set of entities, identifying the best results (represented in positive numbers) and the least favorable results (represented in ne-

gative numbers), as well as those with a closer approximation to the arithmetical mean, through the proximity to zero out of the total of the studied group.

The IPR means that the best results are representative of the subject group, however they are considered relative since they do not mean there is a sufficient level of competitiveness with different or wider environments. However, it identifies positions of particular entities in relation to their necessities for growth in scientific production, whether to get closer to the group's arithmetical mean or to be comparable to those who obtained the best indicators.

3.5. Delimitation of the study

Given the coincidence of localized data according to the evaluated criteria and their performance level in scientific production, the researchers applied the PCA to state public universities because:

a) They are the most representative of higher education in Mexico, both in numbers and in geographical distribution (33 public universities located in 31 out of the 33 states).

b) They are educational entities that create, define the plans, and permanence of their academic programs; promote their academic personnel; and usually enroll a varied and great number of students.

c) They are characterized for participating in the totality of the dimensions and criteria that integrate the catalog that we follow in this research work.

4. Analysis of results

The analysis of results is presented in two clusters of findings. The first is the product of the results identified through the *ECUM* observatory when studying the overview of scientific production in Mexican universities; the second is the product of the application of the PCA exclusively to state public universities.

4.1. Overview of scientific production in Mexican universities

Though the study is limited to the application of the PCA model to Mexican state public universities, it was considered pertinent to present succinctly the general behavior of the approximately 2,400 entities in the *ECUM*, segmented in the nine groups mentioned above.

It should be noted that in each group we observe different characteristic nuances, from their historical context, attending population, the structure of their academic models, the definition of strategic objectives, and the role of the instructors within their work environments. The analysis of these variables warrants a more in-depth study, justified by the complexity we can observe in the Mexican higher educational system (**Mendoza-Rojas**, 2009).

Specifically, from a historical perspective, in the Mexican educational system there are universities founded in the times of the Viceroyalty of New Spain (such as *UNAM*), as well as educational options that arose in recent decades, represented by technological, polytechnical, and intercultural universities, each with different purposes that do not necessarily prioritize scientific production as part of their activities (**Romero-Muñoz**, 2008).

> "The great majority of teachers in universities were hired to teach, but in recent times, the profile of the researcher has acquired more relevance"

First we start from the fact that the distribution by type of educational institution according to their frequency is concentrated in private schools (81.87% of the total), whereas 21.93% are public institutions, with the lower frequency found in federal public universities, which do not reach 1%. Similarly, the majority of instructors work in private educational institutions and the lowest proportion work in intercultural universities. The lowest faculty/student ratio occurs in private higher education institutions (1/7.8) and the highest in state technological institutes (1/19.19).

The academic, economic, and social resources and activities, specifically those related to research, may not depend on the number of students or the number of scholars. It is true that historical issues and strategic purposes may have more influence on the distribution and development of faculty activities. However, other quantitative indicators should be taken into account which may influence behavior in scientific production, for example, evaluating the time in which an instructor is also a researcher (**Bernáldez-Aguilar**, 2005).

The following data relates to scientific production (2007-2011) by type of university:

a) The two types of universities that offer representative and systematic results are federal public universities and state public universities. In the case of federal public technologi-

Table 1. Variables (criteria) identified as principal components

Dimension	Criteria
Knowledge generation processes	Publication of indexed articles
Academic quality of the scholars	Enabling scholars towards educational quality
Characterization of the scientific production impact	Regional and institutional collaboration levels
Innovation capacity	Number of patents filed
Environments for the professional exercise	Capacity for collegiate work (academic bodies in consolidation process)
Institutional capacity for scientific publication management	Scientific journals in *Conacyt*'s catalogue
General data	Number of students

Table 2. Yearly results of positions of competitiveness in scientific production, 2007-2011

State universities	Publication of indexed articles	Enabling scholars towards educational quality	Regional and institutional collaboration levels	Number of patents filed	Capacity for collegiate work (academic bodies in consolidation process)	Scientific journals in *Conacyt´s* catalogue	Number of students	IPR
	2007							
Univ. Aut. de Nuevo León	177	158	201	6	36	0	66.400	2,232
Univ. de Guadalajara	201	417	199	0	80	2	74.265	2,199
Univ. Aut. del Estado de Morelos	165	82	181	0	26	0	11.470	1,902
Benemerita Univ. Aut. de Puebla	170	162	176	0	67	2	44.545	1,820
Univ. Aut. de San Luis Potosí	138	95	156	0	14	0	20.640	1,490
Univ. Aut. del Carmen	7	26	14	0	2	0	3.983	-0,853
Univ. Aut. de Guerrero	11	191	14	0	16	0	21.717	-0,853
Univ. Aut. de Chiapas	7	71	12	0	5	0	18.486	-0,886
Univ. De Quintana Roo	7	22	8	0	4	0	3.179	-0,952
Univ. Aut. Benito Juárez de Oaxaca	3	21	4	0	4	0	18.885	-1,018
	2008							
Univ. De Guadalajara	285	416	271	0	80	2	77.316	2,771
Univ. Aut. de Nuevo León	236	61	252	6	36	0	68.940	2,503
Univ. Aut. del Estado de México	107	88	178	0	31	2	36.299	1,458
Univ. Aut. del Estado de Morelos	163	34	174	0	26	0	11.414	1,401
Univ. Aut. de San Luis Potosí	155	30	166	0	14	0	21.775	1,288
Univ. Aut. del Estado de Hidalgo	98	40	16	0	11	0	19.714	-0,830
Univ. Aut. de Nayarit	17	5	15	0	5	0	11.895	-0,844
Univ. de Quintana Roo	10	4	12	0	4	0	3.260	-0,887
Univ. Aut. del Carmen	10	26	11	0	2	0	4.066	-0,901
Univ. Aut. Benito Juárez de Oaxaca	4	4	4	0	4	0	18.698	-1,000
	2009							
Universidad de Guadalajara	267	358	382	0	78	3	82.543	4,485
Benemerita Univ. Aut. de Puebla	234	161	168	0	73	2	50.088	1,392
Univ. Aut. de Nuevo León	260	155	354	7	37	0	71.650	1,298
Univ. Veracruzana	114	149	164	0	33	0	53.542	1,204
Univ. Mich. de S. Nicolás de Hidalgo	186	118	232	0	37	0	38.079	0,717
Univ. Aut. de Baja California Sur	12	26	35	0	6	0	4.805	-0,727
Univ. Aut. de Campeche	35	26	43	0	6	0	5.898	-0,727
Univ. Aut. Benito Juárez de Oaxaca	4	22	6	0	5	0	18.560	-0,789
Univ. de Quintana Roo	7	16	6	0	5	0	3.265	-0,884
Univ. Aut. del Carmen	7	11	11	0	3	0	4.248	-0,962
	2010							
Univ. Aut. de Nuevo León	287	145	395	8	48	0	75.809	2,361
Univ. de Guadalajara	283	329	394	2	96	3	86.792	2,312
Benemerita Univ. Aut. de Puebla	230	172	134	0	77	2	53.295	1,663
Univ. Aut. de San Luis Potosí	213	66	283	0	25	0	23.468	1,455
Univ. Aut. del Estado de Morelos	191	71	230	0	31	0	12.311	1,185
Univ. Aut. de Chiapas	19	66	44	0	S.D.	0	20.550	-0,922
Univ. Aut. de Ciudad Juárez	19	54	45	0	23	0	21.116	-0,922
Univ. Aut. Benito Juárez de Oaxaca	13	20	16	0	4	0	16.949	-0,995
Univ. de Quintana Roo	12	16	12	0	6	0	3.432	-1,007
Universidad Aut. del Carmen	4	12	25	0	3	0	4.286	-1,105
	2011							
Univ. de Guadalajara	329	344	473	3	99	3	92.451	4,143
Benemerita Univ. Aut. de Puebla	283	177	174	0	74	2	54.434	1,533
Univ. Veracruzana	154	172	255	0	54	0	58.944	1,454
Univ. Aut. de Nuevo León	326	159	439	9	55	0	79.246	1,251
Univ. Aut. del Estado de México	189	134	386	0	36	2	41.362	0,860
Univ. Aut. de Campeche	36	22	63	0	8	0	5.891	-0,891
Univ. Aut. Benito Juárez de Oaxaca	16	22	14	0	4	0	15.667	-0,891
Univ. de Quintana Roo	11	20	15	0	7	0	3.776	-0,922
Univ. Aut. de Baja California Sur	31	14	59	0	4	0	4.756	-1,016
Univ. Aut. del Carmen	20	13	29	0	4	0	4.511	-1,031

cal institutes and other public universities, their results are to a great degree not as representative, null, or sporadic in the six other types.

b) In relation to the publications with impact (indexing in the *WoS*), there is a dominance of federal public universities, with an average by institution of 517.4 articles with a longitudinal growth of 25.46%, followed by state public universities with an average of 84.4 articles by institution and a growth of 42%. The included HEIs located in other public universities only managed to publish an average of 5.2 articles by institution and federal public technological institutes only two articles by institution.

c) About the publication of peer-reviewed journals, the arithmetical means were: publications in *Scopus*, 675.8 ar-

Table 3. General IPR positions, 2007-2011 average

Position	State universities	2007-2011							
		Publication of indexed articles	Enabling scholars towards educational quality	Regional and institutional collaboration levels	Number of patents filed	Capacity for collegiate work (academic bodies in consolidation process)	Scientific journals in *Conacyt´s* catalogue	Number of students	IPR
1	*Univ. de Guadalajara*	273	369,8	343,8	1	86,6	2,6	82.674	3,182
2	*Univ. Aut. de Nuevo León*	257,2	169	328,2	7,2	42,4	0	72.409	1,929
3	*Benemerita Univ. Aut. de Puebla*	217,8	174,2	153,4	3	71,6	2	49.577	1,395
4	*Univ. Mich. de S. Nicolás de Hidalgo*	172	128,4	195,6	0,4	36	0,4	37.545	0,898
5	*Univ. Aut. del Estado de Morelos*	182,6	87	217,8	0	28,2	0	12.082	0,869
6	*Univ. Aut. de San Luis Potosí*	182,6	92,6	229,8	0	18,4	0	22.454	0,792
7	*Univ. de Guanajuato*	168,8	124	184,8	5	18,6	0	16.060	0,780
8	*Univ. Veracruzana*	113,4	121	153,6	0	37,8	0	54.044	0,736
9	*Univ. Aut. del Estado de Mexico*	129,6	118,8	234,4	0	35,2	2	37.520	0,723
10	*Univ. Aut. de Baja California*	149,6	108,6	176,4	0	28,2	3,2	41.564	0,628
11	*Univ. de Sonora*	117,2	69,8	141,8	0	23,8	0	23.892	0,228
12	*Univ. Aut. de Yucatan*	106,8	80,6	147,4	3	25,2	1	12.465	0,146
13	*Univ. de Colima*	77,2	67,2	89	0,8	19	0	11.700	-0,061
14	*Univ. Aut. de Sinaloa*	61,6	68,8	69,2	0	23,6	0	48.407	-0,210
15	*Univ. Aut. del Estado de Hidalgo*	104,2	61,2	41	0	15	0	20.073	-0,233
16	*Univ. Aut. de Zacatecas*	51,8	67	66,4	0	22,8	0	17.733	-0,234
17	*Univ. Aut. de Queretaro*	89,8	51,8	102	0	18,4	0	16.024	-0,253
18	*Univ. Aut. de Guerrero*	32,6	110,8	36,4	0	18,2	0	22.984	-0,359
19	*Univ. Aut. de Tamaulipas*	49	40,8	67,8	1	14,2	0	39.826	-0,485
20	*Univ. Juárez Aut. de Tabasco*	34,2	50,6	46,8	1	17,6	1	26.498	-0,481
21	*Univ. Aut. de Chihuahua*	34,6	62,4	45,6	0	15	0	23.662	-0,513
22	*Univ. Aut. de Aguascalientes*	36,8	52,4	51	0	20,6	0	11.894	-0,522
23	*Univ. Aut. de Ciudad Juárez*	14,4	47,8	39,6	0	16,2	0	20.309	-0,525
24	*Univ. Aut. de Chiapas*	15,2	58,2	31	0	10,8	0	19.694	-0,580
25	*Univ. Aut. de Nayarit*	25,6	31,6	29,8	0	5,6	0	12.213	-0,638
26	*Univ. Juárez del Estado de Durango*	35,4	39,4	52	0	9,4	0	12.031	-0,655
27	*Univ. Aut. de Tlaxcala*	24,2	32	30	0	9,4	0	10.337	-0,692
28	*Univ. Aut. de Coahuila*	27,8	48,4	40	1	38,1	0	22.496	-0,715
29	*Univ. Aut. de Campeche*	29,6	27	42,8	0	9,2	0	5.740	-0,733
30	*Univ. Aut. de Baja California Sur*	18,2	27,6	39,2	0	5,4	0	4.900	-0,798
31	*Univ. de Quintana Roo*	9,4	13,8	10,6	0	5,2	0	3.383	-0,930
32	*Univ. Aut. Benito Juarez de Oaxaca*	8	16,6	8,8	0	4,6	0	17.592	-0,939
33	*Univ. Aut. del Carmen*	9,6	19	18	0	2,8	0	4.218	-0,971

ticles (58.78% growth) for federal public universities and 102.6 articles (53.19% growth) for state public universities. A similar situation is found in the *Clase* and *Periódica* indexes.

d) The creation of their own means for scientific communication, by having scientific journals in the catalogs of Mexico's *National Science and Technology Council* (*Conacyt* in Spanish) and *Latindex*, only federal public universities show substantial indicators.

e) The recognition of scholars as national researchers again shows a higher concentration in federal public universities (an average of 661 members by institution, with a growth of 14.77%); state public universities have an institutional average of 129.4, with a percentage growth of 33.97%. Although they are not representative enough, there is presence of federal public technological institutes and other public universities.

f) For graduate studies programs with recognition of quality (accredited by Mexico's *National Quality Graduate Studies Program*, or *PNPC* in Spanish), the leadership in participation is kept by federal public universities (an average of 37.2 accredited programs by institution, with a growth of 10%), followed by state public universities with an institutional average of 15.2 programs with a growth of 35%.

4.2. Results of the PCA application in state public universities.

The information collected from state public universities, ac-

cording to the dimensions and evaluation criteria matrix for scientific production, were analyzed using PCA (using the *Stata* statistical software), which allowed reducing a set of data, finding the causes for variability of only seven out of the total 18 criteria, which were identified as principal components (table 1). Each criterion showed a correspondence relation with one of the seven dimensions that compose the dimensions and criteria matrix.

Once the principal components were identified, the system itself created tables that compare the position of the evaluated universities according to their principal components, one by year in the period 2007-2011 and another table that averages the general results of the period mentioned before. In the case of the results obtained for each year, which are summarized in table 2, only the behaviors of the five institutions with the highest indicators and the five institutions with the lowest indicators are shown, noting that such positions are not constant so we can infer that short-term evaluations can be more relative than the results of longitudinal analyses.

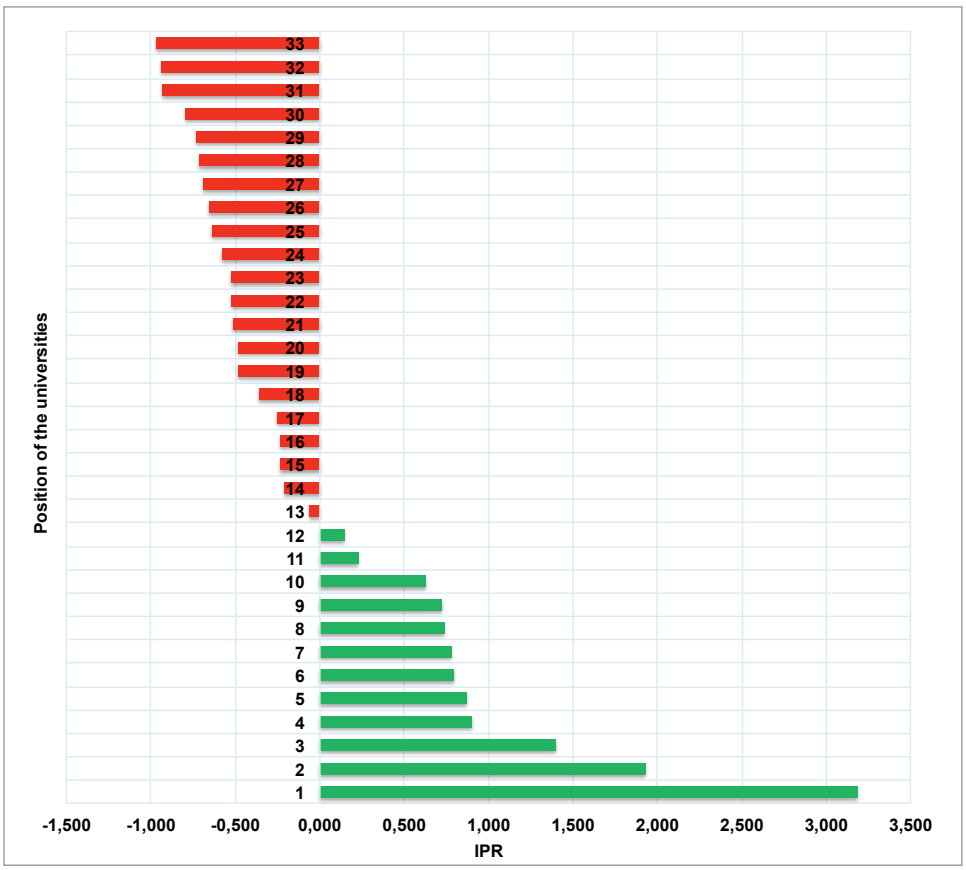


Figure 1. Graphical distribution of the general positions of the IPR

> The applicability of the principal component analysis in the evaluation of scientific production is determined by the identification of systematic and uniform data

Although every year there are important results of the positions of the evaluated universities *per se*, the obtained results weighing the 33 Mexican state public universities (table 3), identify the general average of the seven variables (criteria) during the evaluated period and the general position obtained in the IPR. A general interpretation allows the observation that the most competitive university in scientific production is *Guadalajara's University* with an IPR of 3.182 and the one with the lowest rank is the *Del Carmen University* (placed in position 33) with an IPR of -0.971.

The IPR rank between the entity with the highest results and the one with the lowest results is an IPR of 4.153, while in order to reach the means of the evaluated group, it requires an approximate IPR of 1. Whereas for *Yucatan's University* (placed in position 12 and the first entity among the group, with an arithmetical means above the rest), this institution requires to increase their IPR in 3.036, which indicates that the best result of the institutional ranking of this group of entities is way above the rest of the participating universities.

According to the position obtained in the IPR of the evaluated state public universities, represented in figure 1, we can observe the distribution of positions, identifying that 12 entities are placed above the average (36.36%) and 21 below the average (63.63%). We can also observe the low concentration of evaluated criteria with negative results, in addition of the growing rate experienced by universities with positive results (the number of the figure corresponds to the position obtained by each university in table 3).

> The measurement of competitiveness in scientific production requires the record of the behavior of institutions through time and not as isolated events

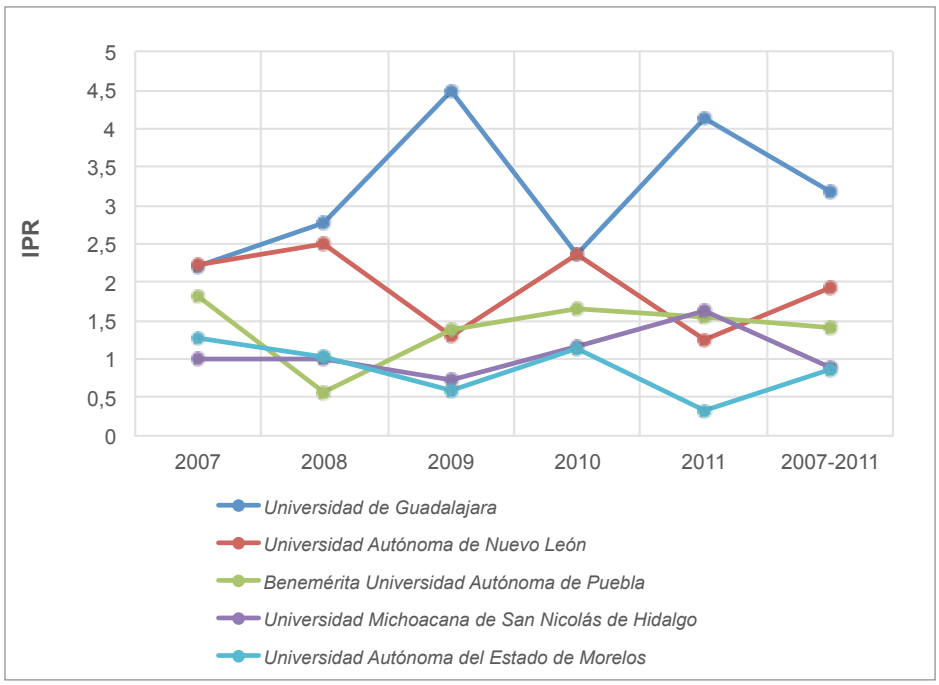
The concentration of results provided by the PCA model, presented in figure 2, allowed for the observation of the variability of the IPR of each evaluated year, as well as the global results, enabling the identification of constancy levels

in the scientific production development. Thus for instance, Mexican state public universities that observed the highest results showed a high variability in each evaluated year, while those with a the lowest results keep a permanent passive behavior, with a decreasing trend.

5. Conclusions

The results of this study allowed the demonstration of the PCA applicability (regularly used in economics and sociology) in the measurement of universities' scientific production competitiveness, both in short periods (one year) and in long periods (this time five years), with the advantage that it may be used with any kind of educational institution, regardless of the characteristics of the criteria included, whenever there are systematic data available (in the case of Mexico, it was only possible to apply to the PCA to two types of universities: state public universities and federal public universities).

The PCA model offers the possibility of developing extended evaluation studies of scientific production depending on the provision of data of later periods, it also facilitates comparisons of different groups of entities and their results which makes it easier to understand, verify, and correct institutional actions. Its main limitations are those related to the lack of availability of uniform information and that it should be considered that the shorter the evaluated period, the less compelling the results.



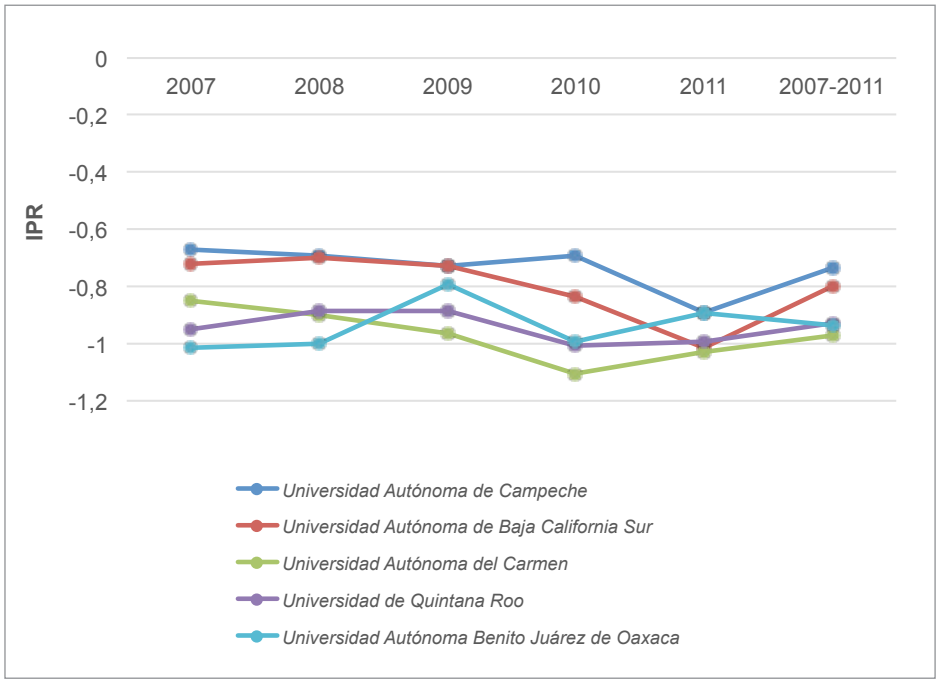


Figure 2. Longitudinal IPR behavior of the entities with the highest and the lowest results, 2007-2011

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Attachment: Dimensions and criteria matrix

Dimensions	Criteria	Definition
Knowledge generation processes	Publication of indexed articles	Counts articles registered in the *Thomson-Reuters* bibliographic indexs, that through the *Web of Science* allow for the follow-up of scientific production. They identify indexes such as *Impact factor*.
	Publication of peer-reviewed articles	They are articles registered in the *Scopus* bibliographic index. Applies the same methodological procedures as the *Thomson Reuters' WoS* databases.
	Publication of dissemination articles	They are articles registered in the bibliographic indexes of the databases *Latin-American Citations in Social Sciences* and *Index of Latin-American Scientific Journals* (*Clase* and *Periódica* respectively in Spanish). Both are produced by the *UNAM*'s *Latin-American Bibliography Department* of the *Sub-direction of Specialized Services* of the *General Direction of Libraries* (*DGB* in Spanish).
Educational quality of scholars	Enabling of scholars with a preferential degree	It presents information about the total number of teaching personnel that attends the classroom modality, according to their level of studies (the doctoral degree is preferential) and working time. Those who are only involved in research are excluded.
	Scholars with national recognition (by level)	Number of scholars that participate in the *Researchers national system* (*SNI* in Spanish), where it is recognized the work of scholars dedicated to the production of scientific and technological knowledge.
	Enabling of scholars towards educational quality	Through the *Program for Teachers' Professional Development* (*Prodep* in Spanish) the relevant participation of scholars is evaluated, with the purpose of identifying those who have improved their professional profile. It applies only to full-time scholars.

Characterization of the scientific production impact	Main author	Frequency of appearance of instructors as main authors of scientific articles. Identifies single or multiple authorship.
	Number of citations	It covers the number of citations of articles in which at least one Mexican institution participates during the year it was published and up to two years after that.
	Regional and institutional collaboration levels	Number of articles that include at least one author attached to a Mexican institution and identifies the origin of the authors' institutions, this means, Mexican and foreign institutions.
Innovation capacity	Number of patent applications	The objective is to provide data related to the dynamics of the invention activities through the follow-up of the record of patent applications and patents filed before the *IMPI* (Mexico's Industrial Property Institute) by the research sector (universities, institutes and national research centers).
	Number of patents filed	
Environments for professional exercise	Capacity for collegiate work	The academic bodies recognized by *Prodep* are evaluated, differentiating three degrees: in formation process, in consolidation process and consolidated bodies. The degree of enabling of the academic personnel and their participation in national and international networks, etc., is evaluated.
	Type of work contract	It presents information about the total number of teaching personnel that attends the classroom modality according to their working time (full-time, partial time and hourly-rate teachers). Those who are only involved with research are excluded.
	Quality level of academic programs	This label concentrates information relative to the higher education programs evaluated by the Inter-institutional *Higher Education Evaluation Committees* (*Ciees* in Spanish). The *Ciees* are nine collegiate bodies integrated by academic peers of all the country's higher education institutions. Their mission is to evaluate the functions and the academic programs that are taught in educational institutions that request it and to formulate punctual recommendations for improvement.
	Accreditation of academic programs	It includes information about the total number of programs [técnico superior universitario (TSU) and undergraduate] that exist in institutions, as well as the number that has been accredited by agencies recognized by the *Higher Education Accreditation Council* (*Copaes* in Spanish).
	Evaluation of the academic quality levels	It presents data about the number of consolidated graduate studies programs (national or international) and the total of graduate studies programs that were identified in the study by order of relevance of the universities and institutions that belong to the *National quality graduate studies program* (*PNPC* in Spanish) *SEP-Conacyt*, whose purpose is to foster continuous improvement and quality assurance of the graduate studies programs, giving recognition to those who have basic academic cores, high graduation rates, necessary infrastructure and high scientific or technological productivity.
Institutional capacity for the management of scientific publications	Scientific journals in *Latindex*	It identifies the number of journals of universities that are registered in the *Online regional information system for scientific journals of Latin America, the Caribbean, Spain, and Portugal* (*Latindex*).
	Scientific journals in *Conacyt*'s catalogue	It presents information about the number of journals that are registered in the *Scientific and technological research journals index* of *Conacyt*, entity that includes them as an acknowledgement of their quality and editorial excellence.
General data	Number of students	Student population in all the academic levels offered by the institution.
	Scholars	Professors, professors-researchers, and professors with a full-time, part-time and hourly-rate work relation.