

## *Measuring research performance in international collaboration*

### **Midiendo el rendimiento de la investigación en la colaboración internacional**

**Resumen:** la colaboración internacional en la creación de conocimiento es responsable de cambiar la estratificación estructural de la ciencia logrando profundas implicaciones en la gobernanza de la ciencia. El análisis de la colaboración en los países de América Latina y el Caribe es de particular importancia, ya que las iniciativas son a menudo el resultado de los acuerdos de "investigación a cambio de ayuda", en general, sobre la base de las asimetrías Norte-Sur. Sin embargo, la colaboración para el beneficio mutuo y la excelencia ha ganado aceptación llegando a convertirse en una prioridad estratégica para mejorar la propia producción a partir de la selección de "socios colaboradores. El objetivo general de este estudio es cuantificar la tasa de beneficio en la visibilidad y el impacto de la producción científica en el ámbito de las N + N, teniendo en cuenta los diferentes tipos de producción (total, liderada, excelente, y excelente con liderazgo) de los seis productores principales del conocimiento en Nanociencias y Nanotecnología en América Latina en el período 2003-2013. Más específicamente aspiramos a visualizar las redes de colaboración internacional en un país determinado (ego-red) para representar la diferencia entre las citas recibidas por cada tipo de producción, e identificar los socios con los que un país tiene un mayor potencial y capacidad para generar conocimiento de alta calidad, así como las diferencias existentes en términos de visibilidad en función del tipo de producción analizada.

**Palabras clave:** colaboración internacional; rendimiento investigador; liderazgo; redes heliocéntricas; nanociencia y nanotecnología; latinoamérica

**Abstract:**

International

collaboration in the creation of knowledge is responsible to change the structural stratification of science having profound implications for the governance of science. Analysis of collaboration in Latin American and Caribbean countries is of particular significance, because initiatives are often the result of “research-for-aid” arrangements, generally based on North–South asymmetries. However, collaboration for mutual benefit and excellence has gained increasing acceptance, with “partner” selection becoming a strategic priority to enhance one’s own production. The general aim of this study is to quantify the benefit rate in visibility and impact of scientific production in the field of N&N bearing in mind the different types of output (total, in leadership, excellent, and excellent with leadership) of the six main producers of knowledge in N&N in Latin America in the period 2003-2013. More specifically we aspire to visualize the networks of international collaboration in a given country (ego-network) to represent the difference between the citations received per type of output, and identify the associates with whom a country has greater potential and capacity to generate knowledge of high quality, as well as the differences existing in terms of visibility depending on the type of production analyzed. In short, we wish to determine the benefits of such collaborative efforts. In this way we could respond to questions such as: a) With which countries is collaboration established? and b) With which collaborating countries are the greatest volume of citations per document obtained, according to the type of output.

**Keywords:** leadership; ego-network; research performance; international collaboration; nanoscience and nanotechnology; LAC

## **Introduction**

International collaboration in the creation of knowledge is responsible to change the structural stratification of science. This change in the relation between the geographical and intellectual dimensions of science has profound implications for the governance of science (Leydesdorff et al. 2013).

Initiatives to promote and support research adopt different forms from one region to another, and may include technical assistance, local training, and support for the development of specific institutions, institutional partnering, or intercountry agreements. Analysis of collaboration in Latin American and Caribbean countries is of particular significance, because initiatives are often the result of “research-for-aid” arrangements, generally based on North–South asymmetries (Bonfiglioli, 2000). Over the years, however, collaboration for mutual benefit and excellence has gained increasing acceptance, with “partner” selection becoming a strategic priority to enhance one’s own production (Velho, 2002). In this context, a key prerequisite for the design of regional collaboration policies is the determination of how Latin American partners attain higher research potential (more and better results).

Collaboration is an added value for increasing productivity and visibility (Gazni, Sugimoto & Didegah, 2012). Multi-country publication increases the chances that an article be more cited; it has also been demonstrated that countries benefit from participation in multinational projects, which ultimately leads to an improved citation factor (Glanzel & Shubert, 2001; Glanzel & De Lange, 2002). Furthermore, increasing international collaborations and developing mixed research teams has a positive effect on the impact factor and the research quality of publications (Wagner et al., 2001). Yet the effects of collaboration do not always translate into benefits at the same magnitude (Persson, 2010)

Whatever type of collaboration may be quantified through collaborative projects, publications in common, informal contacts, the interchange of researchers or fellows among different countries, and participation in congresses (Fernández et al., 1998; Chinchilla & Moya, 2007; Chinchilla et al., 2012; Guerrero, Olmeda & Moya, 2013), it can be said that studies based on the authorship of scientific publications afford a good estimate of this information (Katz & Martin, 1997; Glänzel, 2001). Depending on the level of aggregation under analysis and the techniques used, these conditioning factors can be explored in greater detail. Such a focus affords an opportunity to elaborate indicators that reveal the organization of the patterns of communication, and the possibility of generating visual representations of the system in which they are rooted. Moreover, we may determine the volume and impact of each country's scientific output, the breadth and scope of its networks of collaboration, and, consequently, the national capacity for receiving or transmitting the flow of knowledge (Chinchilla et al., 2010).

## **Objectives**

The general aim of this study is to quantify the benefit rate in visibility and impact of scientific production in the field of N&N bearing in mind the different types of output (total, in leadership, excellent, and excellent with leadership) of the six main producers of knowledge in N&N in Latin America in the period 2003-2013. More specifically we aspire to visualize the networks of international collaboration in a given country (ego-network) to represent the difference between the citations received per type of output, and identify the associates with whom a country has greater potential and capacity to generate knowledge of high quality, as well as the differences existing in terms of visibility depending on the type of production analyzed. In short, we wish to determine the benefits of such collaborative efforts. In this way we could respond to questions such as: a) With which countries is collaboration established? and b) With which collaborating countries are the greatest volume of citations per document obtained, according to the type of output.

## Materials and methods

The data set was obtained from SCImago Journal & Country Rank (SJR) (SCImago 2007) and SCImago Institutions Rankings (SIR) (SCImago 2013), based on the Scopus database.

The indicators used are:

- Output (ndoc): Number of documents published by each country.
- Leadership types (percentages): a) Percentage of documents published by a country in which the "Corresponding author" is affiliated to a national institution of the given country (%lead).
- Collaboration types (percentages): a) No-collaboration (non-collab): papers published by one single institution regardless of the number of authors that signed the manuscript; b) National collaboration: papers published by two or more domestic institutions; c) International & National collaboration: papers published by two or more domestic institutions and at least, one foreign institution; d) International collaboration: co-authored papers with foreign institutions; and e) International collaboration with leadership: internationally co-authored papers where an institution of the given country has the role of "Corresponding author".
- Cites per document by type of production: cites per document received by total (cpd) and leading papers (cpd\_L).
- 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. The values represent the relationship between the average scientific impact of a country and the worldwide average on the whole, with a score of 1 (González-Pereira et al. 2010; Rehn and Kronman 2008).
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- Normalized citation impact with leadership (NIL): this indicator limits its analysis to the output in which at least one author or institution of the given country has the role of "Corresponding author" (Moya et al 2013).
- Benefit rate of collaboration in normalized citation impact (BRCNI): the percentage difference between the Normalized Citation of all output and leading outputs. This indicator acts as a proxy to determine the benefit earned by each 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; in other words, it signals scientifically well-developed countries whose NI of total output adequately reflects their scientific performance. If the difference between is very high we are dealing with scientifically developing countries that depend to a certain extent 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 institution.

## Results and discussion

Latin America published 4,811 documents in the category N&N. This figure represents 2.73% of the world output. At world level, a total of 176,158 documents were indexed in Scopus database, representing 1.07% of all documents. Brazil is the country with the most output (46% of regional publication) followed by Mexico and Argentina with 28.46% and 12.51%, respectively. As medium producers, Colombia and Chile accumulate similar shares of regional outputs (between 5% and 4%), and Cuba only accumulates 2%.

The countries that "lead" a greater quantity of documents in collaboration, that is, those whose corresponding authors pertain to institutions rooted in each land, are Argentina,

collaborative efforts may only take place among national institutions, or between national and foreign institutions, and in this leadership category the documents undersigned by a single institution are excluded, regardless of the appearance of one or more authors in the institutional affiliation.

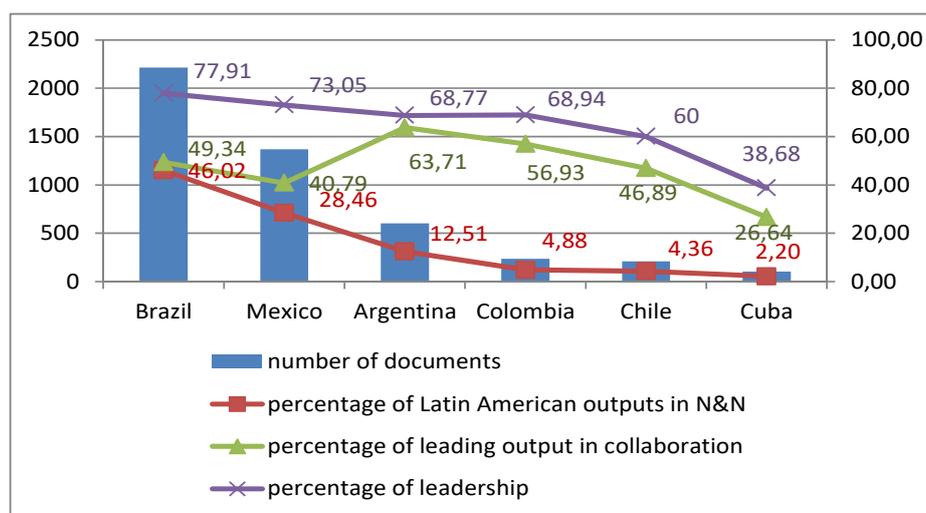


Figure 1. Scientific output in N&N in main Latin American producers of knowledge

These data confirm that the total leadership of each country does not strictly correspond with their capacity to lead research with associates (especially true in the cases of Brazil and Mexico). It also shows that much output is exclusively carried out "indoors", and that such non-collaborative endeavors have repercussions for the real yield of research.

Detailed analysis of the types of collaboration of each country and the normalized impact reached by each set of documents --whether total output (Figure 2) or output with leadership (Figure 3)-- one clearly sees the different yields and benefits (in terms of citation) of each country. Taking as reference the world mean of normalized impact (value = 1) and the impact reached by each country represented by a number between parentheses

abbreviation, we see the benefits of types of collaboration and the most beneficial patterns of relationships. Figure 2 reflects total output and normalized impact, per type of collaboration. It shows that any type of collaboration is more beneficial than no collaboration at all, especially for the main producers like Brazil, Mexico, Argentina and Chile.

Meanwhile, in the case of the small producers, the collaboration among national institutions is the one obtaining the least visibility, and in no case does it attain the world average for impact, even though international collaboration proves more beneficial for them.

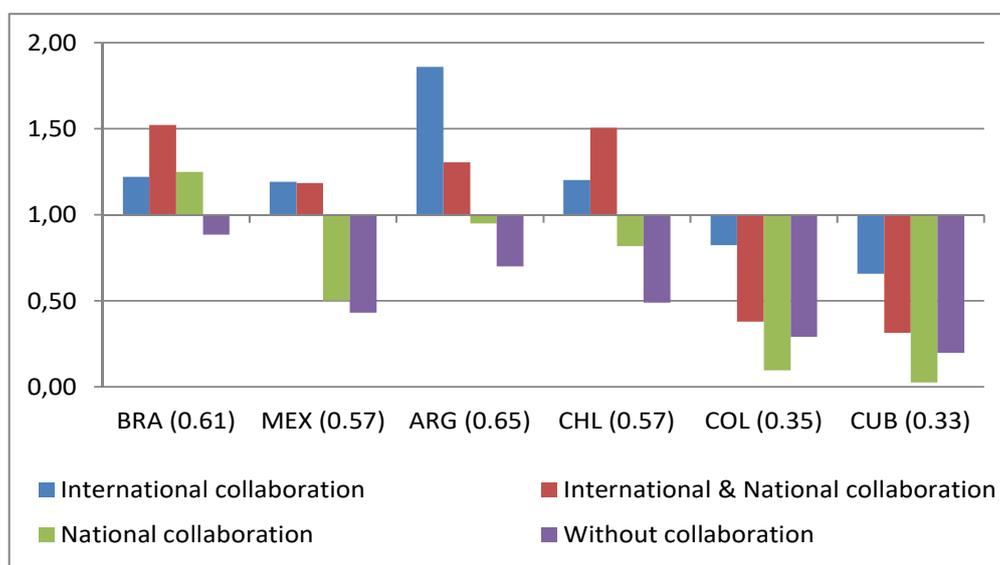


Figure 2. Normalized citation by type of collaboration of all outputs related to the world

In the case of Brazil, the association of two or more national institutions with foreign ones (International & National Collaboration) is the most beneficial, coming to obtain over 50% of the world average in citation. An interesting finding here, not seen with other countries, is the high yield of output carried out among two or more national institutions with no foreign participation (National collaboration). Argentina flaunts three times the average citation with documents undersigned by a single institution on national soil and one or more institutions abroad.

A significant datum acting as the common denominator in the four main producers of N&N in Latin America is that the association among various national institutions and one or more foreign institutions is more beneficial. This pattern also appears for the output with leadership (Figure 3) to a lesser extent. What remains stable in the sets of production is the low impact of output undersigned by a single institution.

The greatest differences appear in the setting of collaboration between one national institution and one or more foreign institutions. Only Mexico is capable of surpassing the world average impact figures when the Mexican institutions lead collaboration with foreign associates. This means that Brazil, Argentina and Chile are the countries most dependent upon international collaboration to obtain good results in terms of yield, and are therefore the ones that most benefit from this association.

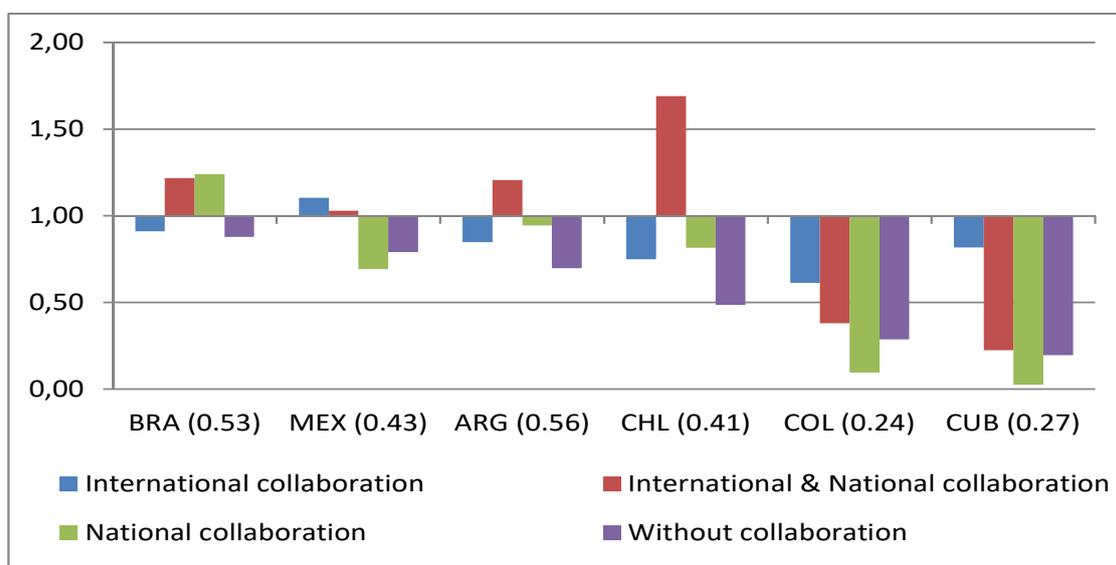


Figure 3. Normalized citation by type of collaboration of leading outputs related to the world

Beyond what the most profitable partnerships are, another important finding in Figures 2 and 3 is the ability to quantify what are the benefits of these associations, in relation to the world (value 1) and in relation to normalized impact of all output leading and (values in brackets that appear next to each country abbreviation)

To look more closely at the autonomy and/or dependence of collaboration and hence the benefits that each country offers or receives from the collaborating associates, Figure 4 presents the foreign countries involved in collaboration and the index of benefit in normalized impact (BRCNI). Brazil, for instance, benefits greatly from collaboration with Switzerland, and to a lesser extent with China and India. It likewise obtains more impact when it leads research with the collaboration of Argentina and Australia. Mexico similarly derives benefits from working with China, Italy and Brazil. Argentina is a good associate for Mexico, Chile, and Colombia, who benefit as well from the impact of the output undersigned by this country. The autonomy of Argentina in obtaining greater citation when it leads research with Austria, China and Japan is also remarkable.

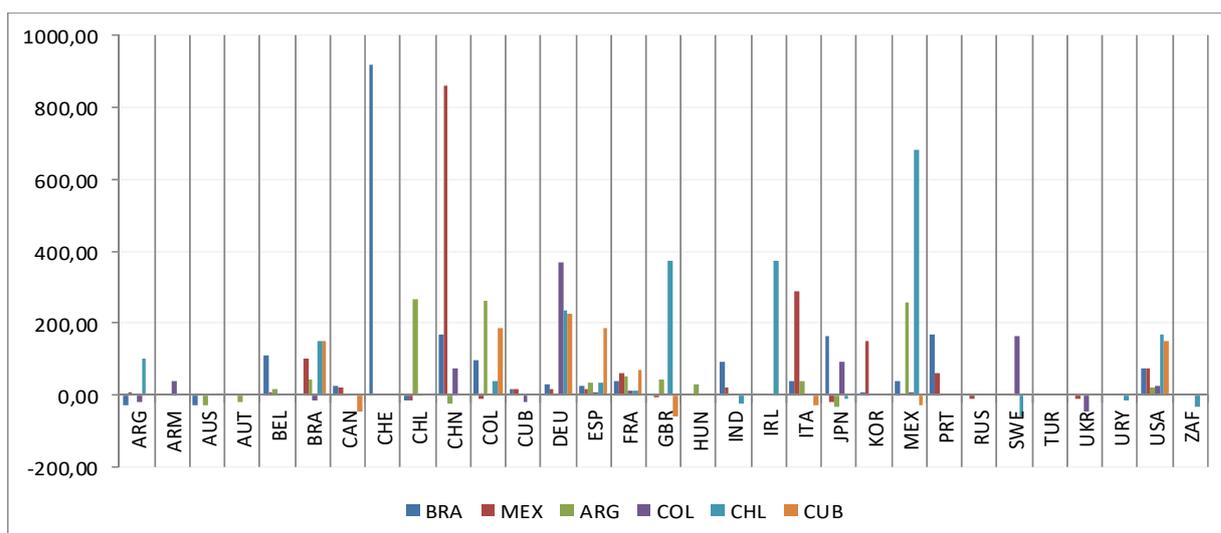


Figure 4. Benefit rate of collaboration in normalized citation (NI vs. NIL) of all scientific production

### Scientific international collaboration and cites per document by types of production

The heliocentric representations depict the international collaboration of Argentinean scientific output in the fields of N&N. Around the central node, at a greater or lesser distance, orbit those countries with which Argentina collaborates; their relationship is represented by a line whose distance is inversely proportional to visibility/impact in terms

the size is proportional to the percentage of collaboration with each country. The two concentric circles represent the average citation per document obtained by the total output (red) and leading output (blue) acting as a reference to know with what countries is reached the better performance. The situation of the orbits differs from one map to the next depending of the type of production and cites per document received. Thus, one can quickly spot with which countries more is published (greater volume) and with which one is more visible (closer to the center) (Chinchilla-Rodríguez, et. al., 2008; 2010; 2012).

The maps lead us to a noteworthy finding: although international collaboration increases impact, it does so to widely differing degrees.

Figure 5 shows international collaboration in all outputs and how collaborative countries such as Nigeria, Israel, Costa Rica, and Oman have global impact values lower than those obtained through leading documents. However, if we look at the results according to the excellence output (Figure 6), we can see just what role each country plays and how the patterns of production differ in terms of impact (position of the orbits and number of countries). A combined reading of the data (Figures 5 and 6) shows Argentina to have relatively poor results in terms of visibility with Canada and South Korea (outside orbit blue)

When Argentina leads international collaboration India, Cuba, Mexico and Colombia are countries with which visibility is so scanty and even when the country reaches leading highly cited documents, countries as Switzerland and Chile not surpasses the average citation of the total output.

In the four representations those countries located into the red orbit are the more cited and put Argentinean research on the map of excellence achieving the highest visibility and international impact.



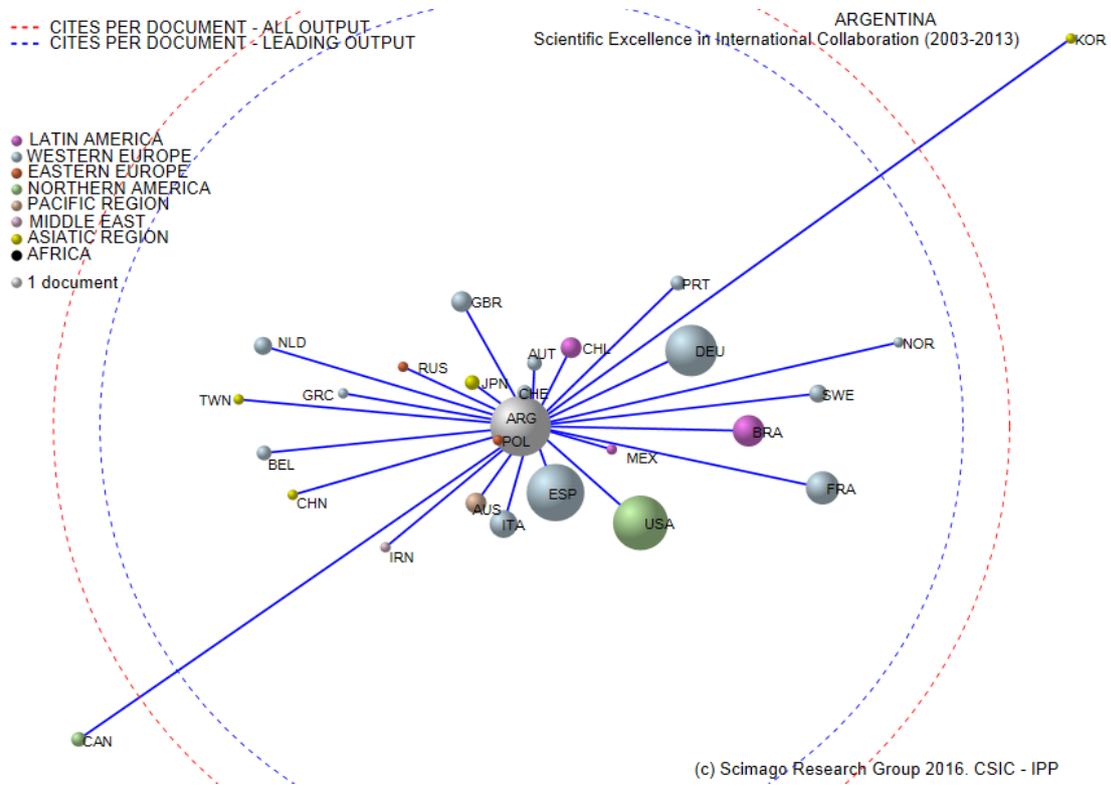


Figure 6. Heliocentric of international collaboration in excellence output

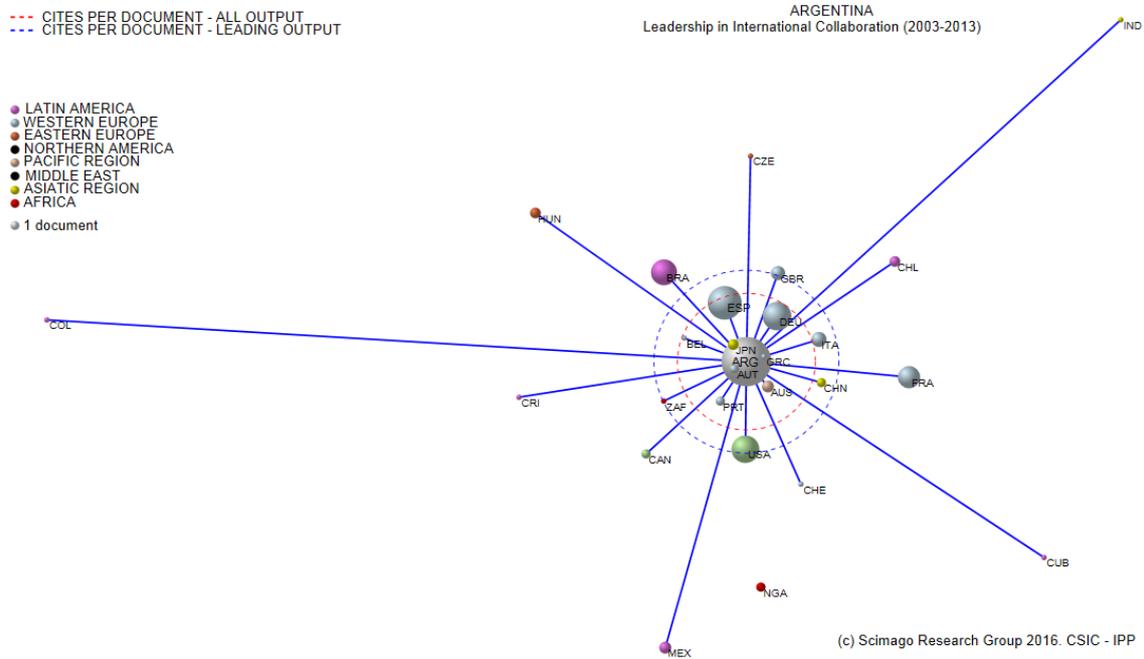


Figure 7. Heliocentric network of international collaboration in leading output

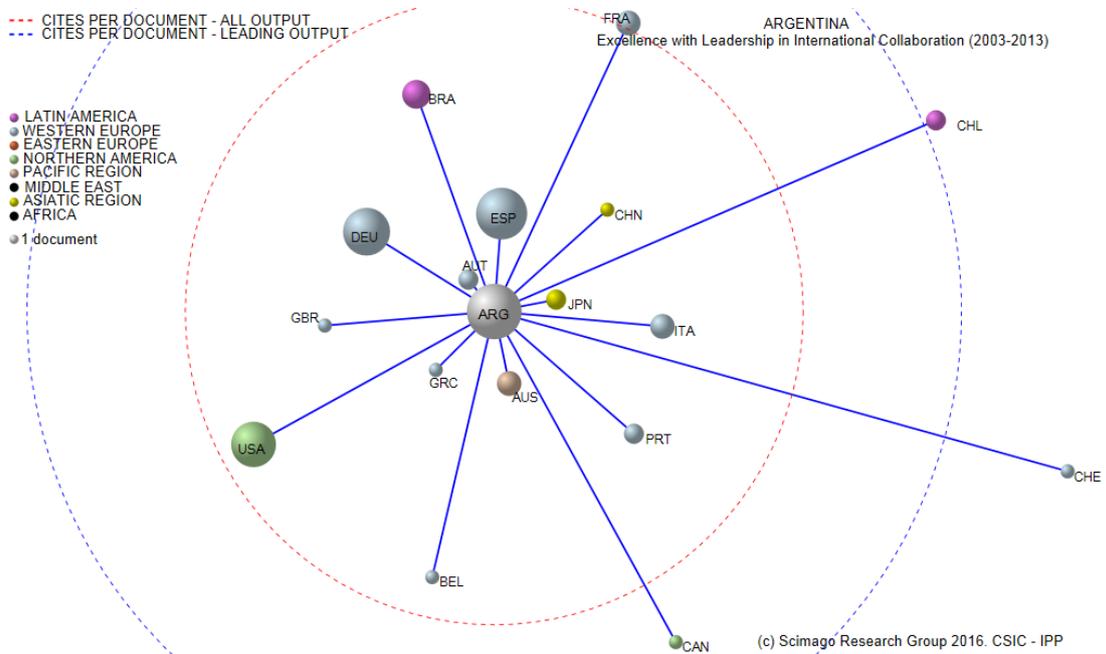


Figure 8. Heliocentric of international collaboration in excellence with leadership output

## **Conclusions**

Visual representations are created in order to analyze different aspects of scientific collaboration. The main objective is to identify the international facet of research by following the flow of knowledge as expressed by the number of scientific publications, and then establishes the main geographical axes of output, showing the interrelationships of the domain, the intensity of these relations, and how the different types of collaboration and production are reflected in terms of visibility. Thus, the methodology has a twofold application, allowing us to detect significant differences that help characterize patterns of behavior of a geographical system of output, along with the generation of representations that serve as interfaces for domain analysis and information retrieval

Against that backdrop and from a perspective aligned with scientific policy, analysis of collaboration is justified as a way to strike an approximate balance between what is expected and what is obtained, between the effects of programs and measures, and their implementation over time. Such an analysis furnishes useful information for decision makers with respect to areas such as avant-garde research, the formation of research teams, mobility program planning, and strategic alliances respecting future collaboration. It also contributes to avoiding the duplication of effort by maximizing both human and material resources, among many other advantages. At the same time, academically speaking, it compares cooperation trends (up, down, flat) in countries or areas of knowledge and identifies where partnering is more or less active and visible (Chinchilla et al, 2010).

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