APPLYING NETWORK ANALYSIS TO STUDY THE SCIENTIFIC COLLABORATION BETWEEN CHINA AND SPAIN DURING THE PERIOD 2000-2009

Julia HABA (*), Julia OSCA-LLUCH(**), Rodrigo MARTÍNEZ NOVO (*)
juhaos@alumni.uv.es, m.julia.osca@uv.es, romarno@alumni.uv.es
(*) Departamento de Sociología y Antropología Social, Universidad de Valencia, Facultad de Ciencias Sociales, Edificio Departamental Oriental, Avda. Tarongers s/n, 46022 Valencia (España)
(**) Instituto de Historia de la Medicina y de la Ciencia López Piñero (UV-CSIC) Palau de Cerveró, Plaza Cisneros, 4, 46003 Valencia (España)

Mots clés:
Collaboracion scientifique, Biblométrie, Analyse de réseau, Chine, Espagne
Key words:
Scientific collaboration, Bibliometrics, Network analysis, China, Spain
Palabras clave:
Colaboración científica, Bibliometría, Análisis de redes, China, España

Résumé

Ce papier étudie le travail de recherche accompli en coopération entre la Chine et l'Espagne couverte par trois bases de données sur le Web de plate-forme de Connaissance (AHCI, SCI et SSCI) sur la période 2000-2009. Une augmentation distinctive dans la collaboration de ces deux pays a été identifiée pour cette période. Les résultats montrent l'évolution au cours du temps, les langues utilisées dans la publication des papiers, la participation des deux pays dans la production des projets et des journaux les plus utilisés ensemble avec leurs domaines thématiques. La physique était le domaine avec le plus grand nombre de papiers, l'Astronomie étant en dehors de ce champ, peut-être en raison des très hauts coûts d'équipement. La publication de la majorité de papiers scientifiques était le résultat d'efforts faits par une ou plusieurs équipes d'au moins deux pays, mais il était surprenant de constater que dans les domaines scientifiques comme les Sciences humaines, la collaboration scientifique était moins fréquente et qu'elle n'a même pas existé dans les Humanités.

Abstract

This paper studies the research work conducted in cooperation between China and Spain covered by three databases on the Web of Knowledge platform (AHCI, SCI and SSCI) in the period 2000-2009. A distinctive increase in these two countries' collaboration was identified for this period. The results show the evolution over time, the languages used in the publication of the papers, the participation of both countries in the production of the projects, and the most commonly used journals together with their thematic areas. Physics was the area with the highest number of papers, Astronomy standing out from this field possibly due to the very high equipment costs. The publication of the majority of scientific papers was the result of efforts made by one or several teams from two or more countries but it was surprising to find that in scientific areas like Social Sciences, scientific collaboration was less frequent and that it did not even exist in Humanities.

1 Introduction

International collaboration is an important element in today's scientific research. More and more, researchers need to publish their papers in journals with a high international circulation if they want their activity to be acknowledged. For this reason, international collaboration offers an opportunity for scientists in certain areas to ensure a greater presence.

Although the research conducted by individual scientists is still predominant in some areas of science such as humanities, in general terms the number of co-authorship articles and the number of authors per paper seem to have grown considerably over the past four decades, partly due to the raising complexity of science, the significant increase in interdisciplinary studies, and quick and effective communication between scientists. In recent decades, scientific cooperation has risen as a result of the growing number of issues requesting and inter and multidisciplinary approach (Russell et al., 2009). Cooperation between scientists is justified by the need for specialists in different techniques, the use of expensive equipment –shared by several institutions–, interdisciplinary investigation or other research activities within the framework of international programmes (Galbán and Gómez, 1992). Research groups have become the minimum unit of the scientific system in many of its areas. In most disciplines, collaboration between researchers is undergoing continuous growth due, among other, to the greater complexity of research projects, which calls for the cooperation of a higher number of scientists from different specialities. Today, researchers rely on each other to create new knowledge, and research groups seek to forge working networks in their area with a view to being more visible and acknowledged within their scientific community. Making multidisciplinary teams or sharing material resources of a high cost are some of the advantages of collaboration but sometimes the number of authors is not in line with the nature and complexity of the investigation.

Some factors can have an influence on research productivity in any country. The most obvious and possibly most important ones are the country's economic level, wealth, and population size. But the importance of the country's scientific research tradition cannot be underestimated as a factor favouring productiveness. This can clearly be seen in the considerable production of small countries with well developed research projects, e.g. The Netherlands,

Sweden, Belgium or Switzerland. Countries with long-standing research experience have adequate infrastructures, a critical mass of researchers and a clear idea about the importance of new discoveries (Demaria, 2009).

A significant factor that determines research publication in a country is the role played by productiveness in a person's professional promotion and progress. In many countries, like Spain, the main criterion used in the evaluation of people's performance is the number of publications, particularly in journals with a high impact factor. This seems to be an important reason that contributes to encouraging scientific collaboration. Since its introduction in the early 1970s the impact factor has been used as an indicator. Though criticised, it seems to be determining in scientific evaluation processes (Seglen, 1997; Bordons et al, 2002; Saha et al., 2003, Torres-Salinas et al., 2010).

On the other hand, the study of collaborative links between individuals may provide an insight into fundamental aspects in order to understand how research problems or lines are developed, especially if it is combined with other types of analyses like citation networks or shared vocabulary. The information that can be drawn from a statistical inquiry into co-authorships can be really valuable in identifying especially productive research groups or in finding and studying relationships between institutions.

In this respect, a striking aspect is the growing interest in studies about China's scientific production (Henk, 2002; Zhou and Leydesdorff, 2006). Different analyses have been completed about the internationalisation of its journals (Zhoy and Leydesdorff, 2007; He and Liu, 2009; Kao, 2009), its cooperation with different countries (He, 2009), and its production in certain scientific fields (Guan and He, 2005). The importance of China in the world's economy is enormous and growing. Numerous elements support the high rise in production and foreign trade, and the pronounced rates of productiveness, saving and investment of China's economy. Its opening is one of them; other factors of success are the growth of international trade, the introduction of new developments, and the growing circulation of international capital, from which China has benefitted to a great extent. All such elements have contributed to consolidating a sound macroeconomic framework and a strong financial system in which China is considered to be one of the emerging countries appealing to students not only from Spain but from all over the world. For this reason, it is a priority to forge and strengthen cultural links that can be used as a basis for subsequent exchanges in technology, science and trade.

The aim of this paper is to study scientific collaboration between Chinese and Spanish institutions in the period 2000-2009, in order to delve into group characteristics associated to scientific success. According to data provided by the Department for Education of Beijing, more than 5,000 people are estimated to have completed a degree in Spanish over the past 50 years. Many of them work in diplomacy, in Chinese ministries, as translators in media companies, as interpreters, teachers and researchers, and more recently in Chinese or international corporations. The number of Spanish language centres is significant and on the rise, but it is obviously very small if compared to other foreign languages. This is why since the opening of the Department for Education in 2005 and the inauguration of Beijing's Instituto Cervantes in 2006 and thanks to the ongoing presence of Spanish representations in Education Exhibitions in China, further growth in cultural and commercial links has been expected, especially on the basis of cultural and technological cooperation projects.

2 Material and methods

In this study, the authors decided to use as a unit of analysis the papers published in the scientific journals of the following databases: Arts and Humanities Index (AHCI), Science Citation Index (SCI) and Social Science Citation Index (SSCI), published by Thomson-Reuters; they were accessed on the ISI Web of Knowledge platform. These databases are used for this type of analysis at an international level, as they include all the authors of the papers as well as their institutional and geographic background. They are well-known and universally used in bibliometric studies and, for some sectors, these databases are thought to analyse scientific excellence journals only, which means that their papers are deemed to make up the mainstream of science.

The literature was searched using the field "place of work", making a search equation by combining the terms "Chine", "China" and "Spain". The investigation was limited to the papers published between 2000 and 2009, combining the search with the field "year of publication".

2.1 Participating institutions and paper adscription

The easiest way of quantifying science cooperation is by means of the publications resulting from research and signed by the teams of the participating countries. In this case, collaboration is deemed to be symmetric, the signing institutions taking part equally, which does not always reflect reality.

The study of the organisations or institutions that participated in a paper by means of their researchers was carried out based on the analysis of the information contained in the "place of work" field. In all cases, the references obtained were checked one by one with a view to standardising and correcting the name of the institutions.

As pointed out by Skea et al. [1991], the papers included in a database can be counted in different ways, and so a choice must be made from several options: dividing joint publications or assigning them to each participating institution; in this study, the authors chose the second option and, both in the selection of the papers and in subsequent counts by centre or institution, the total count criterion was applied, according to which each paper was fully assigned to all signing parties, even though this generated duplicates.

Scientific collaboration plays a relevant part in today's scientific research; it is measured by the co-authorship index and by the number of signing centres. The degree of institutional participation varies across disciplines; in some of them –like Medical Sciences– the publication of most scientific documents is the result of efforts made by one or several teams that may come from one or more countries, whereas in other scientific areas –like Social Sciences or Humanities– scientific co-authorship seems to be less frequent.Based on the papers by authors who work in Spanish and Chinese institutions published in journals included in the ISI databases during 2000-2009, research groups were identified by considering the frequency of co-authorship in the publications.

3 Results

3.1 Productivity

The total number of works jointly undertaken by China and Spain during the studied period came to 1,862. Figure 1 shows the time series with an increase in the number of collaborations, from 121 in 2000 to 319 in 2009, with a distinctive upward trend as from 2004.

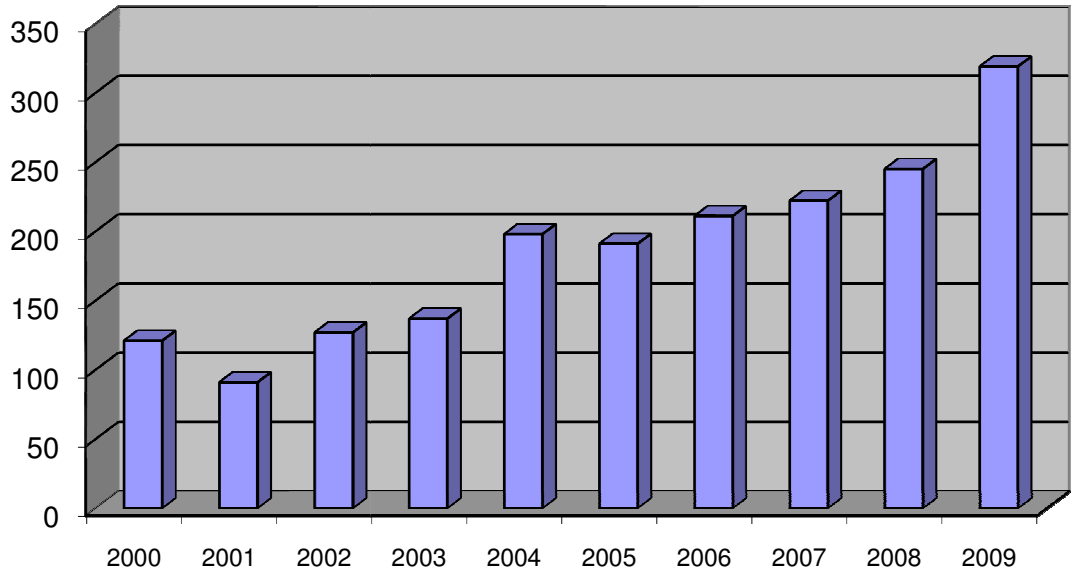

Figure 1: Evolution in time of cooperation between China and Spain

3.2 Publication language

English predominated almost exclusively from all the publishing languages (99.41% of papers), Chinese ranking second (0.48%) and French and German third, each accounting for 0.05% of the papers. Although these findings might be due to a bias in the databases used –they include very few non-English speaking journals–, it is striking to see that Spanish was not used by any publication in any of the papers, in spite of being the language of one of the countries studied. This could be possibly explained by the fact that English was the communication language used by the joint authors, instead of Chinese or Spanish.

3.3 Journals

In the study of the journals where the joint works completed by China and Spain were published, large dispersion was noticed. The 1,862 papers were published in 707 different journals. In 464 journals (24'92%), only one paper was published. Table 1 shows the list of the most commonly used 49 journals. During the studied period 5 or more papers were published in them, this accounting for 48.87% of the total production.

The first three positions on the table are held by three physics journals: *Physics Letters B*., from the Netherlands, with 150 papers, and *Physical Review D* and *Physical Review Letters*, from the US, with 128 and 107 papers respectively. The presence of a Chinese journal must be noted: *Acta Physica Sinica,* a physics journal, in which 5 papers were published.

Table 1: Most used journals

Journal Title	Items published	Country
Physics Letters B	150	Netherlands
Physical Review D	128	United States of America
Physical Review Letters	107	United States of America
European Physical Journal C	52	Germany
Astronomy & Astrophysics	49	France
Inorganic Chemistry	24	United States of America
Astrophysical Journal	23	United States of America
International Journal of Systematic And Evolutionary Microbiology	21	United Kingdom
Physical Review B	20	United States of America
Physical Review C	20	United States of America
Monthly Notices of The Royal Astronomical Society	19	United Kingdom
Applied Physics Letters	16	United States of America
Journal of Applied Physics	13	United States of America
Journal of Physical Chemistry B	13	United States of America
Chemical Communications	12	United Kingdom
Journal of Chemical Physics	11	United States of America

Journal of Mathematical Analysis And Applications	11	United States of America
Nature	10	United Kingdom
Nonlinear Analysis-Theory Methods & Applications	10	United Kingdom
Nuclear Instruments & Methods In Physics Research Section A-Accelerators Spectrometers Detectors And Associated Equipment	10	Netherlands
Physical Review A	10	United States of America
Chaos Solitons & Fractals	9	United Kingdom
Journal of Magnetism And Magnetic Materials	9	Netherlands
Journal of Physics-Condensed Matter	9	United Kingdom
Physics Letters A	9	Netherlands
Dalton Transactions	8	United Kingdom
European Journal of Inorganic Chemistry	8	Germany
Journal of Biological Chemistry	8	United States of America
Journal of Differential Equations	8	United States of America
Optics Letters	8	United States of America
International Journal of Coal Geology	7	Netherlands
Chemistry-A European Journal	6	Germany
Journal of Geophysical Research-Solid Earth	6	United States of America
Journal of High Energy Physics	6	Italy
Parasitology Research	6	Germany
Physical Chemistry Chemical Physics	6	United Kingdom
Physical Review E	6	United States of America
Science	6	United States of America
Tetrahedron	6	United Kingdom
Acta Physica Sinica	5	China
British Journal of Psychiatry	5	United Kingdom
Cancer Research	5	United States of America

Human Molecular Genetics	5	United Kingdom
Inorganica Chimica Acta	5	Switzerland
Journal of Dental Research	5	United States of America
Journal of Molecular Structure	5	Netherlands
Journal of Physics A-Mathematical And General	5	United Kingdom
Langmuir	5	United States of America
Nature Genetics	5	United States of America

3.4 Thematic areas

With the available data, we proceeded to classify the papers into the different subjects in which they were included by the publishing journals. For the thematic study of the papers we used the classification of the journals of the JCR databases (SCI and SSCI). Please note that the same journal can be included in several thematic categories. The number of thematic categories in which the papers written in cooperation between China and Spain for the studied period were classified came to 169, the following ones standing out *Physics, Multidisciplinary* (305 papers), *Astronomy & Astrophysics* (243 papers) and *Physics, Particles & Fields* (206 papers) due to their higher number of papers.

Figure 2 shows a network with the main subject areas of the papers. Social network analysis focuses on the relationships established in a series of elements, whether people, institutions, countries, or subject categories in our case. While in traditional social analyses elements are studied by classifying or grouping them into categories based on their traits, social network analysis relies on the idea that relational structures between elements explain the set, the social environment and each individual element better than their individual attributes. In our case, we applied social network methodology to the identification of the relationships created between the categories of the JCR's thematic classification assigned to each paper. To better understand the diagram, only those subject categories with 5 or more papers published have been included. The size of the nodes is proportional to their productiveness, and the thickness of the links is proportional to the amount of papers that the different disciplines connected have in common.

It is surprising to notice that almost all the thematic disciplines on the diagram are linked to a single element, except for Management and Psychology Applied. The disciplines with the greatest number of papers are *Physics, Multidisciplinary* (305 papers), *Astronomy & Astrophysics* (243 papers), *Physics, Particles & Fields* (206 papers), *Mathematics Applied* (98 papers) and *Mathematics* (90 papers). In general terms, three disciplines stand out in the collaboration between Spain and China, as they account for the highest number of papers in the ISI database for the period studied: physics, mathematics and chemistry.

As expected, the diagram shows that the highest number of papers jointly produced by China and Spain during this period was published in journals from the scientific areas of Experimental Science, Engineering and Technology, and Medical Sciences, and that the lowest number of papers corresponded to subjects from the Social Science and Humanities areas.

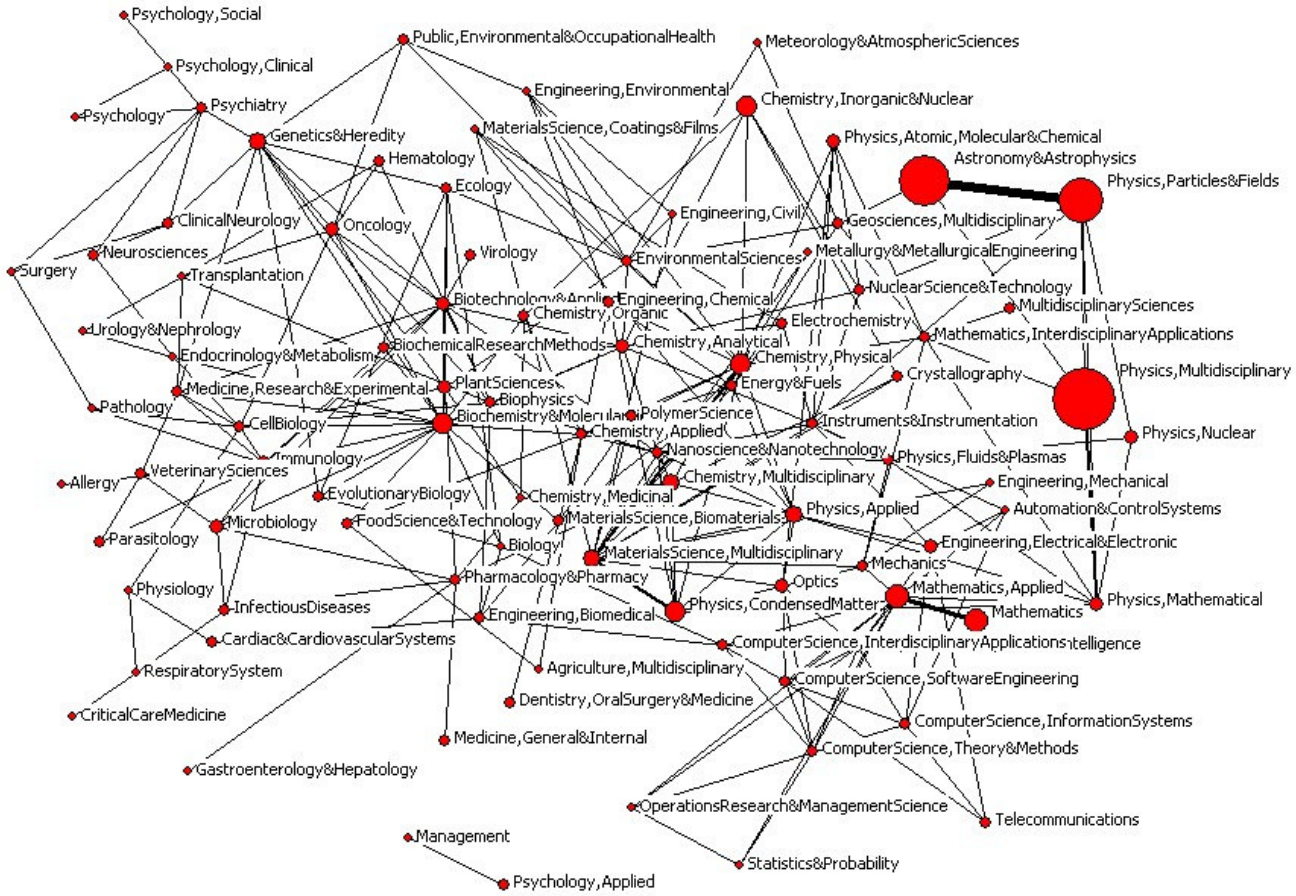

Figure 2: Network of thematic disciplines

3.5 Collaborating countries

We analysed cooperation with the remaining countries that participated with Chinese and Spanish institutions in different projects. 110 countries (China and Spain included) contributed to the scientific production between China and Spain recorded in the ISI databases between 2000 and 2009.

Figure 3 shows the network of all the collaborating countries. Some countries have a greater institutional participation than others, since apart from collaborating with researchers from other countries they also cooperated with researchers from their own countries working for other organisations, as was the case with the United States, Italy and Great Britain. These three countries do not only reach the highest collaboration level in the research jointly conducted by China and Spain; they are also on the lead of the countries with a higher number of participating researchers from the country's different organisations.

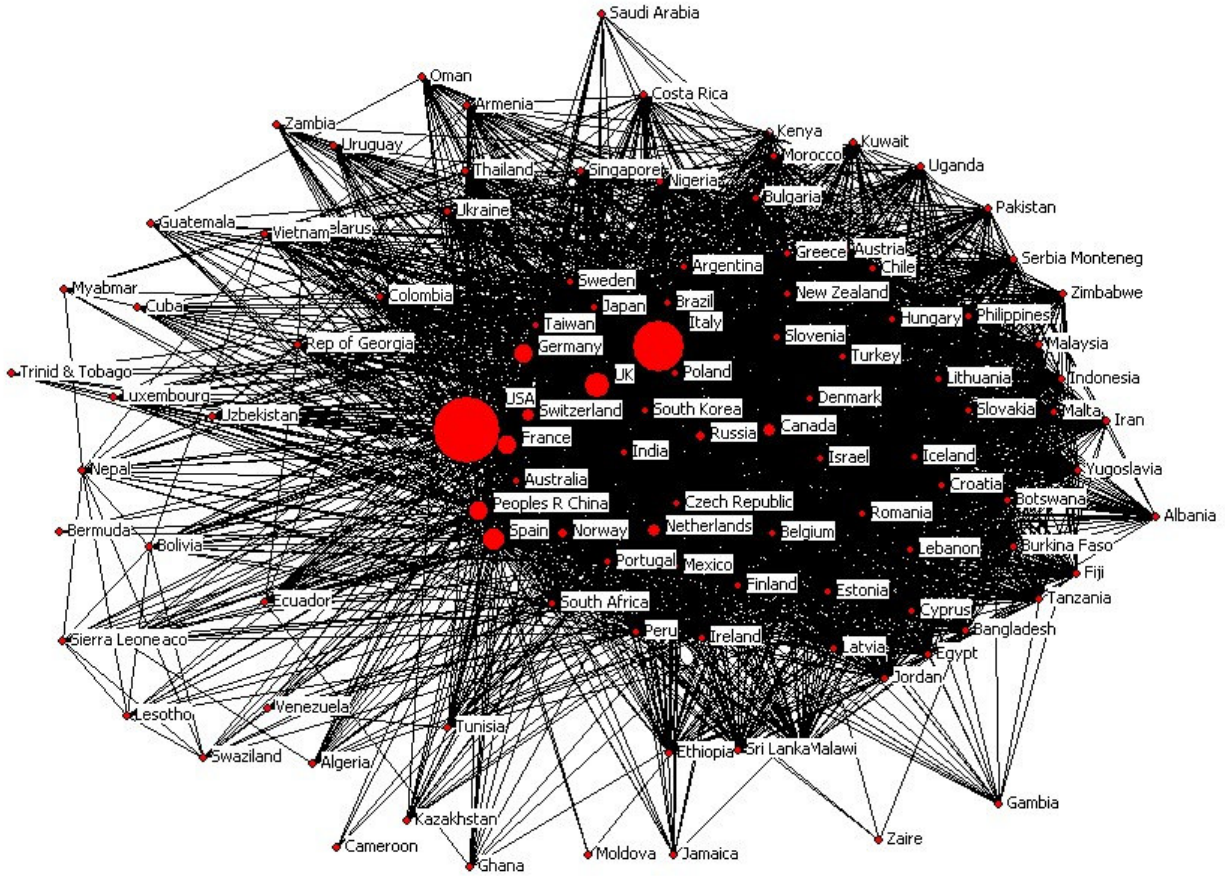

Figure 3: Network of countries

4 Conclusions

The analysis of the cooperation between China and Spain recorded in international databases supports the importance of scientific collaboration for scientific production.

In the period 2000-2009, the number of co-authorship papers produced by China and Spain grew, with a clear upward trend as from 2004. The most important aspect in our study is the increase in the number of joint articles between these two countries and a high collaboration level with other 108 states, the United States, Italy and Great Britain being on the lead with more institutional participation.

Another interesting finding is the confirmation of English as the most commonly used language in scientific communication. Although English is not the official language in either of the two countries studied –China and Spain– all the articles produced jointly and published in international journals were written in English almost entirely.

Great dispersion in the publishing journals was noticed, English-speaking journals being the most common. Out of the 707 journals used by the researchers to publish their articles, there was only one from China *Actas Physica Sínica* (5 papers) and one from Spain, *Revista Española de Enfermedades Digestivas* (1 paper).

It is also relevant to note that although there was an increase in the number of co-authorship articles, it varied across disciplines. Physics was the area with the highest number of papers, Astronomy standing out from this field possibly due to the very high equipment costs. The publication of the majority of scientific papers was the result of efforts made by one or several teams from two or more countries but it was surprising to find that in scientific areas like Social Sciences, scientific collaboration was less frequent and that it did not even exist in Humanities. Yet, we must bear in mind that, for Humanities, only mainstream science was analysed given the database used, and so the papers published in local journals were not identified.

5 References

[1] **BORDONS, M., FERNANDEZ, M. T.and GOMEZ, I**. Advantages and limitations in the use of impact factor measures for the assessment of research performance in a peripheral country. *Scientometrics* 2002, 53 (2): 195-206.

[2] **DEMARIA, A.** Productividad de la investigación en los diferentes países. *Revista Española de Cardiología* 2009, 62 (12): 1347-1349.

[3] **GALBAN, C.y GOMEZ, I.** La cooperación científica entre España e Iberoamerica en revistas internacionales. *Revista Española de Documentación Científica 1992*, 15 (4): 405-415.

[4] **GAO, X. and GUAN, J.** Networks of scientific journals: An exploration of Chinese patent data. *Scientometrics* 2009, 80 (1): 283-302.

[5] **GLÄNZEL, W., DEBACKERE, K.and MEYER, M.** 'Triad? Or 'tetrad'?. On global changes in a dynamic world. *Scientometrics* 2008, 4(1): 71-88.

[6] **GUAN, J.and HE, Y**. Comparison and evaluation of domestic and international outputs in Information Science & Technology research of China. *Scientometrics*, 2005, 65 (2): 215-244.

[7] **HAIQI, Z.** A bibliometric study of medicine chinese traditional in Medline database. *Scientometrics*, 1994, 31 (3): 241-250.

[8] **HE, T.and LIU, W.** The internationalisation of Chinese scientific journals: A quan*titative comparison of three chemical journals from China, England and Japan. Scientometric*s,2009, 80 (3): 583-593.

[9] **HE, T.** International scientific collaboration of China with the G7 countries. *Scientometrics*, 2009, 80 (3): 571-582.

[10] **JIN, B.and WANG, B.** Chinese Science Citation database: It's construction and application. *Scientometrics*, 1999, 45 (2): 325-332.

[11] **KAO, C.** The authorship and internationality of Industrial Engineering Journals. *Scientometrics*, 2009, 81 (1): 123-136.

[12] **ROYLE, J., COLES, L., WILLIAMS, D.,and EVANS, P.** (2007). Publishing in international journals. An examination of trends in Chinese co-authorship. *Scientometrics,* 71 (1): 59-86.

[13] **RUSSELL, J. M., MADERA JARAMILLO, M. J.and AINSWORTH,** S. El análisis de redes en el estudio de la colaboración científica. *Redes*, 2009, 17 (2): 39-47.

[14] **SAHA, S., SAINT, S.and CHRISTAKIS, D.A.** Impact factor: a valid measure of journal quality?. *Journal of the Medical Library Association*, 2003, 91 (1): 42-46.

[15] **SEGLEN, P. O.** Why the impact factor of journals should not be used for evaluating research. *British Medical Journal*, 1997, 314 (7079): 498-502.

[16] **TORRES-SALINAS, D.y JIMÉNEZ-CONTRERAS, E.** Introducción y estudio comparativo de los nuevos indicadores de citación sobre revistas científicas en Journal Citation Reports y Scopus. *El Profesional de la Información*. 2010, 19 (2):201-207.

[17] **VAN RAAN, A. F. J.** The influence of international collaboration on the impact of research results. Some simple mathematical considerations concerning the role of self-citations. *Scientometrics*, 1998, 42 (3): 423-428.

[18] **WANG, S., WANG, H.and WLDON, P. R.** Bibliometric analysis of English-language academic journals of China and their internationalisation. *Scientometrics*, 2007, 73 (3): 331-343.

[19] **ZHOU. P. and LEYDESDORFF, L.** The emergence of China as a leading nation in science. *Rearch Policy*, 2006, 35: 83-104

[20] **ZHOU. P., LEYDESDORFF, L**. (2007). The citation impacts and citation environments of Chinese journals in mathematics. *Scientometrics*, 72 (2): 185-200.