Correlation between a country's centrality measures and the impact of research paper: The case of biotechnology research in Latin America

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Abstract

The aim of this paper is to unveil the latent structure of the Latin American regional biotechnology research collaboration network, as well as to determine whether the impact of a biotechnology paper is correlated to centrality measures (degree, betweenness and closeness) of Latin American countries within the structure of the regional collaboration network. To achieve these objectives, 14,173 Latin American biotechnology papers published between 1988 and 2012 were analyzed, using a combination of social network analysis and bibliometric techniques. Results of the study show the impact of a Latin American biotech-

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nology paper is positively correlated to its country´s betweenness, but not to its degree of centrality or closeness. These findings show the importance of developing collaboration networks to impel biotechnology research in Latin America.

Keywords: Centrality Degree; g-index; Research on Biotechnology; Scientific Impact.

Resumen

Correlación entre las medidas de centralidad de los países y el impacto de sus artículos. Caso de estudio de la investigación sobre biotecnología en Latinoamérica

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El objetivo del presente estudio es develar la estructura latente de la red latinoamericana de colaboración regional en la investigación sobre biotecnología y determinar si el impacto de los artículos latinoamericanos sobre biotecnología se relaciona con las medidas de centralidad (grado, intermediación y proximidad) de los países latinoamericanos en la estructura de la red de colaboración regional. Para lograrlo se examinaron 14 173 artículos, publicados entre 1988 y 2012, combinando técnicas del análisis de redes sociales con métodos bibliométricos. Los resultados obtenidos muestran que el impacto de los artículos latinoamericanos sobre biotecnología está correlacionado positivamente con la intermediación de los países, no así con el grado de centralidad o la proximidad. El hallazgo demuestra la importancia de fomentar las redes de colaboración internacional como una vía favorecedora para desarrollar la investigación sobre biotecnología en Latinoamérica.

Palabras clave: Investigación sobre Biotecnología; Grado de Centralidad; Índice Crown; Impacto Científico; Intermediación, Proximidad.

Introduction

World-wide scientific output in the field of biotechnology has grown significantly over the last 30 years. In 1990 we saw the publication of 5,427 papers in this field in journals listed in *ISI Web of Science*, but by 2010 this number had quadrupled to 23,292. The United States alone accounted for 5,417 of these papers in 2010, which is nearly equal to the output for the entire world in 1990.

Output in the field of biotech from the Latin American and Caribbean region also has grown in recent years. The output for 2010 was 1,157 papers, fully 12 times greater than the 93 published in 1990. Despite this impressive growth in the number of papers published in world-class biotech journals from Latin America, these still comprised only 4.96% of total output for that year. This result exhibits a gap between developing and developed countries with regard to this area of research. For example, South Korea, ranked ninth in world in scientific output in 2010, accounted for three papers more than the entire scientific output of Latin America in 2010.

Because of its substantial societal impact, the increase in the number of published papers and the growing interest of developing countries in biotech has attracted the attention of sciencometrics researchers. This is evident in the research in the field (Dalpé, 2002; Glänzel y Zhou, 2010; Huang *et al.,* 2013; McCain, 1995).

Impact studies of biotech papers are scarce. Previous research has been performed by Dalpé (2002), who analyzed papers and patents, demonstrating that there is no significant difference in the impact of published papers that cite patents and those that do not. Another study by Eslami, Ebadi and Schiffauerova (2013) analyzed the effects of collaboration networks in scientific output in Canada, finding that the structure of the co-authorship network of Canadian paper exerts effects on biotech scientific output. The structure of the network, however, does not exert a significant effect on the impact of the patents produced by the researchers. In Latin America researchers have studied scientific collaboration networks in the field of biotech in northern Brazil (Costa, Da Silva y Macedo, 2012), showing that the predominance of intra-institutional and intra-regional collaboration over international configurations in the field of biotech in northern Brazil.

The relationship between measures of centrality and the impact of papers has been studied in information science at the level of author (Abbasi, Chung and Hossain, 2012), institutions (Abassi, Altmann and Hossain, 2011), researchers within a single institution (Cimenler, Reeves y Skvoretz, 2014); and in the field of chemistry at the level of author in a single country

(Badar, Hite and Badir, 2012, 2014). No previous antecedents on the analysis of the influence of centrality on the impact of papers published in the area of biotech at the level of countries in a region have been found. In previous studies, Cimenler, Reeves and Skvoretz (2014) analyzed the relationship between the measures of centrality to impact using the Hirsch index (2005). Meanwhile, Abbasi, Chung and Hossain (2012; also see Abbasi, Hossain and Leydesdorff, 2012) measured this relationship using the g index (Egghe, 2006); and Badar, Hite and Badir (2012, 2014) measured the impact through standardized scientific output. No antecedents on the analysis of the relationship of measures of centrality to the impact using the Crown index (which will be used in this study) were found.

Thus, the result of this research will contribute information for the design of a publication strategy in research centers and the scientific research funding agencies in the region of Latin American and the Caribbean.

Study objective and research question

The objective of this research is to determine whether the degree of centrality of Latin American countries in the collaboration network predicts the impact of its biotech papers. This objective can be specified on the basis of the following research questions:

1. What is the latent structure of the collaboration network and centrality of countries in Latin American biotech research?
2. As gauged by the Crown index, what is the impact attained by Latin American biotech papers for each of the countries in the network?
3. As gauged by the Crown index, is there a relationship between the measures of centrality, degree, intermediation and closeness of Latin American countries in the regional academic collaboration network and the impact of their papers on biotech?

In order to answer these questions, we have applied sciencometrics methods combined with social network analysis. This approach allows both quantitative analysis of biotech science output in Latin America and qualitative analysis, exhibited in the network the most central countries in scientific collaboration with regard to papers in the field of biotech published in journals from 1988 and 2012 and listed in the *ISI Web of Science*.

Theoretical framework and antecedents

Relación entre las medidas de centralidad y el impacto de las publicaciones

Frenken, Hoolzl and De Vor (2005) have stated that collaboration networks are effective for production and dissemination of new knowledge, and how both of these factors increase the impact of journals.

Table 1 shows previous studies that have analyzed the relationship of measures of centrality and the impact of research. As can be seen, all of these studies analyze the three most important measures of centrality: degree, betweenness and closeness. The differences, however, lie in the areas of study and the indicator used to measure impact. Thus, Abasi, Chung and Hossain (2012) and Abbasi, Altmann and Hossain (2011) gauge performance using the g index Egghe, 2006); Cimenler, Reeves and Skvoretz (2014) use the Hirsch index (2005), and Badar, Hite and Badir (2012, 2014) use the adjusted impact factor of scientific output of researchers in the field of chemistry in Pakistan.

Table 1. Previous studies on the relationship of centrality to the performance of published papers

Study	Centrality measure	Performance indicator	Area of study analyzed
Abbasi, Altmann and Hossain (2011)	Degree Betweenness Closeness Eigenvector	Index g	477 papers on IS from 5 universities
Abbasi, Chung and Hossain (2012)	Degree Ego Betweenness	Index g (Google Academic)	10 researchers in IS
Badar, Hite and Badir (2012)	Degree Proximidad Betweenness	Scientific output Impact Factor (*ISI Web of Science*)	1 699 papers by 2 027 researchers in the field of chemistry in Pakistan
Cimenler, Reeves and Skvoretz (2014)	Degree Betweenness Closeness Eigenvector	Index h	107 researchers in the University of South Florida
Badar, Hite y Badir (2014)	Degree Closeness Betweenness	Scientific output (ISI Web of Science)	1 699 papers by Pakistani authors
This study	Degree Proximidad Betweenness	Index Crown	14 173 papers on biotech from 21 Latin American countries

Relationship of degree of centrality to impact

Abbasi, Altmann and Hossain (2011) have reported a positive correlation between the degree of centrality of the authors of 477 papers on information science and their impact (g index) r= ,305, p< 0,001. Subsequently, Abbasi, Chung and Hossain (2012) analyzed the relationship of centrality of ten researchers in information science and their performance (g index), showing the existence of a positive correlation of r= ,327, p< 0,05 between degree and impact.

In like fashion, Badar, Hite and Badir (2012) analyzed the relationship between centrality and performance of 2,027 Pakistani researchers in the field of chemistry, showing that centrality determined the performance of 56% of researchers with R^2= ,568, p < 0,01. Thereafter, Badar, Hite and Badir (2014) complete their previous study and reported that the degree of centrality of 2,027 Pakistani chemistry researchers influences their performance (= 1.056, p< 0,01). .

Additionally, Cimenler, Reeves and Skvoretz (2014) studied the relationship between the degree of centrality to performance gauged by the Hirsh index of 107 researchers of the University of South Florida, concluding that degree of centrality exerts a positive influence on their performance, while reporting a positive relationship between the degree of centrality to researcher performance of r= ,422, p> 0,01.

According to previous results, the degree of centrality is associated positively with performance of researchers and institutions. Our research expects to find that papers by biotech researchers exhibiting more links to other countries will have higher impact in the field. The number of relationships increases the absorption capacity of the country by promoting its intellectual capital, which would happen because of the increasing capacities to assimilate new knowledge, techniques, technologies and scarce resources, while they learn from the experiences of other researchers with greater scientific development in the field of biotechnology. Thus, an initial hypothesis proposes that there is a positive correlation between the degree of centrality of the Latin American country within the regional collaboration network and the impact of its papers on biotech topics.

Relationship of betweenness to impact

Abbasi, Altmann and Hossain (2011) have reported a positive correlation between betweenness of authors in the collaboration network and their impact (index g) of r= ,529, p< 0,001. In a later study, Abbasi, Chung y Hos-

sain (2012) demonstrated the existence of a positive correlation of r= ,771, p< 0,05 between betweenness of ten information science researchers and their impact.

A study by Badar, Hite and Badir (2012) reports that the betweenness of 2.127 Pakistani chemistry researchers predicts performance of R^2= ,139, p< 0,01. Sin Badar, Hite and Badir (2014) reported, however, that the proximity of 2027 researchers in the network does not exert any such influence on performance in the same sample (β= 0,014, p> 0,01). Meanwhile, Cimenler, Reeves and Skvoretz (2014) found influence of betweenness on the impact (h index) of 107 authors in the collaboration network of the University of South Florida, though this influence was only significant in cases of co-authorships.

This paper expects to find that when the betweenness of countries in the regional collaboration network increases, impact will also increase. As such, the second hypothesis may be stated as follows: There is a positive correlation between the betweenness of the Latin American country in the regional collaboration network and the impact of the biotech literature they produce.

Relationship of proximity to impact

Abbasi, Altmann and Hossain (2011) have reported the existence of a positive correlation between the proximity of authors in the collaboration network and their impact (g index), with r= ,055, p< 0,05. Badar, Hite and Badir (2014) reported that the non-existence of the influence of betweenness of 2,027 Pakistani chemistry researchers in the co-authorship network does not influence their performance (β= 0,046, p> 0,01). In this light, we posit our third hypothesis as follows: There is a positive correlation between closeness of the Latin American country in the regional collaboration network and the impact of the biotech literature they produce.

Dependent variable: the impact of Latin American papers on biotechnology

When employed for the purpose of justifying funding and securing accreditations, the use scientific research output figures and the number of citations received to gauge scientific performance of researchers, research centers and universities is an area of increasing interest of researchers. Currently, the academy is well aware that their careers, salaries and promotions depend on the impact of their research among their academic peers (Cordero-Villafáfila and Ramos-Brieva, 2014; Finkel, 2014). In science in general, the influence of an author within the community is gauged by looking at the frequency with which his or her publications are cited by peers. Thus, the number of

citations an author receives serves as the gauge for measuring performance and assigning one's position on the pay scale. For example, in management it has been found that there is a positive correlation between the number of citations received by a researcher and the salary that researchers earns (Gómez-Mejía and Balkin, 1992).

The relationship between collaboration and impact of journals has been analyzed by several authors (Gazni y Thelwall, 2014; Glänzel, 2002; Li, Liao and Yen, 2013; Yu *et al*., 2014). Since the foundation of the *Science Citation Index,* there has been broad consensus in the international scientific community regarding the importance of measuring the impact of scientific literature. This impact measure is performed largely by adding up the citations received by papers published by an author. In her paper "Self-Citations in Scientific Literature," Renata Tagliacozzo (1977) called attention to the padding impact caused by authors citing themselves. Thus, in recent years the method of counting citations to measure performance has come under further scrutiny, with most of these criticism centering on distortions caused by the practice of self-citation (Chang, McAleer and Oxley, 2013; Diekhoff, Schlattmann and Dewey, 2013; Ferrara and Romero, 2013). This situation has brought about not only serious questioning of the reliability of the citation count approach to gauging performance, but it also has raised doubts about the genuine influence within the scientific community of authors who indulge heavily in self-citation.

Several indexes have been developed that attempt to improve the reliability of impact and performance measures. The most popular of these was created by Jorge Hirsch (2005). This method was elaborated further in the e index developed by Zhang (2009), and discounted h index created by Ferrara and Romero (2013) and the g index of Egghe (2006), the latter of which has become widely accepted in the academic community because it overcomes the limitation of the h index by not rewarding papers with high numbers of citations. Nonetheless, the g index has issues with the reliability of the country impact measurement, because it tends to favor countries with greater scientific production. Thus, a large Latin American country such as Brazil benefits from having much greater scientific output than that seen in other countries of the region.

To overcome these limitations, we have opted to use the Crown index (Waltman *et al*., 2011a, 2011b) to measure the impact of biotech research produced by Latin American countries. The Crown index overcomes the limitation of the Hirsch index and its variants, and those of the g index, which tends to favor countries with higher rates of scientific output.

To generate the Crown index, one takes into account not only citations received by countries, but also the relevance of the journals from whence

these come. The composition of the subset of journals is weighted against the mean, which is this study is against the mean for biotech. Thereafter, the impact is normalized so that the countries with impacts normalized to the world average will have a value of 1. The papers from said country have been published in journals that stand at the mean of impact in their category. Thus, a normalized impact above 1 indicates a means impact above the category of the journal, while normalized impacts below 1 indicates a mean impact below the category of the journal. The procedure for calculating the Crown index is explained in Waltman *et al*., 2011a, 2011b, and Moed, 2010.

Independent variables

The degree of centrality of Latin American countries in the collaboration network

The analysis of social networks has awakened considerable interest in recent years and plays a key role in many disciplines (Liu *et al*., 2005). The analysis of social networks is a powerful strategy for information sciences (Abbasi, Hossain and Leydesdorff, 2012). Otte and Rousseau (2002) define analysis of social networks as a broad strategy for researching social structures. The increased complexity of problems and sustained growth dynamics of knowledge have driven increased interest in the structure and sociology of scientific collaboration (Racherla y Hu, 2010).

The basic principle of analysis of social networks is the quantification of relationships established by the participating members of the group. These relationships constitute a structure. In the analysis of scientific journals, networks can be analyzed by analyzing co-authorships of the papers. Thus, when authors from two distinct countries join forces to write a paper, they create a link between their countries. The greater the number of links received by a country, the greater will be its centrality in the network structure.

The measure of centrality is a subset of algorithms that are calculated in the network and which allow one to determine both the structure and the position of each vertex (understood as the country) within the structure (De Nooy, Mrvar and Batagelj, 2008). The measure of centrality arises from the work of Bavelas (1948; 1950), and currently there are several measures for analyzing the influence of an actor within the network structure. Those most often employed are degree, betweenness (Freeman, 1977), closeness and the information (Stephenson and Zelen, 1989). The present study uses the degree of centrality and betweenness of each Latin American country in the biotech research collaboration network.

The degree of centrality brings together the measure of total centrality of a Latin American country in the biotech research network on the basis of the links that it establishes with other countries participating through co-authorship of papers. This process serves to identify those countries that stand at a central position in the collaboration structure, while determining those that are more related to the rest of the network structure. To calculate the degree, the following formula is employed:

$$C'_D(n_i) = cd(n_i)/g\text{-}1$$

Where $C'_D(n_i)$ is the degree of centrality of the country n_i, $cd(n_i)$ is the number of Latin American countries contributing papers to the biotech field in accord with the ISI data base, and g-1 is the total number of countries in the network excluding the country under examination.

Betweenness of Latin American countries in the collaboration network

Betweenness is a measure of centrality based on the nearest distance between the diverse countries participating in the collaboration structure. Thus, the most central country in terms of betweenness is that which is situated on the shortest link between the other countries in the network. That is, it becomes the communication hub for many other countries. To calculate betweenness the following formula is used:

$$C'_D(n_i) = \frac{C_B(n_i)}{[(g-1)(g-2)/2)]}$$

where $C_B(n_i)$ is the sum of probabilities of a country (n_i) appearing as a bridge along the nearest route between other countries and $[(g-1)(g-2)/2)]$ is the total number of shortest routes between the other countries in the network other than the country (n_i).

The proximity of Latin American countries in the collaboration network

The centrality measure of closeness was proposed by Freeman (1979) in order to measure centrality of several nodes in a network. Thus, a node is central when it is nearest to the other nodes in the network. To calculate the proximity of the counties in this study, we have employed the formula developed by Abbasi, Altmann and Hossain (2011).

To calculate the three measures of centrality of the Latin American countries in the biotech collaboration network, a 1-mode matrix was constructed and the Pajek informatics program was used (Batagelj and Mvar, 1998).

Data and information sources

This study employs social network analysis techniques to reveal and graphically represent the latent structure of the Latin American international research collaboration network in biotechnology. The procedure employed consists of the following three steps:

1. A search of the *ISI Web of Science* data base was performed according to the following strategy: advanced search CU = (country) and category of the *Web of Science* (WC) = *Biotechnology & Applied Microbiology.* Time frame: from January 1, 1988 to December 31, 2012; Language: all, Citation data base: *Science Citation Index Expanded;* Type of document: scholarly paper. To quantify the relationships between Latin American countries in biotech journals, the results by country and territory were ranked with a minimum value of 1.
2. A 1-mode matrix was created (*n x n*) placing the 21 Latin American countries having contributed at least one biotech paper within the time frame as the unit of analysis (rows), and the Latin American countries with which they collaborated in publications as the variables (columns). During the data encoding, we came across two situations: 1) the author signs in representation of a country (in which case one point was assigned for each country represented by each signing author), and 2) 4.07% of papers had authors signing in representation of more than one country. The encoding of these instances entailed adjusting the number of appearances as per the procedure described by Heck and Cooley (1988), Morrison and Inkpen (1991), and Shane (1997). This procedure assigns one half of a point to each country when an author signs for two countries, and one third of a point when the authors signs for three, and so on. .
3. The Latin American biotech research collaboration network was graphically represented using Pajek software and the Kamada-Kawai (1989) spatial distribution technique. Once the latent structure of the collaboration network was determined, the degree of centrality of each country in the network structure was calculated using the partition command provided in the Pajek software.

Analysis and discussion

Table 2 shows the bibliometric data on the study variables. As can be seen, four countries account for 87.29 % of the biotech scientific output between 1988 and 2012. These countries are Argentina, Brazil Chile and Mexico. The papers on biotech from these countries have the weightiest impact in the period under study. This result shows the advantage in terms of impact held by countries with the greater economic and scientific development, in that these are the countries that produce the most papers.

When the impact is normalized using the crown indicator, only two small countries, Bolivia and Costa Rica, exhibit impacts above the world average. This result shows the advantage of using the crown indicator to compare the impacts of counties without allowing the county size to skew the results.

Table 2. Descriptors of biotech research in Latin American countries

Country	Scientific output	Number of citations	Degree	Betweenness	Closeness	Crown index
Argentina	2 262	30 322	0,60	0,087	0,536	0,75
Bolivia	48	715	0,30	0,015	0,409	1,05
Brasil	6 203	82 508	0,65	0,082	0,576	0,54
Colombia	332	4 779	0,50	0,016	0,501	0,5
Chile	994	14 816	0,55	0,035	0,518	0,84
Costa Rica	84	1 799	0,55	0,062	0,501	1,71
Cuba	659	8 490	0,60	0,082	0,501	0,28
Ecuador	24	533	0,20	0	0,345	0,49
Guadalupe	28	495	0,10	0,027	0,324	0,59
Guatemala	20	204	0,15	0	0,361	0
México	2 913	41 949	0,55	0,097	0,518	0,73
Nicaragua	12	376	0,10	0	0,324	0,42
Panamá	23	694	0,25	0,01	0,388	0,41
Paraguay	5	85	0,05	0	0,33	0,06
Perú	102	1 578	0,40	0,001	0,444	0,78
Trin Tobago	45	744	0,15	0,001	0,311	0,49

Uruguay	192	3 552	0,05	0,001	0,33	0,68
Venezuela	198	2 875	0,35	0,022	0,444	0,62
Haití	1	4	0,05	0	0	0,81
Honduras	11	137	0,05	0	0,317	0,16
Barbados	9	55	0,05	0	0	0,47

Figure 1 shows the structure of the Latin American biotech research collaboration network. The countries with highest centrality are Brazil, Cuba, Argentina, Chile, Costa Rica and Mexico. The ones with the lowest centrality in the network are Barbados, Haiti and Honduras, all of which depend on collaboration to be linked to the network.

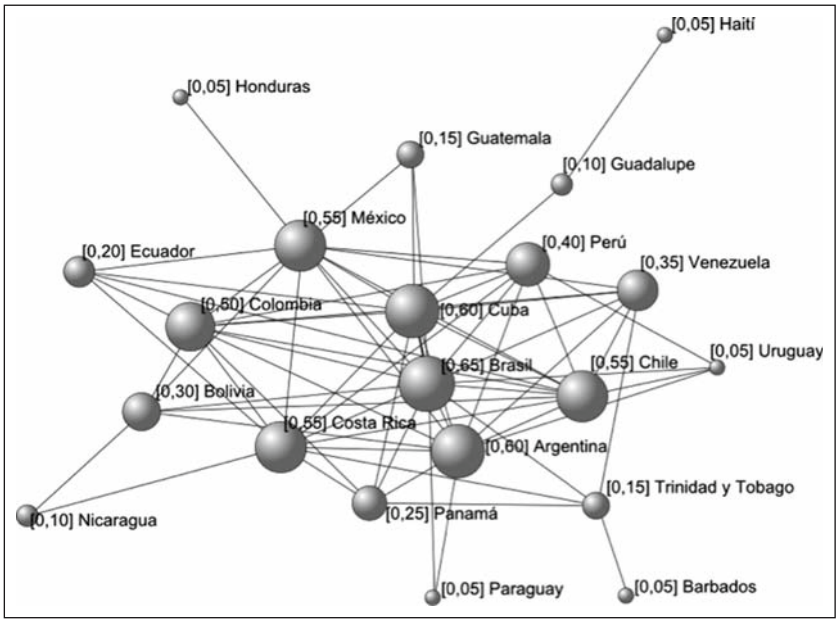

Figure 1. Latin American biotech research collaboration network
Note: Centrality values appear in brackets

1,710 and a mean of ,589. The result of the Shapiro Wilki test (*W-Statistic* = 0,915, p = 0,029) shows that this variable is not normally distributed. *Table 3* shows the mean values and the standard deviation.

Since the four variable in the study do not exhibit normal distribution, a Spearman Rho test was run in order to determine if the variable impact is related to the means of centrality of degree, betweenness and closeness.

Table 3 show the results. As can be seen, the impact variables and the degree of centrality are not correlated (0,369, $p< 0,099$): as such, the first hypothesis is not validated. The result is the opposite of those reported by Abbasi, Chung and Hossain (2012), and Abbasi, Altmann and Hossain (2011), who measured impact with the g index, and of Cimenler, Reeves and Skvoretz (2014), who measured impact with the h index, and of Badar, Hite and Badir (2012, 2014), who used scientific output. The results obtained suggest the influence of the size of the country on impact, when this is measured using the Hirsch, g or discounted Hirsch approaches. Likewise, the result shows the neutralizing effect of the crown indicator of the disadvantage of these indices, which tend to favor large institutions or countries.

Table 3. Inter-correlations, means and standard deviation of impact and measures of centrality (*N*= 14,173).

	Degree	Betweenness	Proximity	Mean	Standard deviation
Impact	,369	,473*	,364	0,590	0,366
Degree		,847**	,934**	0,298	0,223
Betweenness			,819**	0,026	0,034
Closeness				0,380	0,152

**p< 0,05, **p< 0,001.*

A positive correlation was found between betweenness (0,473, $p< 0,05$) of the countries in the regional collaboration structure. This value is interpreted as the median effect in accord with the base values of Cohen (1988). This result validates the second hypothesis. The finding is contrary to that reported by Badar, Hite and Badir (2014) for the area of chemistry in Pakistan, where the researchers found the no correlation between betweenness and impact gauged as normalized scientific production. Thus, in this paper we corroborate the findings of Abbasi, Chung and Hossain (2012) for the g index, although our correlation is lower than that reported by them. Just as in the first hypothesis, the ratio could be lower because of the crown indicator neutralizes country size. This finding also corroborates the results found by Cimenler, Reeves and Skvoretz (2014)..

No relationship was found between impact and closeness of the countries (0,364, *p< 0,105*): as such the third hypothesis is not validated. This result is similar to that reported by Badar, Hite and Badir (2014) and contrary to that of Abbasi, Altmann and Hossain (2011).

Conclusions

The results reported herein show the growing interest of Latin American countries in the field of biotech research in recent years. This facet is evidenced in the 12-fold growth of research from 1990 to 2010. Brazil, Argentina, Mexico and Chile are the countries with the highest levels of scientific output in this research field.

Academic collaboration with developed countries, such as the United States of America, Japan, Germany, England, Spain and France (all of which stand near the center of the biotech research network) has played a key role in this very significant growth in biotech research. These elements constitute evidence of the need to orient regional scientific policy toward promoting links with the major research centers, as part of an overall strategy to increase the impact of regional research in the broader field of biotechnology.

When the centrality values of each Latin American country in the regional collaboration structure are examined, we find Cuba and Mexico trailing only Brazil. This result shows that there is a positive correlation between impact and betweenness of countries in the structure of the regional collaboration network, but this is not the case for measures the degree and closeness measures of centrality.

This result shows that within a scientific network the role of producers of quality, high-impact research is as important as serving as a mediator or hub that facilitates collaboration between other countries in the regional network. In this way researchers in countries that serve this communicating function increase their capacity to attract and vie for resources, bring in new technologies and generally enhance laboratory facilities.

These elements contribute to enhancing the reputations of researchers within the network, thereby favoring the establishment of more collaborative links with researchers and institutions of increasing importance, while also opening the doors for their respective countries to participate in important and ever more complex biotech research projects.

Finally, it has been shown that the crown indicator is an effective way to compare the impact of countries, in that it reduces the effect of size differentials of the countries being compared. This conclusion is based on the finding herein that two of the smallest Latin American countries exhibit impacts above the world biotech research impact mean.

The research reported herein can be complemented by an analysis of the Latin American research collaboration network against countries that lie outside of the region, and by the study of the world-wide collaboration network in order to compare and contrast findings.

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