Hybrid indicators based on scientific collaboration to quantify and qualify individual research outputs

Abstract: governmental initiatives around scientific policy have progressively raised collaboration to priority status. In this context, a need has arisen to broaden the traditional approach to the analysis and study of research results by descending to the group or even the individual scale and supplementing the output-, productivity-, visibility- and impact-based focus with new measures that emphasize collaboration from the vantage of structural analysis. To this end, the present paper proposes new hybrid indicators for the analysis and evaluation of individual research results, popularity and prestige, that combine bibliometric and structural aspects. A case study was conducted of the nine most productive departments in Carlos III University of Madrid. The findings showed hybridization to be a tool sensitive to traditional indicators, but also to the new demands of modern science as a self-organized system of interaction among individuals, furnishing information on researchers' environments and the behaviour and attitudes adopted within those environments.

1 Background

Traditionally, most studies on scientific collaboration have been geared to analyzing output, be it international or domestic, does a given scientific discipline or a research institution. Studies on smaller units such as departments or research groups are less common [Bordons M and Zulueta MA, 1997], [Zulueta MA et al., 1999].

Collaboration has been intrinsic to scientific activity. Collaboration is a complex development, a way to exchange information, to work together, to use resources rationally and to perpetuate communities of scientists. All of these reasons taken together, or any combination thereof, make collaboration more a necessity than a choice.

It is in this context where the necessity for extending the traditional approach of the assessment of research outputs emerges, descending to the group level, even to the individual level, in order to improve the approaches based on production, productivity, visibility and impact with new measures focused on emphasize collaborative aspects through structural analysis [Calero C et al., 2006], [Kretschmer H, 1997], [Moed HF et al., 1998], [van Leeuwen TN and Moed HF, 2005].

2 Application

Our objective is developing hybrid indicators in a micro level with which to synthesize bibliometric and structural approaches. These new indicators are complementary to the traditional simple indicators used in analysis of the research activity [Merton RK, 2000], [Zitt M, 2006].

3 Methodology

3.1. Data and data refinement

A relational database built with records for the period 1990-2004 taken from the Web of Science (SCI-expanded, SSCI and A&HCI), in which at least one author was affiliated with the Carlos III University (UC3M), was used for the bibliometric analysis of the research conducted in the institution. The Institute for Scientific Information assigns each journal one or several subject categories. Journal Citation Reports (JCR) for both Science and Social Science for the years analyzed was the reference used to assign each paper a subject (ISI category).

3.2. Popularity and prestige indexes

Combining bibliometric data with structural analysis appears to improve our understanding of the structure and dynamics of networks [Mählck P and Persson O, 2000].

Our innovative proposal consists of a combination of bibliometric and structural indicators well known: clustering coefficient (CC), production (number of documents) and visibility (number of citations) of each actor:

Popularity Index	Prestige Index
CC(v) x ndoc (v)	CC(v) x ncitations (v)

4 Results

The new formulas for characterizing researchers seem to be valid and effective assessment instruments for identifying excellent authors, i.e., not only the most productive or visible ones, but those who are able to pool their efforts and work in communities. Their excellence is based on both their individual worth and their ability to teamwork with partners, with whom they can generate new, high-quality scientific, technical and/or technological knowledge and obtain additional resources that ensure that further research can be conducted.

Rank	Position	Ndoc	Citations	NIF	Degree	Betweenness	Cluster Coef	Popularity	Prestige
1	Full Professor	36	40	1.17	0.08	0.02793	0.030	1.10	1.22
2	Associate Professor	30	61	1.34	0.30	0.43322	0.608	18.25	37.12
3	PhD Assistant	29	53	1.21	0.17	0.13694	0.069	2.15	3.68
4	Associate Professor	26	79	1.25	0.25	0.27295	0.141	3.96	11.18
5	No UC3M	25	34	1.18	0.06	0.01297	0.017	0.43	0.58
6	Associate Professor	23	52	1.23	0.14	0.09649	0.049	1.17	2.54
7	Associate Professor	22	46	1.30	0.11	0.14356	0.025	0.58	1.16
8	No UC3M	19	56	1.42	0.12	0.02569	0.066	1.25	3.69
9	PhD Assistant	18	51	1.34	0.15	0.07581	0.066	1.33	3.38
10	Associate Professor	17	23	1.27	0.09	0.07878	0.037	0.67	0.86
11	Associate Professor	15	18	1.20	0.07	0.02338	0.056	0.85	1.01
12	PhD Assistant	15	34	1.32	0.05	0.01604	0.030	0.45	1.03
13	No UC3M	15	39	1.27	0.03	0.00037	0.008	0.13	0.33
14	No UC3M	14	39	1.28	0.02	0.00007	0.006	0.08	0.22
15	No UC3M	13	39	1.28	0.02	0.00007	0.006	0.07	0.22
16	No UC3M	12	33	1.29	0.02	0	0.004	0.05	0.13
17	Full Professor	12	32	1.37	0.15	0.02869	0.142	1.70	4.53

Highest | 2nd highest | 3rd highest

Table 1. Department of Physics. UC3M (2000-2004)

Rank	Position	Ndoc	Citations	NIF	Degree	Betweenness	Cluster Coef	Popularity	Prestige
1	Full Professor	65	43	1.03	0.34	0.323	0.41	28.41	17.80
2	Associate Professor	50	27	1.04	0.23	0.071	0.26	13.29	7.04
3	Associate Professor	26	90	1.19	0.19	0.150	0.16	4.25	14.71
4	Full Professor	20	43	0.93	0.16	0.023	0.37	7.78	15.92
5	Associate Professor	20	2	1.02	0.15	0.075	0.11	2.16	0.22
6	Associate Professor	15	15	0.90	0.12	0.037	0.06	0.84	0.84
7	Associate Professor	15	30	0.94	0.10	0.005	0.16	2.76	4.87
8	Full Professor	15	78	1.38	0.10	0.002	0.16	2.35	12.24
9	Assistant	14	12	1.05	0.09	0.009	0.04	0.60	0.52
10	PhD Assistant	14	2	1.09	0.08	0.009	0.03	0.43	0.06

Highest | 2nd highest | 3rd highest

Table 2. Department of Materials Science. UC3M (2000-2004)

5 Conclusions

The development of new convergence indicators has made it possible to discover link patterns between actors, invaluable in understanding the individual scope of the issue.

The positions of individuals and their distinguishing characteristics could, then, be determined, through indicators identifying the leading and most prestigious professors, as well as the intermediaries.

These tools are sensitive to traditional indicators but also to the new demands of modern science as a self-organized system of interactions among individuals. They provide information about researchers' environments and about the way they behave in it (always cooperating with the same colleagues within the same lines of research, or working with new scientific partners to seek new challenges, for example). In this new panorama, it is no longer enough to have (papers published or cited); rather, it is necessary to be, from the perspective of the "connecto ergo sum" so aptly coined by Björneborn [2004].

The results obtained emphasize the new concept of science and research, and give the necessary prominence to the degree of cooperation among researchers, until now ignored. They also reliably confirm the importance of collaboration in the management of science and technology policies.

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