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The long-term dynamics of co-authorship scientific networks: Iberoamerican countries (1973–2010)☆

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ABSTRACT

We analyse the national production of academic knowledge in all Iberoamerican and Caribbean countries between 1973 and 2010. We show that the total number of citable scientific publications listed in the Science Citation Index (SCI), the Social Science Citation Index (SSCI) and Arts and Humanities Citation Index (A&HCI) follow an exponential growth, the same as their national productivity (number of publications per capita). During the last 38 years, Portugal shows the highest growth rate in both indicators. We explore the temporal evolution of the co-authorship patterns within a sample of 12 Iberoamerican countries (responsible for 98% of the total regional publications between 1973 and 2010) with a group of 46 other different nations. We show that the scientific co-authorship among countries follows a power-law and behaves as a self-organizing scale-free network, where each country appears as a node and each co-publication as a link. We develop a mathematical model to study the temporal evolution of co-authorship networks, based on a preferential attachment strategy and we show that the number of co-publications among countries grows quadraticly against time. We empirically determine the quadratic growth constants for 352 different co-authorship networks within the period 1973–2006. We corroborate that the connectivity of Iberoamerican countries with larger scientific networks (hubs) is growing faster than that of other less connected countries. We determine the dates, t_0, at which the co-authorship connectivities trigger the self-organizing scale-free network for each of the 352 cases. We find that the latter follows a normal distribution around year 1981.4 ± 2.2 and we connect this effect with a brain-drain process generated during the previous decade. We show how the number of co-publications $P_k^i(t)$ between country k and country i, against the coupling growth-coefficients a_k^i, follows a power-law mathematical relation. We develop a methodology to use the empirically determined growth constants for each co-authorship network to predict changes in the relative intensity of cooperation among countries and we test its predictions for the period 2007–2010. We finally discuss the implications of our findings on the science and technology policies.

1. Introduction

The application of bibliometric indicators to estimate the characteristics of international scientific cooperation patterns have been explored by diverse authors (i.e. Davison Frame et al., 1977; Beaver and Rosen, 1978; Schubert and Braun, 1990; Katz and Martin, 1997; Beaver, 2001, 2004; Glänzel and Schubert, 2004; Holmgren and Schnitzer, 2004; Wagner and Leydesdorff, 2005b). Few studies employed them to analyse the cooperation profiles among Latin American countries (Fernández et al., 1998; Narvaes-Berthelemot, 1995; Russell, 1995; De Moya-Anegón and Herrero-Solana, 1999; Gómez et al., 1999; Lemarchand, 2007). Most of the previous works only considered the aggregated behaviour among short periods of time, no longer than a decade. By doing so, the information about the annual rate of change in cooperation networks is lost. Consequently, no conclusions can be made about the results obtained by the application of different science and technology (S&T) international cooperation policies or the absence of them. The last might eventually be empirically quantified by contrasting the evolution of international cooperative agreements among institutions and countries against several S&T output indicators (Lemarchand, 2005, 2010). Unfortunately, this work was not carried out yet due to the lack of information about which international treaties and agreements are in operation among different countries.

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Besides the existence of several formal international cooperation instruments, there is no doubt that the informal instruments, among individual scientists of different countries and disciplines, may explain the co-authorship of scientific articles published in mainstream journals.

In this work, we determine the long-term evolution of the cooperation networks among 12 Iberoamerican and Caribbean countries[2] and other 46 regional and extra-regional nations. The selected countries are responsible for the 98% of the total citable scientific publications written by scientists of this region that were listed at the Science Citation Index Extended (SCI), Social Science Citation Index (SSCI) and Arts and Humanities Citation Index (A&HCI), between 1973 and 2010 (38 years)[3]. We study the bilateral co-authorship of citable articles between each of the 12 countries with the 22 most productive Iberoamerican and Caribbean countries; 19 OECD countries not included in the first group and with China, India, Israel and USSR/Russia (see Table 2).

The analysis of the aggregated temporal evolution of SCI, SSCI and A&HCI shows a homogeneous trend that is independent of any academic discipline and also avoids any substantial change in the national trends, due to the continuous incorporation of new journals to the databases. In this way, we focus our study on a cooperation network analysis within regional and extra-regional countries. Obviously, the publication in main-stream journals (listed by SCI, SSCI and A&HCI) represents only a fraction of all the cooperative research and development (R&D) activities that is taking place within the countries of our sample. The main advantage of using these databases is that they were systematically collected and organized over several decades with similar methodologies, allowing us to perform a long-term analysis with relative good confidence.

In Section 2 we analyse the long-term evolution in the production of citable scientific publications for all the countries of the region between 1973 and 2010, as well as their growth rates, productivities and regional distributions. In Section 3 we describe the methodology used to analyse the co-authorship patterns among a sample of 12 Iberoamerican countries and other 46 different nations between 1973 and 2010, and we present the main results. We study the co-authorship patterns in terms of intra and extra regional cooperation. We show that the intra-regional cooperation has been increasing smoothly during the last decades.

In Section 4 we develop a simple mathematical model of social networks applied to the study of the temporal evolution of co-authorship among countries. The model predicts a quadratic growth of co-publications (links) against time, among different countries (nodes). We show that this type of networks behaves with a self-organizing dynamics and we derive the conditions from which this process is triggered. In Section 5 we empirically analyse 352 different scientific co-authorship networks between 1973 and 2006 and we estimate the values of their growth constants, the dates at which the self-organizing dynamics starts and the correlation coefficients between the mathematical model and the real data. We determine the number of co-publications against the values of different growth coupling constants scales with a power-law.

In Section 6, we use our mathematical model and the empirically determined growth constants, to deduce a methodology to predict the near-future behaviour of the co-authorship patterns among the 352 collaborating networks. We contrast their projections with empirical data between 2007 and 2010, showing their usefulness to foresight studies. Finally, in Section 7, we present a summary with the main results of this research and their implications on the regional science and technology policies.

2. Iberoamerican mainstream knowledge production (1973–2010): The database

Within the most scientific productive 147 countries in all fields[4], covering a ten-year plus eight-month period (January 2000–August 31, 2010), the Iberoamerican countries included among the top twenty were Spain (rank 9) and Brazil (rank 15). Within the same period, our analysis shows that Mexico has the rank 28, Portugal the rank 34 and Argentina the rank 35. This is an interesting improvement[5] if we take into account that a similar survey made between 1967 and 1973 had Argentina (rank 27), Spain (rank 29), Brazil (rank 32), and Mexico (rank 34) as the most productive nations of the Iberoamerican and Caribbean region (De Solla Price, 1986: pp. 192–193).

In order to understand the process that took place between these two extremes, we analyse the temporal evolution in the production of mainstream scientific and academic knowledge in all fields. Our analyses cover the period from 1973 to 2010.

To study the distribution of published articles for each Iberoamerican and Caribbean country listed in SCI, SSCI and A&HC, we use Thomson-Reuters' Web-of-Science (WoS)[6] as our information source. We think that these databases constitute a good and qualified indicator to inquire about knowledge-production patterns within the region. The 1973–2006 data was downloaded on April 2007, while the 2007–2010 data was downloaded on April 2011. Due to some delays in the publication of several journals and delays in the WoS data-entry process, there is approximately 10–12% underestimation in the total number of published articles for the year 2010.

In this article we focus our study only in the production of citable scientific articles in all fields of knowledge. Over the years, several scholars debated about the underrepresentation of journals published in Developing Countries at SCI, SSCI and A&HCI (Gaillard, 1991; Gibbs, 1995) and in particular the Latin American and Caribbean ones (Burgos, 1995). Not all the scientists of the region under study submit their research results to mainstream journals (included at SCI, SSCI and A&HCI). Therefore, the existence of domestic journals in several countries may reflect some peculiar domestic circumstances or specific scientific national agendas that are not considered by the mainstream journals. On the other hand, some studies show that Latin American scientific journals do not have the minimum level of bibliographic control necessary to be uniquely identified, read and subscribed to, by an international audience (Cano, 1995). In this context, it is considered that periodical publications from such an infrastructure are condemned to a ghost-like existence, whereas the academics that publish in them will have their research results unrecognized. For these reasons,

[2] The countries included here within the Iberoamerican and Caribbean region are: Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Plurinational State of Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Panama, Paraguay, Peru, Portugal, Spain, St. Kitts and Nevis, St. Lucia, St. Thomas, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos, Uruguay and Bolivarian Rep. of Venezuela. All the previous countries were taken into account to estimate the total number of regional publications per year (1973–2010). Here we have excluded Puerto Rico, because it is an associate State to the USA. Most of the small Caribbean islands have practically no mainstream scientific publications at all during this period.

[3] We tried to extend the search back to 1966, but according to the information provided by the technical support of Thomson-Reuters (MD-165137) on February 2007, the complete entries for authors, addresses and countries at the WoS, were only available for the SSCI since 1966, for SCI Expanded since 1973 and for A&HCI since 1975.

[4] http://sciencewatch.com/dr/cou/2010/10decALL/

[5] Within this period, Argentina showed the opposite behaviour by having a drop from rank 27 to rank 35.

[6] http://scientific.thomson.com/products/wos/