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5 authors, including:


Zaida Chinchilla-Rodríguez
Spanish National Research Council


Sandra Edith Miguel
National University of La Plata


Maria-Antonia Ovalle-Perandones
University Carlos III de Madrid


Carlos Olmeda-Gómez
University Carlos III de Madrid

Autonomy vs. dependency of scientific collaboration in scientific performance[1]

Zaida Chinchilla-Rodríguez[*], Sandra Miguel[**], Antonio Perianes-Rodríguez[***], María-Antonia Ovalle-Perandones[***] and Carlos Olmeda-Gómez[***]

[*] zaida.chinchilla@cchs.csic.es
Instituto de Políticas y Bienes Públicos, Consejo Superior de Investigaciones Científicas (IPP-CSIC) , C/ Albasanz, 26-28. 28037 Madrid (Spain), SCImago Research Group
[**] smiguel@fahce.unlp.edu.ar
Instituto de Investigaciones en Humanidades y Ciencias Sociales, IdIHCS (UNLP-CONICET), Universidad Nacional de La Plata, calle 51 e/124 y 125, Ensenada, 1925, Argentina, SCImago Research Group
[***] antonio.perianes@uc3m.es, antonia.ovalle@uc3m.es, carlos.olmeda@uc3m.es
Departamento de Biblioteconomía y Documentación, Universidad Carlos III, C/ Madrid, 128. 28903 Getafe (Spain), SCImago Research Group

INTRODUCTION

This past decade has staged numerous studies and debates about policy-making processes for science, technology and innovation in Latin America (Campos, Piñero & Figueroa, 2011). Some authors look into the factors conditioning the practice of science in "peripheral contexts", such as selection of research topics, agenda, or criteria behind publication and evaluation (Vessuri, 1984; Kreimer, 2000; 2006). A tension between national and international science is reflected in the research evaluation models, where the criterion based on productivity and publication in peer-reviewed journals of international circulation stands as a bias for the research agendas of the South with respect to the North (Sutz, 2005). López & Taborga (2013) identify international co-authorship, programs of cooperation and scientific mobility as the elements indicating an internationalization of Latin American research. Oregioni (2014) perceives two types of internationalization: direct, established through cooperative relations among researchers, and indirect, promoted by national science organizations by means of evaluation parameters.

Relationships of scientific co-operation among countries and processes of internationalization have also been approached from the standpoint of academic dependence, understood as an unequal structure of output and divulgation of knowledge on the part of industrialized countries as opposed to peripheral ones (Beigel & Sabea, 2014). Within this framework, the concept of autonomy has been broadly interpreted. Some authors hold that peripheral knowledge is the result of a captive mind; others demonstrate that a peripheral community

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may reduce its import of foreign knowledge and increase the local production of concepts or methods.

At present, the scientific field of nanoscience and nanotechnology (N&N) has attracted the attention of policymakers worldwide, and several countries have included N&N research programs in their agendas. Its economic and social advances affect sectors such as industry, health, the environment and national security (Huang, et al. 2011). This implies both challenges and opportunities for other countries at medium levels of development, to harness their capabilities and become better situated to benefit from commercial opportunities through targeted investments and strategic collaborations. The rapid growth of N&N is also reflected in the number of publications and patents entailing advancements in knowledge or industrial applications. Against this background, scientific benchmarking can be seen as a useful aid in decision-making about research performance -especially in the case of Latin America- for two main reasons. The first is tied to the "models of academic dependency" outlined above, while the second would be the scarce representation of Latin America in the international arena due to the fact that most studies that analyze this field focus on developed countries (Foladori 2005; Kay & Shapira, 2009; 2011).

This article explores the capacity of Latin America in the generation of scientific knowledge and its visibility at the global level. The novelty of the contribution lies in the decomposition of leadership, plus its combination with the results of performance indicators. We compare the normalized citation of all output against the leading output, as well as scientific excellence (Chinchilla, et al. 2016a; 2016b), technological impact and the trends in collaboration types and normalized citation. The main goal is to determine to what extent the main Latin American producers of scientific output depend on collaboration to heighten research performance in terms of citation; or to the contrary, whether there is enough autonomy and capacity to leverage its competitiveness through the design of research and development agendas. To the best of our knowledge this is the first study adopting this approach at the country level within the field of N&N.

OBJECTIVES AND RESEARCH QUESTIONS

The objective is to characterize the volume, impact, internationalization, scientific capacity and degree of excellence and to evaluate the scientific levels of autonomy or dependency based on internationalization and leadership. We attempt to answer:

- Which countries have greater knowledge output in N&N and a greater degree of leadership and international collaboration?
- Do the levels of scientific performance of a country match its high(er) global output?
- What levels of scientific autonomy and dependency are found when looking at leadership and international collaboration?

MATERIAL AND METHODS

The data set was obtained from SCImago Journal & Country Rank (SCimago 2007) and SCImago Institutions Rankings (SCImago 2013), based on the Scopus database. The indicators used are:

- Output (ndoc): Number of documents published by country.
- Percentage of documents published by Latin American countries in N&N (%LAC)
- Leadership: Percentage of documents published by a country in which the "Corresponding author" is affiliated to a national institution (%lead) (Moya et al. 2013).
- Collaboration types (percentages): a) No-collaboration (non-collab): papers published by one single institution; b) International collaboration: co-authored papers with foreign institutions; and c) International collaboration with leadership: co-authored papers with foreign institutions acting as "Corresponding author"
- Normalized citation impact (NI): The relative number of citations received by each country, compared with the world average of citations received by a paper of the same document type, year and category (Rehn & Kronman 2008; González-Pereira et al. 2010).
- Normalized citation impact with leadership (NIL): this indicator limits its analysis to the leading output
- Benefit rate of collaboration in normalized citation impact (BRCNI), in scientific excellence (BRCE) and in innovative knowledge (BRCIK): the percentage difference between the Normalized Citation/Excellence/Innovative Knowledge of all output and leading outputs. This indicator acts as a proxy to determine the benefit reaped by a country in these indicators when collaboration is not led by the given country. When the value is very low or even negative, it means that the country does not derive much benefit from the collaborations that it does not lead. It signals scientifically well-developed countries whose NI/Exc/IK of total output adequately reflects their scientific performance. A high difference points to scientifically developing countries that depend largely on collaborations with other countries in order to improve their performance. The threshold can vary from one domain to another, but the rule of thumb is: the lesser the benefit rate, the better developed and more autonomous the country.
- Excellence rate (% Exc.): Percentage of documents included within the set of the 10% most cited papers in that category. The percentages can be compared with the "world expected" value established for the top 10% (Tijssen et al. 2002; Bornmann et al. 2012).
- Excellence with leadership (%EwL): Percentage of documents of excellence considered as main contributor.
- Innovative Knowledge: number of all (IK) and leading papers (IK_L) cited in patents.
- Technological impact (%IK): percentage of documents cited in patents with respect to the total output.
- Leadership in technological impact: percentage of leading papers cited in patents with respect to the total output.

RESULTS

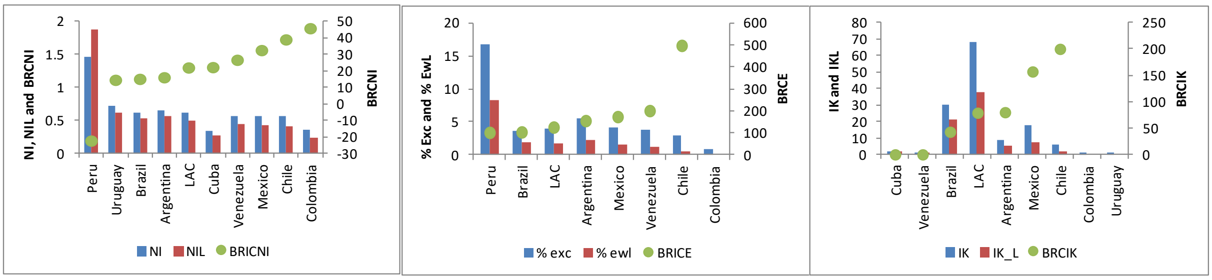
Latin America published 4,811 documents in the category N&N over the time period 2003-2013. This figure represents 2.73% of the world output. Meanwhile, at the world level, a total of 176,158 N&N documents were indexed in Scopus, representing 1.07% of all documents. Brazil is the country with the most output accumulating 46% of the region´s production, followed by Mexico and Argentina (28.46% and 12.51%, respectively). As medium producers, Colombia and Chile contribute similar shares of the regional outputs (roughly 5% and 4%).

Table 1. Main indicators of Latin American countries in Nanoscience and Nanotechnology

Country	ndoc	% LAC	% lead	% non-collab	%lead_collab	% IC	% IC_L	NI	NIL	BRCNI	% exc	% ewl	% eic	BRICE	IK	% IK	IK_L	BRCIK
Brazil	2214	46.02	77.91	28.57	49.34	41.01	24.52	0.61	0.53	15.09	3.66	1.81	1.85	102.21	30	1.4	21	42.9
Mexico	1369	28.46	73.05	32.26	40.79	49.09	30.30	0.57	0.43	32.56	4.16	1.53	2.63	171.90	18	1.3	7	157.1
Argentina	602	12.51	68.77	5.06	63.71	56.98	37.44	0.65	0.56	16.07	5.48	2.16	3.32	153.70	9	1.5	5	80.0
Colombia	235	4.88	68.94	12.01	56.93	67.66	53.09	0.35	0.24	45.83	0.85	0.00	0.85		1	0.4	0	
Chile	210	4.36	60.00	13.11	46.89	70.95	51.59	0.57	0.41	39.02	2.86	0.48	2.38	495.83	6	2.9	2	200.0
Cuba	106	2.20	38.68	12.04	26.64	88.68	70.73	0.33	0.27	22.22					2	1.9	2	0.0
Venezuela	79	1.64	54.43	18.04	36.39	73.42	51.16	0.57	0.45	26.67	3.80	1.27	2.53	199.21	1	1.3	1	0.0
Uruguay	38	0.79	60.53	46.24	14.29	57.89	30.43	0.71	0.62	14.52						0.0		
Peru	12	0.25	16.67	0.00	16.67	100.00	100.00	1.46	1.88	-22.34	16.67	8.33	8.34	100.12	1	8.3		
LAC	4811	100.00	76.20	23.19	53.01	46.21	30.39	0.61	0.50	22.00	3.97	1.77	2.20	124.29	68	1.4	38	78.9

A close look at the relationship between leadership and collaboration (Table 1) reveals diverse patterns, with certain countries showing a high percentage of documents in total and leading international collaboration, such as Cuba. It is followed by Venezuela, Chile and Colombia, with proportions of CI from 67.7% to 73.4%, and output with leadership in CI over 50%. In other countries, the leadership is concentrated in “inbreeding” production, whereby nearly 70% of the output involves documents of national collaboration or non-collaborative production. The most noteworthy cases are Brazil and Mexico, which have the least international collaboration (below the Latin American average of 30.4%). They are followed by Argentina, whose leadership model is more strongly based on national collaboration: it shows the lowest level of non-collaborative output (5.06%), and a moderate degree of international leadership (37.4%), higher than Brazil and Mexico. In Uruguay, leadership essentially entails output not involving collaboration.

Figure 1. Benefit rate of collaboration in normalized citation (left), scientific excellence (center) and innovative knowledge (right)



Peru presents an interesting profile regarding the benefits of collaboration on the impact and excellence. As shown in Fig. 1, Peru´s output is totally dependent on IC. No other Latin American country reaches impact levels near the world average. Yet the levels of impact attained with leadership (NIL) are lower than the global impact (NI). Similarly, regarding excellence, there are greater differences between the output of excellence and the output of excellence that is led by each country.

Colombia derives the greatest benefit from collaboration in attaining impact. At the other end of the scale, Argentina, Brazil and Uruguay have values below the average, benefit less from collaboration with regard to impact, and are more autonomous in achieving scientific impact, although it remains below the worldwide average (Fig. 1-left). Chile gains the most from collaboration with excellence, and Brazil and Argentina are the ones with the least incidence of collaboration in this segment of output.

As can be seen in Fig. 2 (right), Chile is clearly the country that derives the greatest benefits from collaboration in terms of technological impact, followed by Mexico. Argentina and Brazil are less dependent upon collaboration. Figure 2 reflects the position from the perspective of scientific and technological dependence upon collaboration in order to reach their levels of impact. Again, this signals that Chile and Mexico are hardly independent, calling for collaboration in order to attain scientific or technological impact.

Figure 2. Autonomy vs dependency of collaboration in scientific and technological impact

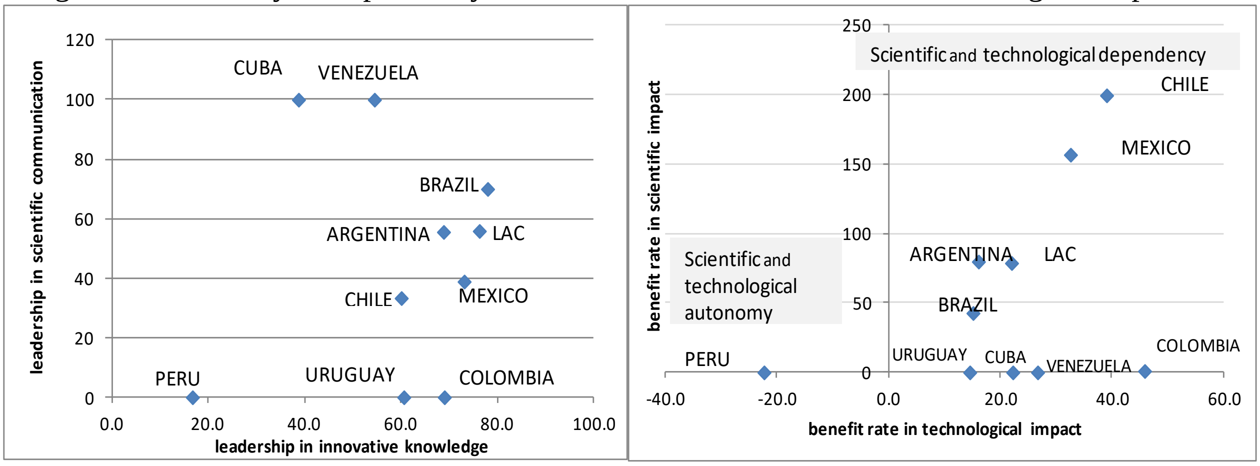
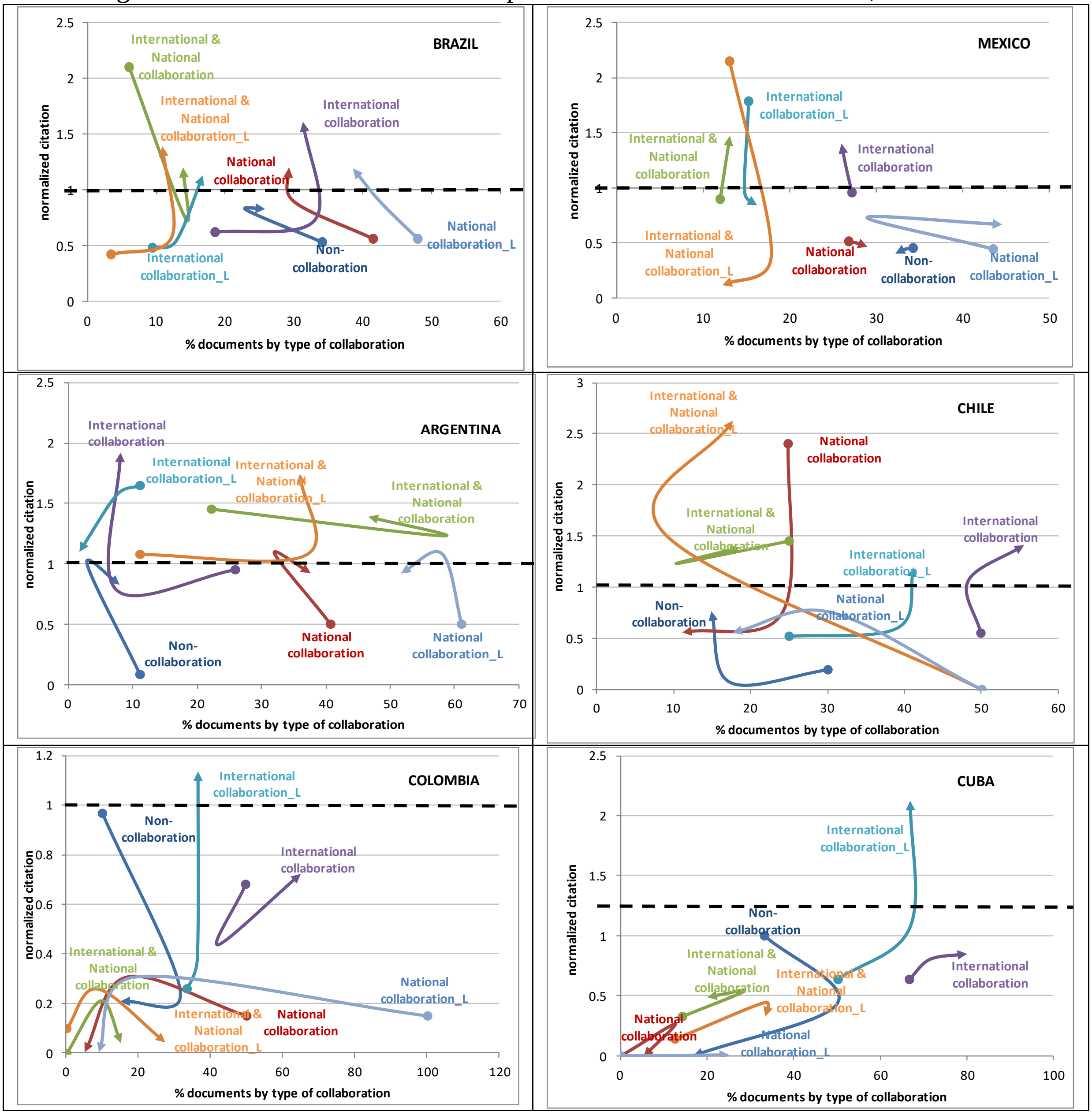


Figure 3 illustrates the trends behind the influence of collaboration in the normalized citation of each country. Brazil presents a clear growing trend in its total and leading international collaboration, as well as in national collaboration and international collaboration with leadership. In all three cases the value has a positive effect on impact, yet international collaboration is the most determinant one for high citation. Furthermore, output in collaboration allows Brazil to eventually obtain normalized citation indexes above the world average. Non-collaboration decreases and has the least impact.

In Mexico the panorama is quite different. There is a rising trend for the impact of output entailing international collaboration, as well as national and international collaboration, whereas a reverse trend is seen for the levels of impact of output coming from leading collaboration, and non-collaboration.

Argentina tends to increase the impact of its output resulting from international collaboration, while the national and international production decline in impact. The other types of output show impact on the rise, by the end of the period over the world average in all cases except non-collaborative output, which holds an impact under 1 throughout the period.

Figure 3. Evolution of collaboration patterns and normalized citation, 2003-2013



Chile´s output with international collaboration and in IC-L increase steadily, in both cases reaching impact values above the world mean by the end of the period analyzed. However, it is the output combining national and international leadership and collaboration which achieves the greatest levels of impact, and finally reaches a value over 2.5, despite a slight drop in the % of documents.

The case of Colombia is interesting indeed. All its output except international with leadership has impact levels under the world mean at the end of the period, showing virtually no percentagewise growth. Thus, this country obtained more benefits from international collaboration with leadership, but did not increase its share of production. It shows no real decline in non-collaborative output, though its impact is substantially reduced. The greatest change is in national and international output, with or without leadership, although in either case the impact achieved lies below the world average.

Cuba only increases its output in international collaboration, and much more in output with leadership than without leadership. This means it also considerably increases the levels of impact, which at the end of the period reach an index over 2. Non-collaboration shows a considerable decline in both output and impact. The national and international collaboration without leadership grows slightly in volume and impact, while collaboration with leadership grows in volume but ends up with somewhat less impact.

CONCLUSIONS

Even if the argument, some theoretical assumptions and the consequences of the method employed should be discussed, the approach taken here, with its emphasis on the autonomy and dependency of countries in their performance, tries to contribute to constructive debate about how best to assess size and performance in future studies. This new methodology can be extrapolated to different fields of study. The metrics provided here are not the only indicators that might account for analyzing research performance. It follows that any measure used to gauge impact will also reflect social factors beyond the conventions or patterns of behavior of scientific output. As strongly advocated in the Leiden manifesto, scholarly metrics should play the supporting role to qualitative and in-depth analyses of scholarly content and activities (Hicks et al. 2015). There are many ways to expand upon this analysis in order to enrich and complement the findings exposed here.

Taking into account that leadership means responsibility and acknowledgment of the responsible for the publication of research, leadership also means merit when it entails international collaboration. Thus, leadership and international collaboration patterns help to characterize how research is carried out, taking into account scientific capacities in linkage networks and to what extent countries play different roles in the management of their own capacities to generate knowledge and to attract international partners (Chinchilla et al, 2016a; 2016b).

The growth of international collaboration with leadership should be interpreted as a positive aspect, a progressive internationalization of scientific activity with capacities for the definition of research agendas concerned with local needs or topics of interest that would likewise be of interest for further communities abroad, in turn contributing to the development of science at a national level. Although we need to explore scientific and technological leadership in greater depth, this statement attempts to sum up the significance of so-called tensions between the autonomy/dependence of scientific agendas and how they might be remedied by greater opportunities to increase the visibility and competitiveness of research in peripheral countries. Therefore, the data stand as an invitation for researchers to carry out studies in greater depth and identify the groups and subject areas in which Latin America demonstrates greater potential.

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