Analysis of the composition and dynamics of research groups under an input-output focus. A case in the field of Library and Information Science

Sandra Miguel (1,2)
sandra@fcnym.unlp.edu.ar

Zaida Chinchilla-Rodríguez (2)
zaida.chinchilla@cchs.csic.es

Claudia González (1,3)
claudiag@ciop.unlp.edu.ar

Félix de Moya-Anegón (2)
felix.demoya@cchs.csic.es

(1) Universidad Nacional de La Plata, Facultad de Humanidades y Ciencias de la Educación. Departamento de Bibliotecología. 48 e/ 6 y 7. 5to piso. La Plata, Argentina.

(2) Consejo Superior de Investigaciones Científicas. Centro de Ciencias Humanas y Sociales. Instituto de Políticas y Bienes Públicos. Grupo SCImago. C/ Albasanz, 26-28. Madrid, España.

(3) Centro de Investigaciones Ópticas. CONICET La Plata – CIC, Argentina.

Abstract

The present study is a contribution to the literature on research group composition and dynamics. Its novelty resides in the strategy of delimiting groups for a comparative analysis of projects (input) with respect to coauthorship (output). A combination of bibliometric techniques and social network analysis is applied to a particular case: the Department of Library Science of the *Universidad Nacional de La Plata*, Argentina, in the period 2000-2009. *Clique* technique is used to delimit the groups, and structural indicators are used to draw comparisons. The empirical evidence obtained is interpreted statistically and by experts to assess the potential of the method. The results obtained show that the method allows for adequate delimitation of groups, identifying their members and reflecting group composition in terms of actor category, as well as indicating the interdisciplinary and the national and international projection of the networks they integrate. The network indicators provide information about the properties of the actors in terms of interaction of a particular collective. The integration of these two aspects at different points within the time period analyzed allows us to make some inferences about group profiles and the roles placed by such actors. We may affirm that this type of study makes it possible to interpret, on the micro level, the work of individual researchers and the group dynamics. The input/output comparative analysis broadens our informational basis for studying the evolution of individual and group development over time, a factor always taken into account in the management, promotion and evaluation of scientific research.

Keywords
Scientific collaboration – Research groups – Bibliometrics – Social Network Analysis – Hybrid indicators

Address for correspondence:
SANDRA MIGUEL
Library Science Department, National University of La Plata
48 e/ 6 y 7 (1900) La Plata, Argentina. E-mail: sandra@fcnym.unlp.edu.ar. Phone: +54-221-4230125

Introduction

One characteristic that defines evolution in a mode of knowledge production is the shift from research carried out on an individual basis to that based on research groups and networks of collaboration (Gibbons et al. 1997). Indeed, collaboration in science is the norm, and one consequence of the professionalization of scientific activity (Beaver 1978). It is likewise a sign of maturity and efficiency in the branches of knowledge, demonstrating an adequate level of scientific infrastructure and the capacity of coordination of multiple actors (Sonnenwald 2007).

This phenomenon has given rise to a significant reappraisal of the role of human resources and the links established between or among groups, as the foundations of the social-scientific capital of institutions and countries. Such a notion of capital is something more than the sum of all its parts (knowledge and skills) of the individual researchers and the "know-how" that drives their capacities to generate and diffuse the products of knowledge. The involvement of social connections and networks of collaboration that develop among the actors (Bozeman 2005) can be so significant that knowledge production and social networks are said to be highly correlated elements (Hildreth and Kimble 2004).

Governments and funding agencies stress the need to evaluate scientific activities and collaboration at all levels and in all productive sectors. Together with the traditional instruments of research support (basically, the competitive financing of R+D projects), we see a development of policies and programs to promote the mobility and long-lasting association of actors as a means of enhancing scientific excellence, visibility and the international reputation of countries, along with the divulgation and interchange of knowledge and innovation (Chinchilla et al. 2008).

The literature offers numerous examples of studies about scientific collaboration on the macro level, though micro-level analysis of coauthorship is rare, perhaps because of the complexity of retrieving such information and standardizing the data (Newman 2004). Yet this information constitutes the smallest unit of study able to reflect the structure and dynamics of research carried out in institutions (Zulueta et al. 1999). Such knowledge is useful for making decisions about the allocation of resources and incentives, for optimizing the use of available infrastructures, promoting the integration of researchers into already existing groups, and thereby enhancing the individual capacities of scientists and the institutions where they work.

Defining research groups, and the working hypothesis

The first problem faced in research group analysis is that of establishing the criteria for their delimitation. Cohen (1991), Zulueta et al. (1999) and Perianes-Rodríguez et al. (2010) underline that there is no consensual criterion for this matter. Some authors consider the group members to be those researchers belonging to a single department or the same research center; whereas others hold them to be all participants in the research project, or else all the coauthors of scientific publications. Although some studies look at the networks of collaboration from the perspective of programs and projects (Cabo 1997), most delimit groups on the basis of coauthorship analysis (Newman, 2001; Barabási, et al., 2001; Sanz Casado, et al., 2004; Gaete Fiscella and Vázquez, 2008; Herrero Solana and Moya Anegón, 2009; Perianes-Rodríguez, 2007; Vargas et al, 2010).

While the term "team" has frequently been used as a synonym of "research group" (Nederhof and Van Raan, 1993), some authors establish a distinction between the two (e.g. Etzkowitz, 1992). The present contribution does not enter in such terminological debates. We simply refer to "research groups", whose identification and delimitation depend on how they define themselves. If the research group is conceived as a collective of scientists who collaborate in creating and developing a particular line of research, sharing material and economic resources (Zulueta et al., 1999), the main criterion for delimitation would be the joint participation of researchers in their projects. However, if the group is defined in terms of the publications they sign in collaboration (Perianes-Rodríguez et al., 2010), then coauthorship constitutes the best delimiting criterion. Further, if we understand research groups to be sets of persons who work together on a given project or specific subject matter, formulating one or more problems of interest, tracing a strategic plan for the mid- to long-term effort, and producing results in terms of knowledge about the subject matter (COLCIENCIAS, 2006), their identification and analysis prove even more complex and should be approached from at least two dimensions, corresponding with the two crucial facets of the research process: input (represented by the research projects) and output (determined by the coauthorship of scientific publications).

This is also a matter of great importance for scientific policy-makers. If we assume that a group exists whenever there is a tangible and verifiable harvest of projects and activities (output) usefully expressed through an adequately formalized plan (input), then knowledge about the group´s output could aid decision-making about the accreditation or financing of new inputs (Van den Besselaar and Leydesdorff, 2009). Similarly, the appearance of hybrid indicators allows us to detect the excellence of certain researchers within a group. Excellence is not only reflected in production and visibility, but by the role a figure executes in the structure of networks, in view of one´s capacity of connection, intermediation, cohesion, popularity and prestige (Perianes-Rodriguez et al., 2009). Thus conceived, research groups and the role of their component members become valuable tools in the context of evaluation, accreditation, and funding.

Cohen (1991) was one of the first to highlight the need for combined studies, integrating both analytical standpoints; his focus was the relationship between scientific productivity and the size and age of the groups. Two considerations behind his work deserve mention here. For one, there is the technical matter of the incomplete image of research results, since output not registered as formal publication in international journals, is disregarded. Hence, in this study, the Curriculum Vitae or *Résumé* is used as an informational source. The second consideration serves as the basic lens of our study: in output groups, individuals do not necessarily belong to the same institution.

Our working hypotheses, then, is that membership to different institutions and reflected by publication in collaboration may be key for the concession/funding of projects. Governments and financing agencies send smoke signals that appear ever more clearly on the horizon: investment in research calls for collaboration, and the association of intellectual forces can be determinant for obtaining funds, as it ensures output in the form of publication in quality forums (international congresses and high impact journals), while saving costs by sharing equipment and resources that can be split up among the participating research teams and the competent agencies backing them up (Perianes-Rodríguez et al. 2009). This paper assumes that the group structure is meant to unite

strengths so as to achieve common objectives, which may arise in different ways. For one, the mobility of researchers who establish casual contacts for a project or a stay abroad may lead to more permanent collaboration over time; and attending conferences and other national or international events can give way to ideas about joint efforts, etc. The fruits of such collaboration would eventually be reflected in the sum of influential curricula, necessary for the concession of projects regardless of institutional or geographical origin of the researchers. Scientific Excellence is the utmost criterion. Thus, output should reflect relations of collaboration similar to those seen in the input. For this reason, we refocus the study of structures defined in terms of input group configuration; in our case, the parties signing the research projects and the patterns of collaboration are observed from a bifocal input-output approach.

Objective

Following the notion put forth by Cohen, our analysis of the composition and dynamics of research groups using the dual "input-output" perspective meant that we would appraise the joint participation of researchers in their respective projects in view of the coauthorship of scientific publications. We hoped to shed new light on the following matters: Is there a strategy behind the design of research groups? Does the definition of input groups attend to a certain institutional structure? Or rather, is there an opening at the end of the tunnel in terms of extramural collaboration? Is there a relationship between the composition of input groups and that of output groups? And if so, what is the role of the actors in these two facets of the process of organizing and developing research efforts? As an exemplary case, we focused on the Department of Library Science of the *Universidad Nacional de La Plata*, Argentina, during the period 2000-2009.

Material and methods

Coauthorship is one of the most evident and best documented forms of scientific collaboration; and practically any of its aspects can be studied by means of social network analysis based on bibliometric methods (Glänzel, 2004). Although bibliometric studies have been looking into the patterns and tendencies of scientific collaboration for some time (Sonnenwald, 2007), the eventual incorporation of social network analysis (SNA) made it possible to delve deeper into aspects such as the precise delimitation and analysis of group composition and dynamics, better reflecting the social character of science. Graph theory affords a good methodological support for SNA, since it has a vocabulary that can be applied to many properties of social structures (Izquierdo and Hanneman, 2006), and the graphs moreover facilitate visualization of networks, helping us detect the fluxes of scientific communication between or among researchers and research teams (Hu and Racherla, 2008). The main difference between the explanations given by social network analysis and conventional bibliometric analysis is the inclusion of concepts and information about relations between units and the study of structures. The present study combines techniques from both directions. The results obtained are contrasted with the opinion of experts to assess their validity and significance.

Data source

The original units of analysis were the 25 research professors of the current teaching staff of the Department of Library Science (DHUBI) at the *Facultad de Humanidades y Ciencias de la Educación* of the *Universidad*

Nacional de La Plata, Argentina. We later included other researchers having collaborative links with them, through projects or publications, in the period 2000-2009. The source of data was the corpus of *curricula vitae* (CV). The choice of source in this case is justified by the fact that these career *résumés* represent the academic paths of researchers as well as their professional experience and areas of interest; thus, they are documents of obligatory presence when requesting funding for new research projects or relaying the results of previous research efforts (Cañibano and Bozeman, 2009).

Normalization of data

Despite initiatives to create and standardize CVs on an Argentinian basis (Onofrio, 2009), there is a lack of consistency of CV data in some cases, or incomplete information, making it necessary to control the quality of such information. In our case, not all the researcher CVs included *all* the participants in their research projects, so it was necessary to consult the institutional registers of research projects to complete these data. It was likewise necessary to standardize the ways the names of researchers were recorded, both for projects and for publications. Once these data had been purged and normalized, each one of the participants/authors (actors) was associated with a project or publication identifier, where they were mentioned, adding data about their institutional origin, professional category and subject area. For this purpose, six exclusive categories were created: a) DHUBI researcher (R-DHUBI); b) DHUBI graduate student or undergraduate (UGS-DHUBI); c) LIS researchers from other institutions in the country (LIS-ROIC); d) LIS foreign institutions researcher (LIS-RFI); e) Researchers of other disciplines in Argentinian institutions (ODAIR), and f) researchers of other disciplines from foreign institutions (ODFIR). These categories were to be used in the analysis of the composition of the networks to detect professional category (a and b), intra-institutional collaboration (a and b), national and international collaboration (c and d), and interdisciplinarity (e and f). A total of 17 projects and 146 publications (52 journal articles and 94 conference papers/presentations) were include in the analysis, with a mean coauthorship index of 2.4, and 60% of the work involving collaboration.

Generating matrixes

Using a database processing program, the frequencies of co-participation and co-authorship were calculated. These data were used to generate the input and output networks for three partial time periods (2000-2002, 2003-2005 and 2006-2008 for input; plus 2001-2003; 2004-2006 and 2007-2009 for output). The time frames of output were defined according to two criteria: 1- one year after initiation of the project, as it is unlikely to produce a publication within the first year, and 2- one year after finishing the project, given the delay of the peer-view publishing process itself.

Structural analysis and calculation of indicators

Although it can prove difficult to define or delimit research groups (Rey et al. 2008) because of their functional and dynamic character, we must not forget that they are the result of relationships among individual researchers and they present structural and functional particularities that can help us define

them, either on the basis of cohesion, stability or synergy. We can use any one of a number of network indicators as the mechanism for delimiting the subgroups. K-cores or k-pkexes analysis allows one to define cohesive subgroups in view of the nodal degree or number of relations of each one of the nodes. N-cliques, n-clans or n-clubs are means of appraising the geodesic distances (closeness), whereas LS sets and Lambda sets account for the frequency of links among the members of the subgroup with respect to the links established with external nodes (Wasserman and Faust 1994). By means of betweenness, the Girvan-Newman algorithm (Girvan and Newman 2002) permits detection of those nodes that serve as bridges between some groups and others. The use of blockmodeling entails a regrouping of the network on the basis of the similarity or dissimilarity of the vertexes in light of their relation-based behavior; while Factor Analysis relies on the tendency of the nodes to seek relations with members of a same group (Perianes-Rodríguez et al. 2010). Our study focused on the structural properties of the networks in light of cohesion indicators such as density, the average degree, centralization and component analysis. Moreover, a clique analysis was carried out based on the criterion of reciprocity and the proximity of the nodes. We consider a clique to be the most complete subgroup, in which all the nodes are adjacent. Our reason for choosing this technique over others was that it allowed us to detect the most direct collaborators of a given researcher. Finally, the definition of groups and the application of clique analysis were discussed and analysed by the members of the department itself, in order to contrast the objective results obtained with the opinion of experts. In a series of open interviews where results were exhibited, the researchers and administrators of each given department identified every node with the member(s) and line(s) of research carried out, and explained intellectual and social motivation behind the evolution of joint relations.

To study the role of the actors, the classic measures of centrality were used: nodal degree, betweenness and closeness, in addition to the clustering coefficient and the index of popularity, calculated for the input groups on the basis of the number of projects, and for the output groups in terms of the number of documents produced (Perianes-Rodríguez et al. 2009).

Network visualization

To position the nodes we used the Kamada Kawai algorithm (1989), which assigns coordinates to the vertices, attempting to maximize the distances between them, to theoretical distances (Vargas-Quesada 2007). Their size reflects the number of projects in which each actor of the input networks has participated; and the amount of publications in the case of output. The lines indicate the relationships among actors, the color (a shade of grey) indicating the degree of intensity; in the case of the input networks, it shows the number of projects in which they participated together, and in the output networks, the number of co-authored publications. Finally, we used different colors and shapes to distinguish the different actor categories: R-DHUBI (black circle); UGS-DHUBI (white circle); LIS-ROIC (white square); LIS-RFI (white triangle); ODAIR (grey diamond) and ODFIR (grey triangle). To calculate and visualize the indicators, we used the Pajek program, and clique analysis was performed using UCINET.

Results

Structural characteristics of the networks

From the input perspective, we see that the number of actors increases with each one of the analyzed series (from 19 to 32 and then 43; **Table 1**). During the second period, this increase owes mainly to the incorporation of Argentinian researchers from other disciplines; whereas in the third time period, it is due to the participation of DHUBI research professors. The presence of under/grad students dropped in relative terms from the first to the second period, and then remained stable in the third.

As regards output, the number of actors also increases, though less notably (32, 36 and 38, respectively; **Table 2**). The number of DHUBI research professors was practically unaltered, though their relative presence decreased due to the increasing participation of other actors, especially the under/grad students, who doubled in number in the second period, then kept steady in the third. Worth underlining is the fluctuating behavior in terms of the interdisciplinarity. A significant decrease in research professors from other disciplines was recorded in the second time period, with some recovery in the third. The patterns of collaboration show an absence of international researchers from other disciplines until the second and third time periods of study, in which contacts with colleagues from beyond the national arena take place.

Table 1 Evolution of actors per category in the input networks

Actors category	2000-2002		2003-2005		2007-2009	
	Actors	%	Actors	%	Actors	%
R-DHUBI	11	57,9	14	43,8	21	48,8
UGS-DHUBI	3	15,8	3	9,4	4	9,3
LIS-ROIC	1	5,3	0	0,0	1	2,3
LIS-RFI	1	5,3	0	0,0	4	9,3
ODAIR	3	15,8	15	46,9	11	25,6
ODFIR	0	0,0	0	0,0	2	4,7
Total	**19**	**100,0**	**32**	**100,0**	**43**	**100,0**

Table 2 Evolution of actors per category in the output networks

Actors category	2001-2003		2004-2006		2007-2009	
	Actors	%	Actors	%	Actors	%
R-DHUBI	19	59,4	20	55,6	19	50,0
UGS-DHUBI	4	12,5	9	25,0	9	23,7
LIS-ROIC	1	3,1	1	2,8	0	0,0
LIS-RFI	0	0,0	3	8,3	3	7,9
ODAIR	8	25,0	3	8,3	7	18,4
ODFIR	0	0,0	0	0,0	0	0,0
Total	**32**	**100,0**	**36**	**100,0**	**38**	100,0

From the standpoint of structural evolution, the average degree of network input increases over the period of study (**Table 3**), pointing to a greater number of links among nodes. In the output networks this measure

remains more or less constant, though below the value of the input networks, which surpass it easily in all three periods. This would be because not all the actors who participate in a project end up publishing works in collaboration. Meanwhile, the capacity of connection of the nodes, or degree of centralization, is nearly 0.30 in the three time periods, in both input and output networks. In other words there is little interconnection of nodes, just a few agglutinating all the relations.

Table 3 Comparison of indicators of cohesion and centralization of the network for each time period

	2000-2002	2001-2003	2003-2005	2004-2006	2006-2008	2007-2009
	Input	Output	Input	Output	Input	Output
Number of nodes	19	32	32	36	43	38
Density	0,45	0,16	0,44	0,19	0,34	0,13
Average degree	8,10	5,19	13,87	6,67	14,32	4,84
Degree	0,28	0,38	0,32	0,22	0,32	0,25
Betweeness	0,13	0,54	0,48	0,18	0,48	0,2
Closeness	*	*	0,55	*	0,46	*
Number of components	3	4	1	3	1	3
Main component size	10	28	32	34	43	22
Main component size (%)	53%	88%	100%	94%	100%	58%
Secondary component size	6	2	*	1	*	15
Secondary component size (%)	32%	6%	*	3%	*	39,5%
Clustering Coefficient	0,36	0,12	0,19	0,14	0,34	0,13

Similarly, the clustering coefficient, which might be expected to be high (Barabasi et al. 2002; Krestchmer and Aguillo 2004; Newman 2004), actually presents low values for all the periods, both in input and in output. Despite the decrease seen in the second period of the input network, they are stronger than the output networks. This can be explained by the fact that all the participants of a project are interlinked.

Results are interesting in terms of internal cohesion or betweenness potential, which reflects the capacity of an actor to control the flux of information, becoming the bridge for others actors to access links otherwise inaccessible. We see a slight strengthening of the input networks, with a greater flux of links in the last two periods than in the first. In the first, the situation varies, and it is the output network where the highest betweenness centrality is seen (0.54 as opposed to the 0.13 of input). This is because, in the input network 2000-2002, node 62 is the only one with the high capacity of interconnection. This trait is better defined in the number of components. With regard to the input networks, the first period is the only one to present a different composition with respect to the second and the third, as we observe in three components (53% the main component) are mutually isolated. This tendency toward unification reveals a change in strategy in seeking projects. The output networks, in contrast, evidence a certain fragmentation of the nodes at the time of publishing results, presenting 4 components in the first period, 3 in the second, and another 3 in the third, although the latter reveals a drastic reduction in the first component and a considerable increase in the second one, which can be seen as a certain consolidation of this second component.

Composition and dynamics of the groups

First period

In the **input network** (**Fig. 1**), by means of *clique* analysis, 4 groups were identified (A, B, C and D). All of them are well defined, and have a fairly homogeneous composition in terms of the category of their members and the strength of the relations established among them. Groups A and B are linked by means of actor 62, who, on the individual level, has the greatest collaborating capacity and social potential, attaining the highest level for all the indicators (degree = 0.5; betweenness = 0.13; closeness = 0.53; clustering coefficient = 1 and popularity = 2). Noteworthy is the multidisciplinarity of group C. Furthermore, a high degree of cohesion among actors is seen, all achieving more or less the same value for the clustering coefficient (around 0.5) and the popularity index (0.56).

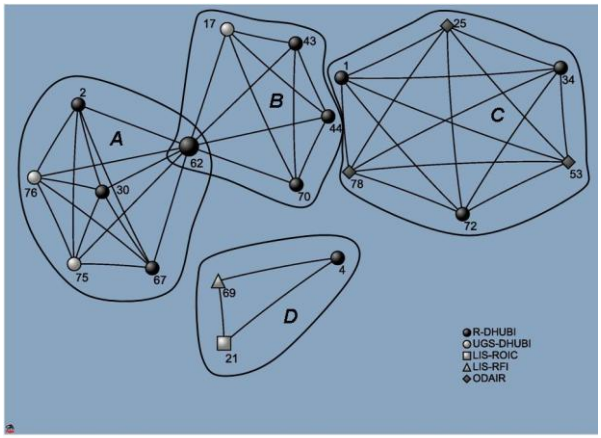

Fig. 1 Input Network (2000-2002)

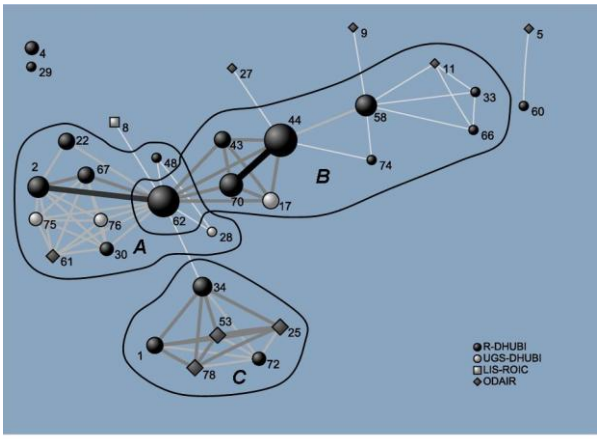

Fig. 1 Output Network (2001-2003)

In the **output network** (**Fig. 2**), group D does not appear because the results of the project took place at a later date (it is represented in the network of the second period). Groups A and B appear with new incorporations and with stronger links among their members. The indicators of analysis show group A to present the greatest number of integrated members, some standing out because of their popularity index, and their number of collaborations (actors 2 and 62). Group B stands out in terms of the good positions occupied by their researchers in relation with the total set of the network, and because of the facility with which they establish contacts. Group C has great internal cohesion and a high clustering coefficient of members, who benefit somewhat from the productivity of the group, as is made manifest by the popularity of the researchers.

Second period

In the **input network** (**Fig. 3**), group A stands out among the five groups detected: it is the most multidisciplinary one, it has more researchers (most from Argentina, but from different disciplines), and secures the best position for contact with other groups. Groups F and C share 4 important nodes —1, 34 and 53— which form an outstanding triad in the total context of the network, in view of the strong relationships among themselves and the high number of collaborations with Argentinian researchers from other disciplines. On the individual level, node 22 is remarkable, pertaining to groups A and F, as is 62, a member of group A; they obtain the highest values in all the indicators (*degree = 0.58*) when compared with the rest of the actors.

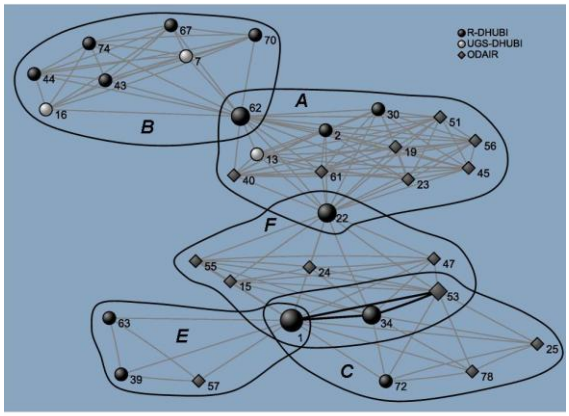

Fig. 2 Input Network (2003-2005)

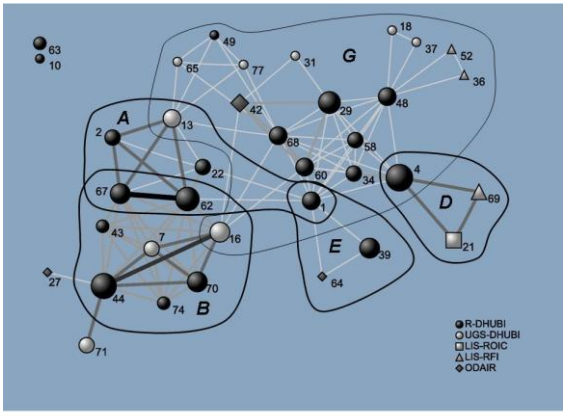

Fig. 3 Output Network (2004-2006)

In the **output network** (**Fig. 4**) we identify 5 groups (A, B, D, E and G). As before, this network has a stronger mesh than the corresponding input network. Group D stands out again (it was important in the input network of 2000-2002), and actor 4 is highly popular (2.52) and has more publications (9), most of them conference papers. Group A once again has a strategic position, in this case gathering important nodes of betweenness and control (nodes 1, 16 and 62). Group G stands out in terms of its size and high degree of independence. We see a nucleus made up of DHUBI research professors and several smaller subgroups linked through international collaboration and grad/undergrad student activity. Meanwhile, Group B is the most cohesive one, its strong links having high clustering coefficients. Deserving attention above all is the marked interdisciplinarity when seeking projects in contrast with the scarce presence of researchers from other areas in the authorship of publications.

Third period

In general, we can see clear differences among the 6 **input groups** (**Fig. 5**), as well as among researchers and their categories. Group A tends to be more multidisciplinary. The DHUBI professors making up this group (nodes 2, 30 and 62) at the same time serve as intermediaries for the other groups; yet group A has lost the centrality it showed in the first and second time periods of study. Thus, other groups increase in centrality. Such is the case of group B and its interaction between group A and the rest of the groups. This group predominantly contains DHUBI research professors and is quite cohesive internally. Group G is the strongest one, with more researchers and a high betweenness. In terms of popularity and cohesion, the subgroup of DHUBI research professors constituting its nucleus stands out. These researchers collaborate with foreign scientists from other disciplines as well as from the same area of knowledge. The rest of the groups (D, E and F) contain members of group G that have established collaborative efforts with colleagues from their area or from other disciplines, whether Argentinian or foreign, confirming their power of interconnection.

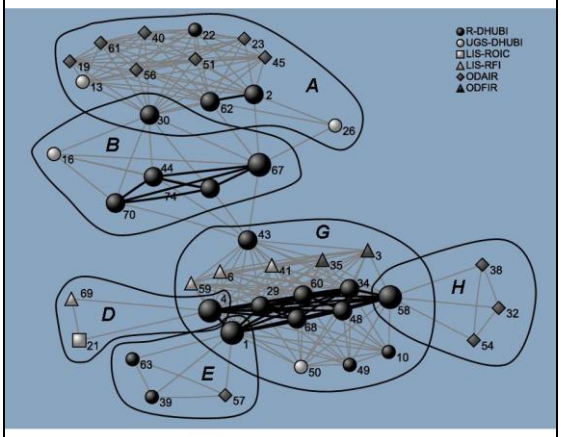

Fig. 4 Input Network (2006-2008)

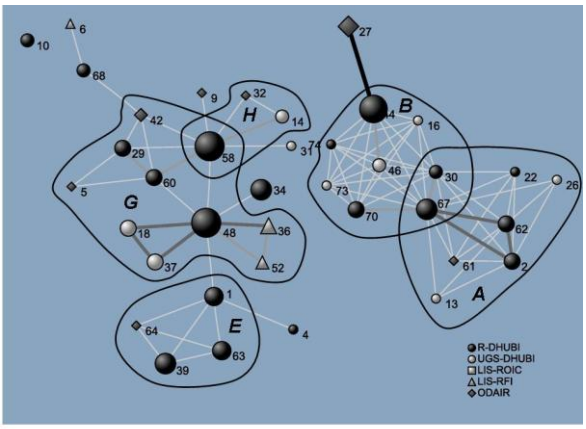

Fig. 5 Output Network (2007-2009)

In the **output network** shown in **Fig. 6**, group D —which was included in the input network— is not visible, for the same reasons as in the first period. The fact that its publications may take shape in coming years leads us to consider lengthening the time slot of study in future work. We observe two major components, one made up of groups A and B. In the input network, these two groups appeared united by node 43; yet here it is not present, leaving this subnetwork isolated. Group A contains a triad made up of DHUBI researchers (nodes 2, 57 and 62); and the rest are students or perhaps professors recently joining the faculty. Group B has even more students or grad students than group A. Node 44 has strengthened collaboration with a researcher from another discipline, whereas the other nodes of the group have no access to such collaboration. However, it is confirmed as the most cohesive group by the clustering coefficient of its researchers, practically all interconnected in terms of coauthorship. Groups G, H and E are discerned. Group G is the one serving as intermediary between the other two, by means of its strongest nodes in terms of betweenness (node 48: 0.21 and node 58: 0.15). The two branches of this group might represent different research lines, one with a multidisciplinary vision, directed by actor 58; and the one directed by actor 48 having a more specialized focus within BCI. Collaborations on the national and the international level with researchers from the same area are reflected, demonstrating their strong power of attraction.

Comparison

Comparative study of the indicators calculated for output (**Table 4**) and for input (**Table 5**) illustrates how Group A acts as a relatively homogeneous team in terms of the number of component actors and categories. Nonetheless, we observe a lack of exact correspondence between input actors and output actors, suggesting that not all participants in research projects also publish in conjunction. As the number of integrating members in input increases (from 6 to 14), we see a decrease followed by recovery for output (10, 6 and 8). At first there is a single leader, but in the final period this leading role is shared by 3 members, who also present the highest popularity values. The centrality and popularity of the actors in the input image is not mirrored in the output (they do no stand out in coauthorship). Noteworthy are actors 62, 2, 67 and 30, at different times. In the final period, the former leader node 62, with the greatest number of links (degree), power of betweenness and popularity, is now mingled in with the rest of the members, while a new leader looms on the horizon (actor 67).

Nodes 67 and 30 have taken on the main output tasks of the group. Consultation with experts revealed that the actor 62 was here in the final stage of their academic career. Finally, we should point out that this group works mainly on Reference and Information Users.

Table 4 Comparison of the indicators of cohesion and centralization of input per group and time series

	Total actors	% R-DHUBI	% UGS DHUBI	% LIS-ROIC	% LIS-RFI	% ODAIR	% ODFIR	Degree	Betweeness	Closeness	Clustering Coeff.	Nproy	Popularity
input 2000-2002													
A	6	66,7	33,3					0,28	0,00	0,36	0,28	1	0,28
B	5	80,0	20,0					0,22	0,00	0,34	0,13	1	0,13
C	6	50,0				50,0		0,28	0,00	0,32	0,56	1	0,56
D	3	33,3		33,3	33,3			0,11	0,00	0,16	0,22	1	0,22
input 2003-2005													
A	12	33,3	8,3			58,3		0,35	0,00	0,54	0,30	1	0,30
B	8	62,5	37,5					0,23	0,00	0,42	0,09	1	0,09
C	6	50,0				50,0		0,24	0,00	0,45	0,12	2	0,20
E	4	75,0	25,0					0,97	0,00	0,37	0,01	1	0,01
F	8	8	37,5		62,5			0,27	0,00	0,51	0,12	2	0,20
input 2006-2008													
A	14	35,7	14,3			50,0		0,45	0,01	0,45	0,42	1	0,42
B	6	83,3	16,7					0,24	0,00	0,33	0,02	2	0,04
D	3	33,3		33,3	33,3			0,71	0,00	0,32	0,00	1	0,00
E	4	75,0				25,0		0,12	0,00	0,32	0,00	1	0,00
G	15	66,7	6,7		20,0		6,7	0,48	0,12	0,46	0,47	2	0,41
H	3	33,3	33,3			33,3		0,12	0,00	0,32	0,00	1	0,00

Table 5 Comparison of the indicators of cohesion and centralization of output per group and time series

	Total actors	% R-DHUBI	% UGS DHUBI	% LIS-ROIC	% LIS-RFI	% ODAIR	% ODFIR	Degree	Betweeness	Closeness	Clustering Coeff.	Ndoc Journal	Ndoc Proceed.	Ndoc Total	Popularity
output 2001-2003															
A	10	60,0	30,0			10,0		0,19	0,00	0,37	0,19	1	1	2	0,38
B	10	80,0	10,0			10,0		0,13	0,00	0,37	0,09	1	2	3	0,12
C	6	50,0				50,0		0,16	0,00	0,29	0,30	0	3	3	0,90
output 2004-2006															
A	6	83,3	16,7					0,26	0,46	0,45	0,17	1	4	4	0,66
B	8	75,0	25,0					0,20	0,00	0,38	0,26	1	2	5	1,20
D	3	33,3		33,3	33,3			0,57	0,00	0,31	0,01	1	2	3	0,03
E	2	66,7				33,3		0,57	0,00	0,35	0,00	2	3	4	0,00
G	18	50,0	27,8		11,1	11,1		0,19	0,25	0,43	0,13	1	3	3	0,53
output 2007-2009															
A	8	62,5	25,0			12,5		0,24	0,02	0,24	0,14	1	2	2	0,32
B	8	62,5	37,5					0,30	0,00	0,26	0,27	1	1	2	0,68
E	4	75,0	25,0					0,15	0,00	0,18	0,14	1	3	4	0,46
G	11	45,5	18,2		18,2	18,2		0,19	0,06	0,23	0,10	1	3	3	0,30
H	3	33,3	33,3			33,3		0,11	0,00	0,21	0,01	0	2	2	0,02

Group B is seen to have a strong connection to Group A, sharing certain members such as node 62, in early years the leader of this group. The indicators reveal that group B is losing in centrality and popularity in the realm of input, and in output it presents a rather erratic development, the most influential nodes concentrating practically all the potential. There is a specialization in Information Processing. This may have some bearing on the endogamous tendency of the group, nearly all its members being DHUBI research professors or else graduate students from this same academic department.

Also interesting is the fact that a nucleus of DHUBI researchers maintains its identity over the years in both input and output, while the presence of the graduate students changes: they appear in the input-output of a specific time period and then disappear, making evident their specific participation in certain projects, while also demonstrating that not all graduate students who begin to collaborate in research will later evolve at the core of the group.

Group C has a short-lived existence, with presence in the input and output of the first period and in the input of the second. It consists of six members (three DHUBI researchers and three Argentinian researchers from other disciplines), all of whom were present in both input and output, with a high level of mutual attraction and cohesion. In the second period of input, a leader appears (actor 1) showing the highest degree, betweenness and popularity, although productivity is not reflected in the output. The group disappears, and 4 of its members do not show up in the posterior networks. The other two actors (1 and 34) join other groups. The line of study of group C is Terminology, an interdisciplinary field, which would explain the participation of researchers from the area of language studies.

The three members of Group D (one DHUBI researcher and two LIS foreign researchers) participate in the input of the first and last periods, and in the output of the second period. This group has a uniform profile in its early stage, and later on a node stands out —a DHUBI researcher—, with high popularity and communicative capacity. Although at the beginning the group was isolated, over time it becomes part of the reticular structure, connected with group G. This means that this researcher is on a team outside the department, and another inside it. The line of research is Metric Studies of Information.

A minor component is Group E, which comes forth only after the second period. Comprising three DHUBI researchers and a single Argentinian researcher from another discipline, it is dedicated to Information Policy and Communication Media. The potential of its nodes in establishing communication with the rest of the network is limited, as it presents a low degree of centrality and scarce betweenness. The one wielding the most interconnective capacity and control is actor 1, who is integrated in several groups. This team gains in internal cohesion, and by maintaining its level of productivity, it harvests benefits in terms of popularity.

Group F is ephemeral, dedicated to the Publishing Industry. Its nucleus appears outside the academic department, for which reason the research professor involved would belong to a different department. The actors are capable of integration in external groups, yet it is clearly a circumstantial strategy, as the link is not preserved over time.

In the second output period, Group G appears for the first time. It is a numerous and diversified group. We detect a dense nucleus consisting of eight DHUBI researcher joined by several subgroups with actors from other categories. The thematic axis that goes through it, explaining the existence of the different connected subgroups, is Evaluation: of libraries, of collections, of science, etc.

Finally, Group H is only distinguished in the last period, and is dedicated to the subject matter Archives. It is small in size and has an interdisciplinary nature.

Discussion

Regarding the delimitation of groups

Overall, less cohesion is observed in the output networks than in the input networks analyzed, as the relations established through joint participation in a project means that all the actors are interconnected. Contrariwise, in coauthorship, even if it is reasonable to expect that there will be collaboration among the participants in a single common project, this is not always true. Thus, we see that input groups present a better, clearer delimitation and are easier to identify than the output groups. Because the relationships of coauthorship are not the sole result of joint participation, points of collaboration may go beyond participation in formal research projects; it would be interesting to look further into the origin of these links, which may have to do with assignments of departmental chairs, or the relations between doctoral students and fellows and their mentors or thesis directors, among others. Another possible explanation is that it is unlikely to find publications coauthored by "all" the participants in a project, especially when the input groups are large in size. In this sense, we must bear in mind the division of labor and the specialization of the persons who may take part in different stages of a project, with distinct tangible results of their tasks. At the same time, we must remember that the results of a project do not necessarily take shape as a publication, a limitation to be assumed when adopting coauthorship as a unit of analysis for study.

About the dynamic composition of the groups

Some groups disappear and others persevere. Those that endure and keep a group identity are, in general, the researchers who fulfil the function of directing projects, as well as some DHUBI researchers closely related with these directors; whereas other members have a sporadic participation, tied to a certain period of time. This is the case essentially of the undergraduate and grad students and of researchers from other disciplines, who appear to be more related with specific projects than with stable groups. Meanwhile, the appearance of new groups could be explained by new professors with research tasks joining the academic faculty, which would give rise to the opening of new research lines and the gathering of new actors with similar interests and the rotation of other groups over time.

In the output networks, there is quite a clear evolution over time in the weight of the actors in terms of production. The size of the nodes reveals that the ones publishing most in the first period (44 and 62) later give way to other protagonist nodes (48 and 58) in the intermediate stages of their research careers. In other words, researchers approaching the end of their working careers may be less productive. This is one dynamic aspect of research groups: the transfer of knowledge to later generations of researchers.

Finally, it is interesting to note the gradual increase in the number of actors, more obvious in input than in the output picture, and variations in the presence of different actor categories. Output mostly involves professionals, with a considerable contribution by grad/undergraduate students, and there is a sharp decline in disciplines, with increasing participation of researchers from other disciplines.

Group design

For the time period analysed here, eight groups of differing size and make-up were identified, having different strategies of configuration: some take in young researchers, others are more interdisciplinary, and others have the capacity of international projection. Group character may be influenced by the thematic profile of the individual researchers themselves, as the groups that take on interdisciplinary topics tend to have researchers from other areas, unlike the groups who explore topics specifically pertaining to LIS. Interesting in this sense is the marked interdisciplinary nature in the configuration of the input groups as opposed to its absence in the output. This may be an indication of some strategy behind group configuration. As for institutional origin, there are two apparent trends. Some groups are more endogamous, drawing borders around the department per se, whereas others are associated with external LIS researchers, either national or foreign. Although the indicators used do not allow us to conclude that these factors have an impact on group productivity, we believe that it may influence prestige, as measured by citations received for the published works; this is a notion we will examine in future studies.

The professional category also seems to be an important factor in group design. A look at the time periods established here reveals an important discrepancy regarding the presence of professors in input and output. This finding suggests that some groups stem from coauthored publications, to later on become integrated in joint research projects. For instance, our group G appears to have followed this developmental path. Moreover, the teachers tend to be central figures in the transfer and interchange of information in the network. This is especially true of the input networks, as generally the persons soliciting projects/funding are the more consolidated researchers, with sound CVs that act as a guarantee for obtaining the assignment requested.

Conclusions

Given the complexity of the type of information studied, before tracing any conclusions we should clarify that here we do not take into account the social aspects which may also influence knowledge generation. The proposal focuses on results that can be quantified, to compare two component stages in the scientific process. Our findings show the method to be suitable for delimiting groups, identifying their members, and characterizing actors according to their category, institutional affiliation and disciplinary field. The larger picture conjured up by these aspects allows one to make inferences about the roles played by actors and research groups. Furthermore, the input-output comparative approach broadens the information base and makes it possible to follow individual careers and group dynamics over time. This affords new standpoints for interpreting scientific collaboration at the micro level, always a key factor in the management, promotion and evaluation of researchers and projects.

With regard to interdisciplinarity and the national or international profile in group design, we have demonstrated that belonging to different institutions and areas can influence the concession of projects (input) as well as the publication of results (output). Furthermore, there is an apparent relationship between the composition of the input groups and that of the output groups. Those who work on a team both in input and in output and endure over time, maintaining an identity regardless of some partial exchange of actors, are the researchers best positioned for competition in the allocation of projects and funding, and in the evaluation of results. Yet there are output actors who would have gone undetected if it were not for the fact that we used the CV as a source of information, it being more exhaustive than other records (i.e. bibliographic databases such as Web of Science or Scopus). We propose that studies advance in the detection of such groups using other informational sources. Such information is relevant for assessing social capital when configuring research groups, or appraising individual or group projection.

The subject area of specialization is likewise important, since it affects the patterns of publication and collaboration. In the case of LIS we can speak of distinct research fronts in which patterns may differ, as the literature confirms. The effect of specialized area is, then, another facet to take into consideration for any micro-level evaluation. While the forming of groups and collaborative work may be incentivated from the input standpoint (whether regarding national or institutional policy), co-authored output tends to be penalized, above all in the social sciences and humanities, perhaps due to unfamiliarity with or over-generalization of the dynamics of knowledge production. The implications of different means of financing and evaluating has been addressed in previous studies, where the unfairness of the system has been brought to light along with certain "good" publishing practices (Sanz Menéndez, 2001; Moed, 2008; Perianes, 2009). Therefore, the agencies that finance research should periodically revise the systems of evaluation that oversee each discipline, and which ultimately depend on the public policies governing science and technology of the country or institution in question. Such review should take into account the indicators habitually used (number of publications and journal impact), and should also be permeable to the incorporation of new criteria, methods or indicators, such as the ones put forth in this study. The proposed methodology, in this sense, could be useful in decision-making stages, in order to discern individual research profiles —not just the figures on publications and impact, but also the capacity for establishing contacts for writing up projects and configuring research teams, and then again in coordinating groups when the time comes to publish the results of joint efforts.

The role of the actors in the two phases of the research process leads to some interesting observations. In general, those occupying more central positions do so because of their capacity to establish connections as well as their power of intermediation and their closeness with the rest of the nodes. However, the implications are not the same on both sides of the coin; it is not always the same actors who exert greatest influence in input and then again in output. There is a need to appraise the consequences of this phenomenon in face of feedback in the form of funding and accreditation of new projects. In structural terms, both in input and in output we see that the researchers who attain greatest popularity are the ones who have the highest nodal degrees and clustering coefficients. The best connected and with greatest power of collaboration with other researchers not only achieve better group cohesion, but also manage to publish more. Meanwhile, those nodes with a high

betweenness normally have high production as well. This benefits collaboration, but not so much at the group level as at the individual level. Further, the research groups who have a strong node in terms of centrality seem to benefit in terms of opportunities. It would certainly appear that an enhanced capacity for setting up networks translates as greater network size and productivity during both stages of the research process. Yet to support this hypothesis we would need more solid evidence, especially involving groups of diverse disciplinary domains.

All the above goes to show that analysis of groups using a comparative perspective of input-output constitutes a novel lens for the study of formal collaborative relations over the different stages of the research process. This method allows us to detect strengths and weaknesses at the individual and group levels, and analyze collaboration as a process inherent to scientific activity that should be acknowledged in all realms, from accreditation of projects to the evaluation of results.

From the methodological viewpoint, our work demonstrates that the complementary use of relational analysis, bibliometrics and the opinion of experts_stands as a powerful tool for the study of patterns governing research group composition and dynamics. This is because it provides new knowledge and aids in the interpretation of work habits of researchers and the networks of collaboration that they configure. The contribution of experts in the elaboration and discussion of methodology and results can be seen as a very important aspect to bear in mind. In the end, experts will be the ones to support or reject the results that have been quantified for analysis.

Finally, we emphasize the need to more deeply explore network structures and the associated bibliometric indicators, both relational and hybrid ones, as a means of advancement in the analysis of scientific activity and production. The implications of group structures are far-reaching and difficult to grasp and appraise. Yet scientific policy and decision-making will always rely on an objective body of data regarding the scientific and technological activity of institutions.

Acknowledgements

The authors would like to thank María Benavent Pérez, Carlos Olmeda Gómez, Antonio Perianes Rodríguez, Benjamín Vargas Quesada and Elena Castro Martínez for their corrections and recommendations. This work was made possible in part through funding by the CSIC in the framework of the project «Generación de herramientas cienciométricas para el análisis de la colaboración científica» (Proyecto Intramural CSIC 200810I210).

References

Barabási, A. L.; Jeong, H.; Néda, Z.; Ravasz, E.; Schubert, A.; Vicsek, T. (2002). Evolution of the social network of scientific collaborations. Physica A, 311, 590-614.

Beaver, D. d. B., & Rosen, R. (1978). Studies in Scientific Collaboration: Part I. The Professional Origins of Scientific Coauthorship. Scientometrics, 1, 65-84

Bozeman, B. (2005). La problemática contemporánea de la aplicación e institucionalización de la evaluación de la ciencia, la tecnología y la innovación. SECTIP Taller "Evaluación de Resultados e Impacto de la

Ciencia, la Tecnología y la Innovación". Buenos Aires: Ministerio de Educación, Ciencia y Tecnología. Secretaría de Ciencia, Tecnología e Innovación Productiva. http://www.secyt.gov.ar/publicaciones/Taller_evaluacion_impactos_cyt.pdf.

Cabo, P.G. (1997). The knowledge network. European subsidized research and development cooperation. University of Groningen. Dissertation. http://dissertations.ub.rug.nl/FILES/faculties/management/1997/p.g.cabo/titlecon.pdf

Caníbano, C., & Bozeman, B. (2009). Curriculum vitae method in science policy and research evaluation: the state-of-the-art. Research Evaluation, 18(2), 86-94

Chinchilla-Rodríguez, Z., Moya-Anegón, F., Vargas-Quesada, B., Corera-Álvarez, E., Hassan-Montero, Y., (2008). Inter-institutional scientific collaboration: an approach from social network analysis. First Europe-Latin American Conference on Science and Innovation Policy 2008. Mexico City, 24-26 September

Cohen, J. E. (1991). Size, age and productivity of scientific and technical research groups. Scientometrics, 20(3), 395-416

Colciencias. (2006). Índice para la medición de grupos de investigación, tecnológica o de innovación. http://www.colciencias.gov.co/portalcol/downloads/archivosSoporteConvocatorias/1448.pdf. Accessed 10 November 2009.

Etzkowitz, H. (1992). Individual investigators and their research groups. Minerva, 30, 28-50.

Gaete Fiscella, J. M., & Vázquez, J. I. (2008). Conocimiento y estructura en la investigación académica: una aproximación desde el análisis de redes sociales. Redes: Revista Hispana Para El Análisis De Redes Sociales, 14(5). http://revista-redes.rediris.es/pdf-vol14/vol14_5.pdf Accessed 5 October 2009

Gibbons, M., et al. (1997). La nueva producción del conocimiento: La dinámica de la ciencia y la investigación en las sociedades contemporáneas. Barcelona: Ediciones Pomares-Corredor.

Girvan, M., & Newman, M.E.J. (2002). Community structure in social and biological networks. PNAS, 99(2), 7821-7826

Glänzel, W., & Schubert, A. (2004). Analyzing scientific networks through co-authorship. In: H. F. Moed et al. (Eds.). Handbook of quantitative science and technology research. The Netherlands: Kluwer Academic Publishers.

Herrero Solana, V., & Moya Anegón, F. (2009). Redes de coautoría del Departamento de Biblioteconomía y Documentación de la Universidad de Granada (1982-2006). In C. García Caro, & J. Vílchez Prado (Coords.), Homenaje a Isabel de Torres Ramírez: estudios de documentación dedicados a su memoria (pp. 323-332). Granada: Universidad de Granada

Hu, C., & Racherla, P. (2008). Visual representation of knowledge networks: A social network analysis of hospitality research domain. International Journal of Hospitality Management, 27, 302-312

Izquierdo, L. R., & Hanneman, R. (2006). Introduction to the Formal Analysis of Social Networks Using Mathematica. http://www.luis.izquierdo.name. Accessed 12 January 2010.

Kamada, T., & Kawai, S. (1989). An Algorithm for Drawing General Undirected Graphs. Information Processing Letters, 31, 7-15.

Kretschmer, H.; Aguillo, I. (2004). Visibility of collaboration on the Web. Scientometrics, 61(3), 405-426.

Moed, H.F. (2008). UK Research Assessment Exercises: Informed judgments on research quality or quantity? Scientometrics, 74, 141-149.

Moya-Anegón, F., Vargas-Quesada, B., Chinchilla-Rodríguez, Z., Corera-Álvarez, E., González-Molina, A., Muñoz-Fernández, F. J., Herrero-Solana, V. (2007). Visualizing the Marrow of Science. Journal of The American Society for Information Science and Technology (Jasist), 58 (14), 2167-2179.

Newman, M. E. J. (2001). The structure of scientific collaboration networks. Proceedings of the National Academy of Science of the United States, 98(2), 404-409.

Newman, M. (2004). Who is the best connected scientist? A study of scientific coauthorship networks. In: E. Ben-naim; H. Frauenfelder; Z. Toroczkai (Eds.). Complex Networks. Springer.

Onofrio, M. G. (2009). The public CV database of Argentine researchers and the 'CV-minimum' Latin-American model of standarization of CV information for R&D evaluation and policy-making. Research Evaluation, 18(2), 95-103

Otte, E.; Rousseau, R. (2002). Social network analysis: a powerful strategy, also for the information sciences. Journal of Information Science, 28(6), 443-455

Perianes-Rodríguez, A. (2007). Análisis y Visualización de Redes de Colaboración Científica. Grupos de Investigación en la Universidad Carlos III (ISI, Web of Science, 1990-2004). [Ph.D. Thesis]. Madrid: Universidad Carlos III. 405 p.

Perianes-Rodríguez, A., Chinchilla-Rodríguez, Z., Vargas-Quesada, B., Olmeda-Gómez, C., Moya-Anegón, F. (2009). Synthetic hybrid indicators based on scientific collaboration to quantify and evaluate individual research results. Journal of Informetrics, 3(2), 91-101.

Perianes-Rodríguez, A. Olmeda-Gómez, C., Moya-Anegón, F. (2010). Detecting, identifying and visualizing research groups in co-authorship networks. Scientometrics, 82(2), 307-319.

Rey-Rocha, J., Martin-Sempere, M., Sebastian, J. (2008). Estructura y dinámica de los grupos de investigación, 184(732), 743-757

Sanz-Casado, E., Conforti, N., et al. (2004). Estudio de la colaboración científica de los Departamentos de la Facultad de Humanidades de la Universidad de Mar del Plata, durante el período 1998-2001. VI Taller de Indicadores de Ciencia y Tecnología RICYT/CITED SECYT-ARGENTINA

Sanz Menéndez, L. (2001). Indicadores Relacionales y Redes Sociales en el Estudio de los Efectos de las Políticas de Ciencia y Tecnología. Cuadernos de Indicios, 1, 79-95

Sonnenwald, D. (2007). Scientific Collaborations. Annual Review of Information Science and Technology, 41, 643-681

Van der Besselaar, P., & Leydesdorff, L. (2009). Past performance, peer review and project selection: a case study in the social and behavioural sciences. Research Evaluation, 18(4), 273–288

Vargas-Quesada, B., Minguillo, D., Chinchilla-Rodríguez, Z., Moya-Anegón, F. (2010) Estructura de la colaboración científica española en Biblioteconomía y Documentación (Scopus 1999-2007). Revista Interamericana de Bibliotecología, 33(1), 105-123, enero-junio.

Wagner, C. S., & Leydesdorff, L. (2005). Network structure, self-organization, and the growth of international collaboration in science. Research Policy, 34, 1608-1618

Zulueta, M. A., Cabrero, A., Bordons, M. (1999). Identificación y estudio de grupos de investigación a través de indicadores bibliométricos. Revista Española de Documentación Científica, 23(3), 333-347

Annex 1. Indicators of centrality and cohesion of the input networks for the time periods of study

actor	Input network 2000-2002					Input network 2003-2005					Input network 2006-2008				
	% Degree	% Betweeness	% Closeness	Clustering Coeff.	N Proy	% Degree	% Betweeness	% Closeness	Clustering Coeff.	N Proy	% Degree	% Betweeness	% Closeness	Clustering Coeff.	N Proy
1	**27,8**	0,0	31,6	0,56	1	**41,9**	**23,0**	**55,4**	0,24	3	**47,6**	8,7	46,2	**0,71**	3
2	**27,8**	0,0	36,4	0,28	1	**35,5**	**4,9**	**54,4**	0,30	1	**35,7**	0,0	36,5	0,52	2
3	--	--	--	--	--	--	--	--	--	--	**38,1**	0,0	36,5	0,34	1
4	11,1	0,0	15,8	0,22	1	--	--	--	--	--	**47,6**	2,7	46,2	**0,78**	3
6	--	--	--	--	--	--	--	--	--	--	**40,5**	0,1	39,6	0,41	1
7	--	--	--	--	--	22,6	0,0	**50,0**	0,09	1	--	--	--	--	--
10	--	--	--	--	--	--	--	--	--	--	**28,6**	0,0	33,1	0,19	1
13	--	--	--	--	--	**35,5**	**4,9**	**54,4**	0,30	1	**45,2**	0,2	46,2	0,42	1
15	--	--	--	--	--	22,6	0,0	**50,0**	0,08	1	--	--	--	--	1
16	--	--	--	--	--	22,6	0,0	**50,0**	0,09	1	11,9	0,0	32,6	0,03	--
17	22,2	0,0	33,8	0,13	1	--	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	**35,5**	0,0	**54,4**	0,30	1	**45,2**	1,3	46,2	0,42	1
21	11,1	0,0	15,8	0,22	1	--	--	--	--	--	7,1	0,0	31,6	0,00	1
22	--	--	--	--	--	**58,1**	**50,3**	**70,5**	**0,62**	2	**45,2**	1,3	46,2	0,42	1
23	--	--	--	--	--	**35,5**	0,0	**54,4**	0,30	1	**45,2**	1,3	44,7	0,42	1
24	--	--	--	--	--	22,6	0,0	**50,0**	0,08	1	--	--	--	--	--
25	**27,8**	0,0	31,6	0,56	1	16,1	0,0	37,8	0,07	1	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	7,1	0,0	31,6	0,01	1
29	--	--	--	--	--	--	--	--	--	--	**50,0**	**27,9**	**48,8**	0,68	2
30	**27,8**	0,0	36,4	0,28	1	**35,5**	0,0	**54,4**	0,30	1	**50,0**	**15,3**	47,7	**0,76**	2
32	--	--	--	--	--	--	--	--	--	--	11,9	0,0	31,6	0,00	1
34	**27,8**	0,0	31,6	0,56	1	**32,3**	0,0	**52,5**	0,16	2	**50,0**	**14,4**	47,2	0,68	2
35	--	--	--	--	--	--	--	--	--	--	**40,5**	0,0	39,6	0,41	1
38	--	--	--	--	--	--	--	--	--	--	11,9	0,0	31,6	0,00	1
39	--	--	--	--	--	9,7	0,0	36,9	0,01	1	11,9	0,0	31,6	0,00	1
40	--	--	--	--	--	**35,5**	0,0	**54,4**	0,30	1	**45,2**	1,3	44,7	0,42	1
41	--	--	--	--	--	--	--	--	--	--	**40,5**	0,0	36,8	0,41	1
43	22,2	0,0	33,8	0,13	1	22,6	0,0	41,9	0,09	1	**59,5**	**50,2**	**55,3**	0,52	2
44	22,2	0,0	33,8	0,13	1	22,6	0,0	41,9	0,09	1	23,8	0,0	32,8	0,02	2
45	--	--	--	--	--	**35,5**	0,0	**54,4**	0,30	1	**45,2**	1,3	44,7	0,42	1
47	--	--	--	--	--	22,6	0,0	41,9	0,08	1	--	--	--	--	--
48	--	--	--	--	--	--	--	--	--	--	**50,0**	**14,3**	47,2	0,68	2
49	--	--	--	--	--	--	--	--	--	--	**28,6**	0,0	33,1	0,19	1
50	--	--	--	--	--	--	--	--	--	--	**28,6**	0,0	33,1	0,19	1
51	--	--	--	--	--	**35,5**	0,0	**54,4**	0,30	1	**45,2**	0,1	44,7	0,42	1
53	**27,8**	0,0	31,6	0,56	1	**32,3**	0,0	**52,5**	0,16	2	--	--	--	--	--
54	--	--	--	--	--	--	--	--	--	--	11,9	0,0	31,6	0,00	1
55	--	--	--	--	--	22,6	0,0	41,9	0,08	1	--	--	--	--	--
56	--	--	--	--	--	**35,5**	0,0	**54,4**	0,30	1	**45,2**	0,1	42,9	0,42	1
57	--	--	--	--	--	9,7	0,0	36,9	0,01	1	11,9	0,0	31,6	0,00	1
58	--	--	--	--	--	--	--	--	--	--	**50,0**	**10,1**	47,2	**0,85**	3
59	--	--	--	--	--	--	--	--	--	--	**40,5**	0,0	36,5	0,41	1
60	--	--	--	--	--	--	--	--	--	--	**50,0**	**8,7**	47,2	0,68	2
61	--	--	--	--	--	**35,5**	0,0	**54,4**	0,30	1	**45,2**	0,1	40,8	0,42	1
62	**50,0**	**13,1**	52,6	**1,00**	2	**58,1**	**36,1**	**62,0**	**0,73**	2	**35,7**	0,0	36,2	0,52	2
63	--	--	--		--	9,7	0,0	36,9	0,01	1	11,9	0,0	31,6	0,00	1
67	**27,8**	0,0	36,4	0,28	1	22,6	0,0	41,9	0,09	1	21,4	0,0	32,6	0,05	3
68	--	--	--		--	--	--	--	--	--	**50,0**	1,2	46,0		2
69	11,0	0,0	15,8	0,22	1	--	--	--	--	--	7,1	0,0	31,6	0,00	1
70	22,0	0,0	33,8	0,1	1	22,6	0,0	41,9	0,09	1	23,8	0,0	32,8	0,02	2
72	27,8	0,0	31,6	0,56	1	16,1	0,0	37,8	0,07	1	--	--	--	--	--
74	--	--	--	--	--	22,6	0,0	41,9	0,09	1	23,8	0,0	32,8	0,02	2
75	**27,8**	0,0	36,4	0,28	1	--	--	--	--	--	--	--	--	--	--
76	**27,8**	0,0	36,4	0,28	1	--	--	--	--	--	--	--	--	--	--
78	**27,8**	0,0	31,6	0,56	1	16,1	0,0	37,8	0,07	1	--	--	--	--	--
Arithmetic Mean	27,8	0,7	13,9	0,36	1,05	28,2	3,7	48,6	0,19	1,19	28,2	3,7	48,6	0,34	1,47
Median	8,3	0,0	0,8	0,28	1,00	22,6	0,0	50,0	0,09	1,00	22,6	0,0	50,0	0,41	1,00
Standard desviation	27,8	2,9	8,4	0,22	0,23	11,7	11,1	8,2	0,16	0,47	11,7	11,1	8,2	0,27	0,67
Variability Coeff.	100,0	423,0	59,9	*		41,3	298,5	16,9	*		41,3	298,4	16,9	*	
Centrality	27,8	13,1	*	*		31,8	48,1	54,6	*		31,8	48,10	45,9	*	
Density		45,0					44,0					34,0			

Annex 2. Indicators of centrality and cohesion of the output by time periods

actor	Output network 2001-2003						Output network 2004-2006						Output network 2007-2009					
	% Degree	% Betweeness	% Closeness	Clustering Coeff.	ndoc journal	ndoc proceed.	% Degree	% Betweeness	% Closeness	Clustering Coeff.	ndoc journal	ndoc proceed.	% Degree	% Betweeness	% Closeness	Clustering Coeff.	ndoc journal	ndoc proceed.
1	**16,1**	0,0	29,2	0,30	--	3	**31,4**	**21,1**	**54,7**	0,23	1	3	**21,6**	**10,7**	**24,8**	0,09	1	3
2	**22,6**	0,5	**37,5**	0,24	2	3	11,4	0,0	35,8	0,04	--	3	**27,0**	0,4	**25,1**	0,18	1	2
4	0,0	0,0	0,0	0,00	--	2	**25,7**	**10,4**	**45,8**	0,28	2	7	8,1	0,0	17,6	0,00	--	1
5	3,2	0,0	6,3	0,00	--	1	--	--	--	--	--	--	10,8	0,0	19,9	0,02	--	1
6	--	--	--	--	--	--	--	--	--	--	--	--	8,1	0,0	13,5	0,00	--	1
7	--	--	--	--	--	--	**20,0**	0,0	**38,0**	0,26	2	1	--	--	--	--	--	--
8	3,2	0,0	34,2	0,00	--	1	--	--	--	--	--	--	--	--	--	--	--	--
9	3,2	0,0	24,9	0,00	--	1	--	--	--	--	--	--	8,1	0,0	20,6	0,00	--	1
10	--	--	--	--	--	--	0,0	0,0	0,0	0,00	1	--	5,4	0,0	0,0	0,00	--	2
11	9,7	0,0	25,4	0,09	1	--	--	--	--	--	--	--	--	--	--	--	--	--
13	--	--	--	--	--	--	**22,9**	**5,9**	**45,2**	0,10	--	4	**13,5**	0,0	21,3	0,02	--	1
14	--	--	--	--	--	--	--	--	--	--	--	--	10,8	0,0	21,0	0,01	--	2
16	--	--	--	--	--	--	**28,6**	**16,6**	**48,7**	0,24	3	2	**29,7**	0,0	**26,3**	0,27	--	1
17	12,9	0,0	40,0	0,04	1	2	--	--	--	--	--	--	--	--	--	--	--	--
18	--	--	--	--	--	--	5,7	0,0	32,1	0,00	--	1	**13,5**	0,0	21,7	0,02	1	2
21	--	--	--	--	--	--	5,7	0,0	31,5	0,01	1	2	--	--	--	--	--	--
22	6,5	0,0	34,7	0,00	--	3	14,3	1,7	**43,9**	0,03	1	2	**21,6**	0,0	**23,0**	0,09	1	--
25	**16,1**	0,0	29,2	0,30	--	3	--	--	--	--	--	--	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	--	--	**13,5**	0,0	21,3	0,02	--	1
27	3,2	0,0	30,3	0,00	--	1	2,9	0,0	27,8	0,00	1	--	8,1	0,0	16,7	0,00	3	2
28	6,5	0,0	34,7	0,00	--	1	--	--	--	--	--	--	--	--	--	--	--	--
29	0,0	0,0	0,0	0,00	1	--	**25,7**	**3,8**	**45,8**	0,30	--	6	**18,9**	0,6	**22,9**	0,10	--	3
30	**19,4**	0,0	**36,9**	0,19	1	1	--	--	--	--	--	--	**37,8**	**2,2**	**32,5**	**0,69**	1	1
31	--	--	--	--	--	--	5,7	0,0	34,6	0,00	--	1	8,1	0,0	20,6	0,00	--	1
32	--	--	--	--	--	--	--	--	--	--	--	--	10,8	0,0	21,0	0,01	--	1
33	9,7	0,0	25,4	0,09	1	--	--	--	--	--	--	--	--	--	--	--	--	--
34	**19,4**	**23,7**	**40,0**	0,09	--	4	**20,0**	0,0	**44,5**	0,20	--	3	8,1	0,0	21,3	0,00	1	4
36	--	--	--	--	--	--	5,7	0,0	32,1	0,00	1	--	10,8	0,0	21,7	0,02	3	--
37	--	--	--	--	--	--	5,7	0,0	32,1	0,00	--	1	**13,5**	0,0	21,7	0,02	1	2
39	--	--	--	--	--	--	5,7	0,0	35,4	0,00	2	3	**13,5**	0,0	18,1	0,14	1	4
42	--	--	--	--	--	--	14,3	2,6	**42,7**	0,03	--	4	**18,9**	**5,7**	**23,4**	0,07	--	2
43	12,9	0,0	40,0	0,04	1	2	**20,0**	0,0	**38,0**	0,26	1	1	--	--	--	--	--	--
44	**22,6**	**31,4**	**45,4**	0,08	8	4	**25,7**	**10,6**	**39,0**	0,35	6	2	**27,0**	**2,0**	**27,6**	0,32	5	4
46	--	--	--	--	--	--	--	--	--	--	--	--	**27,0**	0,0	**26,3**	0,27	1	1
48	6,5	0,0	34,7	0,00	--	1	**31,4**	**20,2**	**47,2**	**0,37**	2	2	**29,7**	**21,5**	**32,9**	0,08	4	6
49	--	--	--	--	--	--	11,4	0,0	**39,0**	0,03	--	1	--	--	--	--	--	--
52	--	--	--	--	--	--	5,7	0,0	32,1	0,00	1	--	10,8	0,0	21,7	0,02	2	--
53	**16,1**	0,0	29,2	0,30	--	3	--	--	--	--	--	--	--	--	--	--	--	--
58	**19,4**	**20,4**	**34,2**	0,11	3	2	**20,0**	0,0	**44,5**	0,20	--	3	**29,7**	**15,1**	**31,2**	0,19	--	10
60	3,2	0,0	6,3	0,00	--	1	**25,7**	**6,4**	**51,9**	0,21	--	4	**21,6**	**4,7**	**28,9**	0,10	--	3
61	**19,4**	0,0	**36,9**	0,19	1	1	--	--	--	--	--	--	**21,6**	0,0	**23,0**	0,09	1	--
62	**48,4**	**56,2**	**54,9**	**0,55**	3	8	**31,4**	**12,9**	**50,3**	0,31	1	6	**27,0**	0,4	**25,1**	0,18	1	2
63	--	--	--	--	--	--	0,0	0,0	0,0	0,00	--	2	**16,2**	0,0	18,1	0,14	2	2
64	--	--	--	--	--	--	5,7	0,0	35,4	0,00	--	1	**13,5**	0,0	18,1	0,14	--	1
65	--	--	--	--	--	--	11,4	0,0	**39,0**	0,03	--	1	--	--	--	--	--	--
66	9,7	0,0	25,4	0,09	1	--	--	--	--	--	--	--	--	--	--	--	--	--
67	**19,4**	0,0	**36,9**	0,19	2	1	**28,6**	3,3	**41,0**	**0,42**	1	4	**40,5**	**4,5**	**36,8**	**0,97**	1	4
68	--	--	--	--	--	--	**37,1**	**20,4**	**56,7**	**0,37**	--	4	**13,5**	3,0	17,4	0,00	--	2
69	--	--	--	--	--	--	5,7	0,0	31,5	0,01	1	2	--	--	--	--	--	--
70	12,9	0,0	40,0	0,04	4	2	**20,0**	0,0	**38,0**	0,26	3	2	**24,3**	0,0	**26,3**	0,27	--	3
71	--	--	--	--	--	--	2,9	0,0	27,8	0,00	2	1	--	--	--	--	--	--
72	**16,1**	0,0	29,2	0,30	--	2	--	--	--	--	--	--	--	--	--	--	--	--
73	--	--	--	--	--	--	--	--	--	--	--	--	**29,7**	0,0	**26,3**	0,27	--	1
74	6,5	0,0	32,4	0,01	--	1	**20,0**	0,0	**38,0**	0,26	1	1	**29,7**	0,0	**26,3**	0,27	--	1
75	**19,4**	0,0	**36,9**	0,19	1	1	--	--	--	--	--	--	--	--	--	--	--	--
76	**19,4**	0,0	**36,9**	0,19	1	1	--	--	--	--	--	--	--	--	--	--	--	--
77	--	--	--	--	--	--	11,4	0,0	**39,0**	0,03	--	1	--	--	--	--	--	--
78	**16,1**	0,0	29,2	0,30	--	3	--	--	--	--	--	--	--	--	--	--	--	--
Arithmetic Mean	13,1	4,1	30,5	0,12	2,00	2,11	15,7	3,8	37,75	0,14	1,70	2,53	11,5	1,9	22,7	0,13	1,72	2,29
Median	12,9	0	34,2	0,09	1,00	2,00	14,3	0,0	38,48	0,04	1,00	2,00	8,1	0,0	21,7	0,09	1,00	2,00
Standard desviation	9,3	12,0	12,1	0,13	1,86	1,52	10,4	6,5	11,6	0,14	1,22	1,65	8,2	4,4	6,0	0,19	1,23	1,83
Variability Coeff.	71,2	289,4	39,6	*	93,1	72,3	66,2	173,0	30,7	*	71,7	65,0	71,1	239,5	26,4	*	71,3	80,0
Centrality	37,6	53,8	*	*			22,1	17,8	*	*			24,9	20,1	*	*		
Density		16,0						19,0						13,0				