BIBLIOMETRIC ANALYSIS OF SCIENTIFIC DEVELOPMENT IN COUNTRIES OF THE *UNION OF SOUTH AMERICAN NATIONS* (*UNASUR*)

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Abstract

The *Union of South American Nations* (*Unasur*) can be considered as a new emergent region in the world. By using advanced bibliometric methods, the development of science and technology in *Unasur* is explored. Based on data from the *InCites* tool of *Thomson Reuters*, which facilitates national comparisons across long time periods using publication output and normalized citation impact values, we explored how this region (particularly the most productive individual countries within it) is developing. The publication output results reveal an increase in the scientific and technological activities in most of the *Unasur* countries (especially Brazil). Compared to the rest of the world, the citation impact trend is less favourable for all *Unasur* countries.

Keywords

Normalized citation impact, Publication output, Scientific output, Research output, Citations, Impact, National comparison, *InCites*, *Unasur*, Latin America.

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Resumen

La *Unión de Naciones Suramericanas* (*Unasur*) se puede considerar como una nueva región emergente. En este artículo se explora el desarrollo de la ciencia y la tecnología en la Unasur utilizando métodos bibliométricos avanzados. Basándonos en datos del sistema InCites de Thomson Reuters, que facilita comparaciones nacionales en períodos de tiempo largos, y proporciona datos de publicación y valores de impacto de citación normalizados, exploramos cómo se desarrolla esa región (y en particular los países más productivos dentro de la misma). Las cifras de publicaciones revelan un incremento en la actividad científica y tecnológica en la mayoría de los países de la Unasur (especialmente Brasil). En comparación con el resto del mundo, la tendencia en el impacto de citación es menos favorable para todos los países de la Unasur

Palabras clave

Impacto de citación normalizado, Producción de publicación, Resultados de investigación, Publicación científica, Impacto, Citas, Citación, Comparación nacional, *InCites*, *Unasur*, América Latina.

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Introduction

Inspired by the *Cusco Declaration* (December 8th, 2004), the *Brasilia Declaration* (September 30th, 2005), and the Cochabamba Declaration (December 9th, 2006), the *Union of South American Nations* (*Unasur*) was officially constituted in 2008 and is made up of the following countries: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Perú, Surinam, Uruguay, and Venezuela. Its founding treaty states: The objective of *Unasur* is to build, in a participatory and consensual manner, integration and union among its peoples in the cultural, social, economic and political fields, prioritizing political dialogue, social policies, education, energy, infrastructure, financing and the environment (among others). *Unasur* has the intention to eliminate socioeconomic inequality and to strengthen social inclusion, participation of civil society, and democracy as well as to reduce asymmetries within the framework of obtaining the sovereignty and independence of the States. *http://www.unasursg.org*

Similar to China, India, Russia, and South Africa, *Unasur* can be considered as a new emergent region in the world. Unasur has a population of 381,959,612 (2008), a land area of 17,649,335 Km^2 and a gross domestic product (GDP) of USD 4,431,793 million (2010), making *Unasur* the fourth largest economy in the world (**Formento**, 2012). The recent economic expansion of the region can be mainly explained by the high price of commodities that are abundant and varied in South America: cereals, minerals, oil, etc. This situation, combined with the new social policies of the region, has allowed improvements in living conditions. For instance, the poverty rate was around 43% at the beginning of this century and is now around 31%. Despite the progress, the region is still one of the poorest in the world[1].

As has been frequently discussed in *Unasur*, the region's long-term development needs the incorporation of value added to the natural resources. This would certainly generate more daily occupations, with the accompanying improvement in social conditions than the simple continuation of exporting natural resources. As it is expressed by the *South American Council of Education, Culture, Science, Technology and Innovation* (*Cosecti*), it is crucial for the development of the region to foster science and technology developments.

As mentioned above, the *Unasur* treaty states the necessity of improving the living conditions of the region. The promotion of science and technology is one of the large number of ways to achieve this aim. In this context, it is interesting to explore the actual state of affairs with respect to science and technology by studying publication output (productivity) and citation impact: How does the *Unasur* region (particularly the most productive individual countries within it) develop in comparison to other countries worldwide in terms of bibliometric data over a longer time period? The answer to these points may be useful for future discussions about possible policy actions on science and technology.

Methods

We have analysed for the first time the research performance of *Unasur* (and also of Latin America) as a whole. For the purposes of comparison, we present results for the European Union (EU 15: UK, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, and Sweden) as well as China, India, and the USA. Our study is based on data from the relatively new *InCites* tool of *Thomson Reuters*, which facilitates national comparisons across long time periods using publication output and normalized citation impact values[2].

InCites is a web-based research evaluation tool allowing the assessment of the publication output and citation rates of institutions and countries. Citation rates measure a specific important part of scientific quality: scientific impact (**Martin**; **Irvine**, 1983). The *InCites* global comparisons module provides output and citation metrics from the *Web of Science* (*WoS*, *Thomson Reuters*) for the evaluation of research productivity and performance. The metrics are generated from a dataset of 22 million *WoS* papers from 1981 to 2010. The metrics for country-specific comparisons are created

based on address criteria (i.e. addresses of authors having published the papers) using the whole-counting method: Counts are not weighted by numbers of authors or addresses.

Besides publication numbers, we show normalized citation impact values for the most productive *Unasur* countries given below. *Thomson Reuters* calculates the mean citation rate of a country's set of publications in the specific subject area and then divides it by the mean of all publications within the relevant subject area. A value of 1 for a specific country (in a specific subject area) indicates that the citation impact of papers published by scientists in this country is no more or less than the worldwide average impact of papers in the subject area. If this value stands at 1.2, for example, the corresponding papers were cited 20 percentage points, on average, above the worldwide average in the subject area. Normalized citation-based impact indicators allow us to measure the performance of a researcher, an institution or a country within the impact bandwidth of the relevant scientific community worldwide. Therefore, research evaluation based on bibliometrics (i.e. quantitative methods) requires consulting such data. Time curves of normalized impact reveal the amount of the overall and/or field-specific performance as well as its evolution, e.g. in comparison with other countries. This is most important for any discussions concerning the improvement of research and development in these countries. *InCites* is the only source of normalized data currently available. Very few institutes worldwide are able to calculate such data on the basis of the *WoS* (e.g. the *Centre for Science and Technology Studies*, *CWTS*, of *Leiden University*).

As the subject area scheme for the citation impact analyses of this study, the main categories of the *Organisation for Economic Co-operation and Development* (*OECD*, 2007) were used. In contrast to the other schemes provided by Thomson Reuters, the *OECD* scheme enables the use of six broad subject categories for *WoS* data: (1) Natural Sciences, (2) Engineering and Technology, (3) Medical and Health Sciences, (4) Agricultural Sciences, (5) Social Sciences, and (6) Humanities. A concordance table between the *OECD* categories and the WoS subject categories is provided by *InCites*.

Results on the citation impact of the countries in Agricultural Sciences are not considered in this analysis since the annual publication numbers for most of the countries analyzed here are too low (mostly fewer than 100 annual country publications). The numbers for the Social Sciences and Humanities also were not included in the study. According to **Blockmans** and **Thomassen** (2005), "one can scarcely expect researchers in the humanities and the social sciences to accept the performance indicators used in the natural sciences as valid in their own field. As a result, alternative methods are required. The success of any evaluation procedures and instruments depends on their being accepted by the relevant researchers" (p. 5).

For each broad subject category mentioned above, the countries' data (*InCites*™ *Thomson Reuters*, 2012) was downloaded as an Excel sheet and imported in *Stata* (*StataCorp.*, 2011) for the statistical analysis.

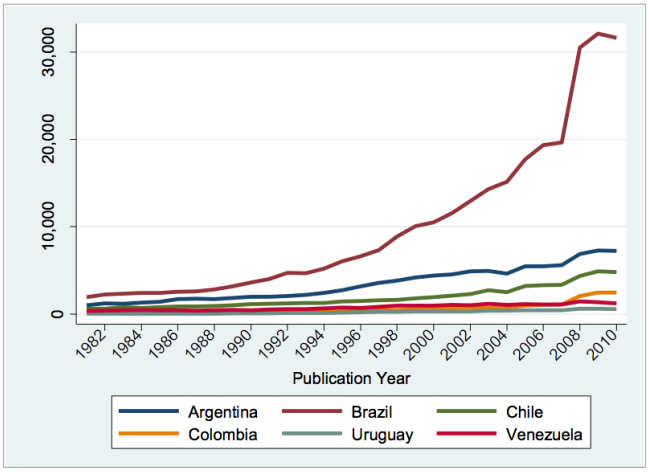

Figure 1. Number of publications for the six most productive *Unasur* countries. Source: *InCites*™ *Thomson Reuters* (2012)

Results

Publication output

Figure 1 shows the number of publications (all subject categories) between 1981 and 2010 for the most productive *Unasur* countries: Argentina, Brazil, Chile, Colombia, Uruguay, and Venezuela. It is clearly visible that amongst this set the countries with the highest scientific output are Brazil, Argentina and Chile, in that order. Furthermore, these three countries (especially Brazil) show an increase in the number of publications, particularly since the early 1990s. This increase may be due to a more productive system of science, but also to greater coverage of journals from Latin America and Spanish language journals in the *WoS*[3]. In the figure, a clear gap is visible between the number of publications for Brazil and both Argentina and Chile and another gap between the two latter and the other countries. Both gaps indicate a large degree of heterogeneity in the region.

In contrast to Brazil, the number of publications for Argentina increased between 1994 and 2003 with a slight negative curvature, slowing down the productivity. The period of negative curvature tends to saturate around the major economic crisis at the end of 2001. The fact that this negative curvature period is only visible in Argentina may show that the efforts of the Argentinean government with regard to science and technology issues were less pronounced than those of other countries in the region during the 1990s. The efforts were certainly accelerated around 2003 by a new policy towards science and technology: (a) The budget for science and technology was significantly increased and (b) a *Ministry of Science and Technology* was set up and funded in 2007[4].

Figure 2 shows the output (in terms of publication numbers) of the six most productive *Unasur* countries in terms of percentages of publications to 1981. The relative increase of the countries' scientific output can be measured as all countries have the same reference point at 1981. As the results indicate, all countries have more or less the same relative increase of output until 1990. A split is then visible in subsequent years. Brazil achieves one of the best performances at the relative level in Figure 2 (a similar result is visible at

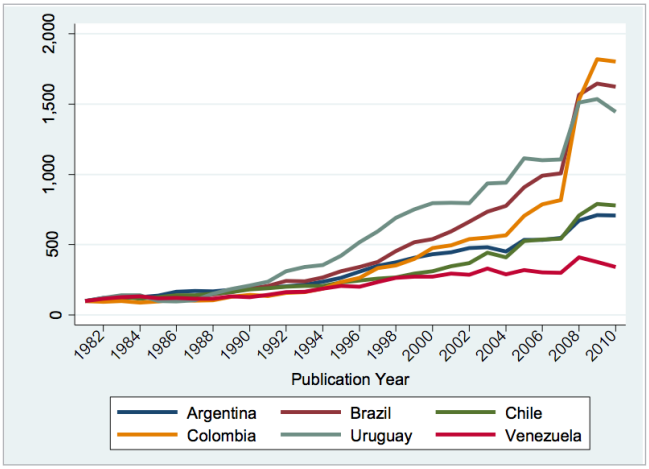

Figure 2. Number of publications for the six most productive *Unasur* countries relative to the year 1981. The number of publications in 1981 is the reference value of 100%. Source: *InCites*™ *Thomson Reuters* (2012)

the absolute level in Figure 1). In contrast, science in Argentina, which is second in terms of the number of publications in Figure 1, shows a less relative increase than Brazil (and also Uruguay, and Colombia). In recent years, three countries (Brazil, Colombia and Uruguay) have achieved percentages of over 1000%. By comparison, the relative increase of publication output in the EU 15 and USA reached values of around 200% and 300% in 2010 (figures not shown) and are thus (significantly) smaller than for the countries in Figure 2. However, on an absolute level the EU 15 and USA publish significantly more frequently than the countries in Figure 2.

Citation impact

Figure 3 shows the relative citation impact of publications (published by the six most productive *Unasur* countries) with regard to the subject areas of Natural Sciences, Medical and Health Sciences, and Engineering and Technology as well as all fields (all subject categories). For a better understanding of these results in Figure 3 the focus should be on the rough trends. The peaks are presumably originated by single papers with unusually high citation numbers.

Natural sciences

One of the two most productive countries, Argentina (see Figure 1), showed a continuously increased citation impact for its publications from just above 0.5 to values close to 1. While Argentina has almost reached the global average in recent years, the impact of publications from Brazil (another very productive country) has decreased since around 2005 and has reached an impact level similar to that in 1981. The publications from Chile show, with some greater oscillations, a trend similar to that of Argentina. To assess the citation impact of the countries properly, it should be noted that countries like the USA, UK and Germany have significantly higher values of around 1.3 at present (**Bornmann**; **Leydesdorff**, 2012).

Medical and Health Sciences and Engineering and Technology

Similar to Argentina in the Natural Sciences, Brazil and Argentina show a continuous increase in citation impact between 1981 and the beginning of 2000 in Medical and Health Sciences. While in recent years Argentina has shown values higher than the global average (i.e. above 1) in this subject category, Brazil has decreased since 2005. The increasing citation impact trend (by a factor of about 2) for Argentina can be interpreted as a favourable performance in the medical and health area. In contrast to the Natural Sciences and Medical and Health Sciences, Engineering and Technology shows only a slightly increasing trend (a value of around 0.8) for most of the six productive countries.

All fields

The citation impact relative to the world follows the main trends observed for Natural Sciences for all fields. A similar result is reported by **Bornmann** and **Leydesdorff** (2012) for six prolific countries (China, Japan, France, Germany, United States and the UK).

In Figure 4, the citation impact relative to the global average is shown for Latin America in total (*InCites* does not provide this data for *Unasur* in total) and also, for comparison, for two emergent countries (China and India) as well as EU 15, UK, and USA. The figure indicates a large gap in citation impact between Latin America and EU 15, UK, and USA. Looking at the citation impact trend for Latin America, it cannot be anticipated that this gap will become smaller in the future. This becomes more evident if one takes a look at the results for China and India, where the increasing trend is more accelerated than for Latin America. At the beginning of the 1980s, the citation impact of the papers from China and India was about half of that for Latin America, but nowadays the impact is quite similar. If this trend continues, China and India may significantly reduce the gap to EU 15, UK, and USA in the near future (see **Leydesdorff**, 2011), while this scenario can hardly be anticipated for Latin America.

Discussions and conclusion

In this paper, using advanced bibliometric methods, we have investigated for the first time how the *Unasur* region (with emphasis on the six most productive *Unasur* countries) is developing in comparison to other countries worldwide in terms of bibliometric data.

The results concerning the publication output indicate an increase in the scientific and technological activities in most of the *Unasur* countries (especially Brazil). However, the trend of the citation impact relative to the world is less favourable for all countries. While the increase of the six *Unasur* countries' output in terms of percentage of publication numbers to 1981 is more accelerated than for EU 15, UK, and USA, this trend is not reflected at all in the citation impact. Besides the large gap in the citation impact between Unasur and EU 15, UK, and USA, the present citation impact trend for *Unasur* does not suggest that the gap will be smaller in the future. This is contrary to countries like China and India, which show a favourable citation impact development. It seems that *Unasur* still has to increase its efforts to enhance the quality of research in order to achieve a higher citation impact of the publications.

The increase of the scientific output and citation impact (on a relatively low level) in the region goes back to the early

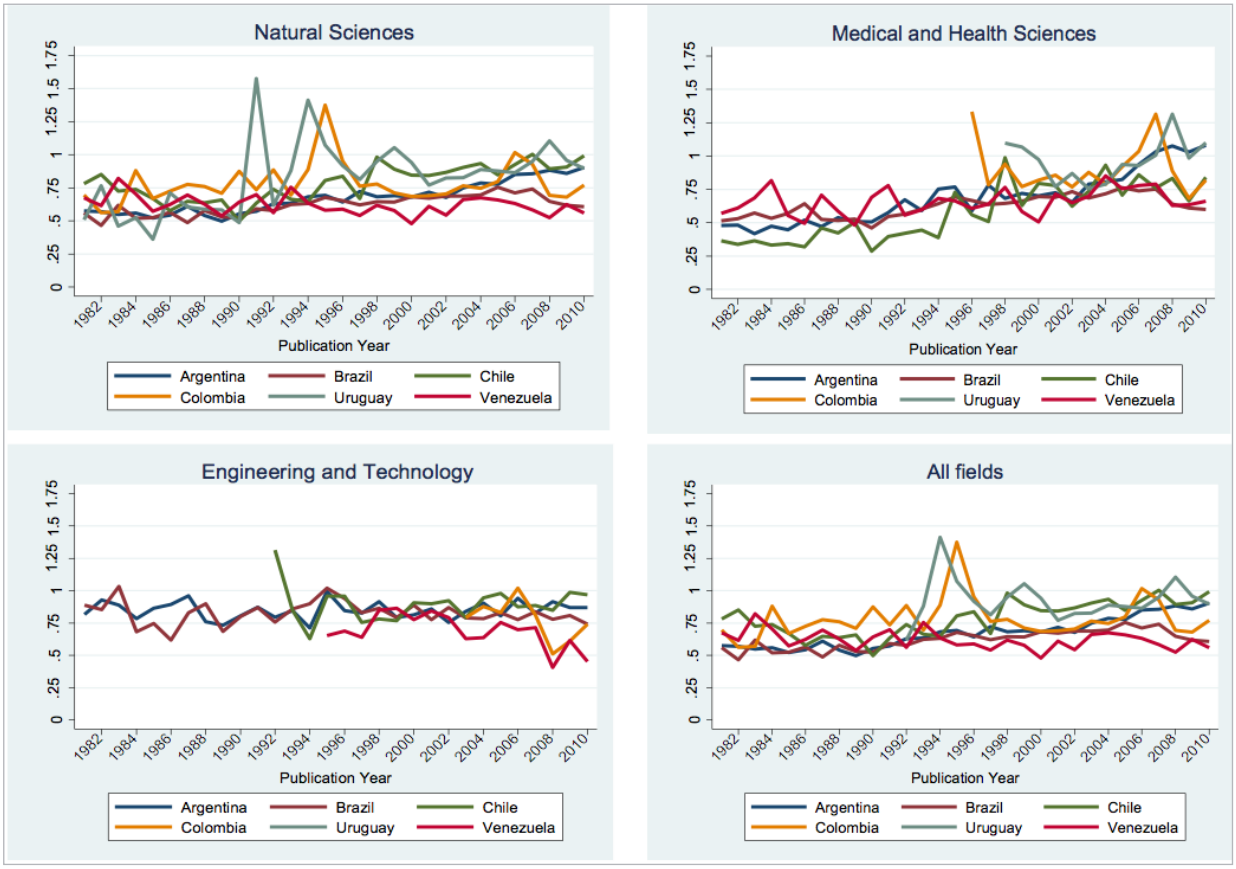

Figure 3. Citation impact relative to subject area of the six most productive *Unasur* countries within three specific subject areas (Natural Sciences; Medical and Health Sciences; Engineering and Technology) as well as for all fields. The mean citation impact of all publications in the subject area (across all fields) worldwide is 1. Source: *InCites*™ *Thomson Reuters (2012)*

1990s, long before *Unasur* was formed. This is an interesting finding because there is a general belief that *Unasur* was created to improve the living conditions inherit from the 1990s. In other words, while there is a noticeable improvement of the poverty rate and other social variables after the creation of *Unasur*, this is not visible at present in the science and technology development, as measured by bibliometric data.

For *Unasur*, the increase of the citation impact is mainly visible in Natural Sciences and Medical and Health Sciences. However, a similar trend is not recognizable in the area of Engineering and Technology. The lack of increase seen over the past 30 years is in fact a significant cutback because this area represents a key field for industrial success. A lack of development in Engineering and Technology may lead to the danger of further supremacy of the export model of raw materials over the industrial model in the countries. We have also found a large heterogeneity in the region. Most of the scientific and technological productivity is mainly concentrated in only a few countries. In our opinion, a more homogeneous development is desirable. The scientific and technological development of the whole region would profit significantly by, e.g., stimulating cooperation between scientists from different countries of the region.

Besides scientific papers, another important aspect for analysing the technical development of a country or region is related to patents. In comparison to scientific papers, counting patents and their citations is more problematic. Since the national patent offices of most Unasur countries do not deliver patent information for the relevant databases, we discuss here a brief search of the relative output of patents for the two most productive *Unasur* countries: Brazil and Argentina. The relative number of patents compared to the output in terms of papers can be estimated. According to the patent database *Inpadoc*, 409,857 patent documents from Brazil and 87,247 from Argentina were registered within the period 1981 to 2010. Thus, the overall patent ratio of both countries is 4.7 but this ratio decreased to 1.8 in 2010 (3,075 patents from Brazil and 1,703 from Argentina). The corresponding ratios of the WoS documents are 3 for the overall period 1981 to 2010 and 4.4 for 2010 alone. Hence, the overall productivity of patents from Brazil relative to Argentina is greater than the total productivity of papers. In 2010, however, the situation had reversed and, compared to papers, Argentina produced a larger proportion of patents than Brazil. Obviously, Argentina has been able to increase its productivity with regard to patents (at least relative to Brazil), although the citation impact of its Engineering and Technology publications shows a rather constant level comparable to the level of Brazil.

As we have mentioned in the Methods section, the subject category Agricultural Science could not be analysed because the numbers of publications for most of the years are too low to provide reliable bibliometric results. This limitation

of our study is unsatisfactory because this subject area is of fundamental interest to *Unasur's* economy at present. In a recent paper on Argentina (**Rojas-Sola**; **De-San-Antonio-Gómez**, 2010), the subject area Agricultural Science is studied for the period 1997 to 2009 through the *WoS* database, and results for Latin America are also presented. Although the reported number of publications is in agreement with our research (not shown), contrary to **Rojas-Sola** and **De-San Antonio-Gómez** (2010), we think that a sample size of fewer than 100 annual country publications is too small to yield reliable results.

We hope that our study will encourage discussions about possible science policy actions in order to improve research performance in the *Unasur* region, particularly in the area of Engineering and Technology.

Notes

1. For more details about the countries against the backdrop of different social and economic indices see **Formento** (2012) and:
http://www.eclac.org
http://www.unasursg.org

2. InCites
http://incites.thomsonreuters.com

3. See *http://www.colciencias.gov.co/sobre_colciencias*

4. *http://www.mincyt.gob.ar*

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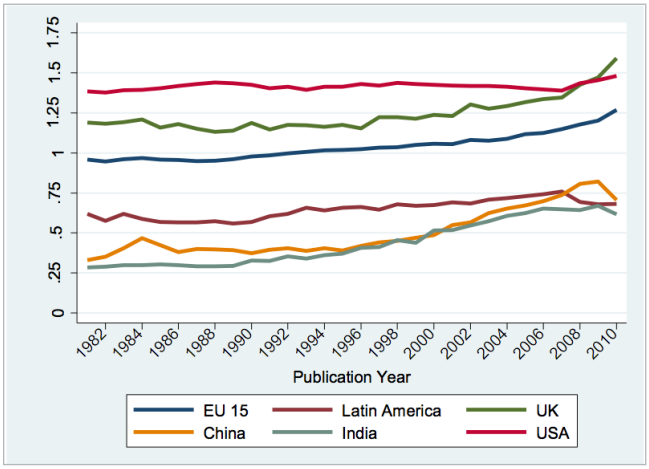

Figure 4. Relative citation impact of Latin America compared to other emergent countries as well as developed countries and regions (all fields). The mean citation impact of all publications worldwide is 1. Source: *InCites™ Thomson Reuters* (2012)

InCites™ Thomson Reuters. *Report created: 03.2012. Data Processed Dec 31, 2010*. Data Source: Web of Science. This data is reproduced under a license from Thomson Reuters, 2012.

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