A Bibliometric Methodology for Supporting Research Assessment at Individual Level: a Classification Approach

Rodrigo Costas[1], Thed N. van Leeuwen[1] and María Bordons[2]

[1] *costacomesanar@cwts.leidenuniv.nl; leeuwen@fsw.leidenuniv.nl*
CWTS, FSW, Universiteit Leiden, Wassenaarseweg 62A, 2333 AL Leiden (The Netherlands)

[2] *maria.bordons@cchs.csic.es*
Instituto de Estudios Documentales sobre Ciencia y Tecnología (IEDCYT), Center for Human and Social Sciences (CCHS), CSIC, Albasanz 26-28, 28037 Madrid (Spain)

Abstract
This paper describes a general methodology for conducting bibliometric analyses at the micro-level. It combines several indicators grouped into three factors or dimensions which describe different aspects of scientific performance. Different profiles of scientists are described according to their research performance in each dimension. Some results based on the outcomes of the methodology applied to the study of CSIC scientists in three thematic areas in Spain are presented. The main advantages and possibilities of the methodology for supporting research assessment and management are pointed out. The classification approach proposed can be a useful tool for exploring potential determinants of research success.

Introduction
Micro-level analyses are highly demanded by policy makers, research managers and even by researchers themselves. However, bibliometric indicators at micro-level present several limitations and their calculation is a complex task. Special care is required for collecting the data, calculation of indicators and final interpretation of results (Costas & Bordons, 2005). Among the difficulties to be faced in the collection and management of data, we can mention: the lack of normalization of author and center names (Borgman & Siegfried, 1992; Fernandez et al, 1993; Ruiz-Perez et al, 2002); problems in the identification of scientists due to common names (Wooding et al, 2006) or mobility of scientists (Canibano et al, 2008); and inaccuracy of data gathered by databases (Araujo Ruiz et al, 2005).

Another crucial issue is the fact that the abuse and uncritical use of bibliometric indicators at the individual level can cause changes in the behavior of scientists (Weingart, 2005). In this sense, it is important to understand that the introduction of wrong research assessment methodologies and especially the misuse of bibliometric indicators can cause unintended changes in the behaviour of scientists, such as changes in their selection of topics of research (selecting more secure topics and less risky fields, more disciplinary approaches instead of interdisciplinary ones, etc.), fostering quantity instead of quality and encouraging inappropriate publication strategies (massive publication, hyper-authorship, honorific authorship, salami slicing, etc.). In spite of these important warnings, bibliometrics at this level are frequently used from very uncritical perspectives, due to the pressure over the importance of analysing objectively the research performance of scientists. A response from the bibliometric community is necessary in order to prevent negative consequences for science as well as for scientists themselves.

The most common and rational suggestion is to combine different indicators in order to provide larger pictures of the scientific performance of researchers (Martin, 1996; van Leeuwen et al, 2003) and it is also suggested to combine indicators with peer review in what is called "*informed peer review*" processes (Nederhof & van Raan, 1987; Aksnes & Taxt, 2004). It is also crucial to differentiate when analyses are carried out from a "Top Down" or

Proceedings of ISSI 2009, pages 817–828.
Edited by B. Larsen and J. Leta.

"Bottom up" approaches (van Leeuwen, 2007), because the use of the indicators is very different according to these two perspectives. In this line, "Top Down" analyses start from a country, institutional or a scientific field level, and they can "go down" up to the micro-level. However, their utility is only descriptive and never can be used for evaluative purposes. On the other side, "Bottom up" approaches start on the individual level and "go up" up to the level of institutions or even countries. At individual level, "Bottom up" approaches can be used for evaluative purposes as the data has been validated by scientists and there are guarantees that they represent properly their scientific performance. Another important aspect mentioning here is the larger degree of transparency on the latter type of bibliometric studies.

It must be said that, up to the moment, there are not clear methodologies or suggestions on how to use bibliometric indicators at micro-level, neither there are clear conclusions on what bibliometric indicators should be used to support properly the evaluation of scientists and research teams (van Raan, 2005). According to this, there is an important necessity of methodologies and instruments which could support individual research assessment, avoiding as much as possible the limitations previously mentioned; and providing useful and handy information for research managers in order to inform properly their decision processes.

In this paper, a general methodology for informing analysis of research performance of individual scientists is presented, showing its main advantages and properties, by means of its application to the study of a set of scientists working at the Spanish CSIC. In a previous paper (Costas & Bordons, 2007a) a preliminary classificatory scheme for the analysis at micro-level was introduced, now that methodology is improved with the introduction of new indicators and the simplification of the dimensions finally included.

Objectives

The main aim of this paper is to describe a general methodology for obtaining bibliometric indicators useful for the research assessment of individual scientists. Secondary objectives are to detect and to describe different profiles of scientists and to analyze the different scientific classes obtained through classificatory schemes. Special emphasis is put in the identification of Top researchers as well as in the description and study of their main characteristics. In this sense, our aim in not only to provide information on who are the "best" scientists from a bibliometric point of view, but also to determine some of their main features, including those related to personal aspects, such as their age and experience.

Methodology

The starting point of this work is a list of 1064 researchers working at the Spanish National Council for Scientific Research (CSIC). These scientists are organized in three main scientific areas: Natural Resources (349); Biology and Biomedicine (388) and Material Sciences (327). All researchers are included in one of the three scientific professional categories at the CSIC (Tenured Scientists – the basic category; Research Scientists – medium category; and Research Professors – upper category).

For every researcher, all his/her documents have been downloaded to build his/her bibliometric profile. All documents have been considered, including documents published both in Spain and abroad. In this sense, a careful methodology of detecting documents and classifying researchers has been applied; the main steps of this methodology are presented below.

1. *Data downloading and document assignment*

Documents published by these scientists during the period 1994-2004 were downloaded from the Web of Science and gathered in a relational database (Fernández et al, 1993). Almost all scientists were active during the entire 11-year period. For those who joined the institution at any year within the analysed period their production before entering CSIC was collected. To ensure that the whole production of scientists was retrieved all different scientists' signing forms were included in the search strategy following the methodology suggested by Costas & Bordons (2006). A sample of scientists was checked against their CVs on the Internet, and a 98% of accuracy was detected in the document assignment process.

2. Individual bibliometric profiles

For every researcher, a bibliometric profile comprising the following indicators was obtained:

a) Total number of documents (***P***), including all types of documents.
b) Total Number of Citations (***C***), including citations received by documents during the period 1994-2004. Author self-citations have been excluded.
c) Citations per Document (***CPP***), this is the citation per document rate for every researcher.
d) Percentage of Highly Cited Papers (***%HCP***). Highly Cited Papers are those documents whose citations are above the Percentile 80 in their respective research areas.
e) ***h-index***, following Hirsch (2005) methodology.
f) ***Median Impact Factor*** of documents, that is for every researcher the median value of the Impact Factor of their publication journals.
g) Normalized Journal Position (***NJP***), this indicator takes into account the position of journals in descending order of impact factor within WoS subject categories (Bordons & Barrigon, 1992). This is a measure of the average position of the publication journals in their fields.
h) ***CPP/FCSm***, this indicator, suggested by the CWTS in the University of Leiden (van Raan, 2004), measures the impact of a research unit (in this case individual researchers), compared as to the world citation average in the subfields in which the researcher is active.
i) ***JCSm/FCSm***, the impact of the journals in which a research unit has published (the research unit's journal set), compared to the world citation average in the subfields covered by these journals. This is a measure of the real impact of the publication journals within their scientific fields.

For the last two indicators, only documents considered in the WoS as normal articles, letters and reviews (no book reviews) are included and only external citations (citations that are not produced by the authors of the source document) were considered.

3. Indicators reduction

The number of initial indicators has been grouped with Factor Analysis in order to simplify the study (Table 1).

Table 1. Factor Analysis. Rotated component matrix.

	Component		
Indicators	**1**	**2**	**3**
%HCP	.876		
CPP/FCSm	.831		
CPP	.770		
Median Impact Factor		.871	
NJP		.866	
JCSm/FCSm		.765	
P			.975
h-index			.878
C			.775

Indicators were grouped in three factors or dimensions, which explain the 87% of the total variance. The following dimensions were found: 1) One first dimension dealing with the "Observed impact", comprising the percentage of Highly Cited Papers (*%HCP*), the internationally normalized impact (*CPP/FCSm*) and the citations per document rate (*CPP*). 2) The second dimension can be labelled as "Journal Visibility dimension" and includes the Median Impact Factor, the Normalized Journal Position (*NJP*) and the *JCSm/FCSm*. This dimension is very interesting as it includes two general concepts, on the one hand the "sociological" success in selecting journals (trying to publish documents in the best journals of the different fields), and on the other hand the real quality measured through the citations that journals receive in their scientific fields (*JCSm/FCSm*). 3) Finally, the most quantitative dimension ("Production dimension") that is related with the total number of documents (*P*), the total number of citations (*C*) and the h-index. This dimension gives a general idea of the absolute production of scientists.

It is important to highlight that the same analysis has been performed in the three scientific areas, and the same results as regards to reduction of indicators and final dimensions were obtained in the three areas.

4. *Indicator standardization*

Since the different indicators presented above have different scales, standardization is necessary in order to have all of them in the same range of values. Every value of each indicator was divided by the maximum value in that indicator. As a result, all standardized indicators ranged between 0 and 1. Afterwards, the following composite indicators were built for each scientist:

Quantitative dimension= *P*-ST + *C*-ST + *h-index*-ST
Observed Impact dimension= *%HCP*-ST + *CPP*-ST + *CPP/FCSm*-ST
Journal Quality dimension= *Median IF*-ST + *NJP*-ST + *JCSm/FCSm*-ST
("-ST" stands for standardized indicators)

5. *Classification of researchers*

Percentiles 25 and 75 were calculated for each composite indicator and researchers were classified into 3 zones according to the following criteria:

- Zone 1: values lower or equal P25. Final score=1;
- Zone 2: values greater than P25 and lower or equal P75. Final score=2;
- Zone 3: values greater than P75. Final score=3

As a result of this methodology, every scientist was classified according to his/her position (zone 1, 2 or 3) within each dimension (see Table 2).

Table 2. Three-vector scheme for classification of scientists.

Scientists	Production Dimension	Observed Impact Dimension	Journal Quality Dimension
Researcher 1	**3**	**3**	**3**
Researcher 2	**2**	**3**	**3**
Researcher 3	**2**	**2**	**2**
Researcher 4	**2**	**1**	**2**
Researcher 5	**1**	**1**	**2**
Researcher 6	**1**	**1**	**1**
…	**…**	**…**	**…**

In Table 2 is shown how every scientist can be classified. As it can be seen, researchers can get “pure” vectors having the same score in the three dimension (i.e. Researchers 1, 3 and 6 in Table 2) or they can achieve “mix” scores (mixing 3/2/1, i. e. Researchers 2, 4 and 5) in their final classification. This detailed classification of scientists has a great value from the individual evaluation point of view, being a research assessment tool in itself with validity and clear utility for research managers and research decisions. It is also useful for researchers themselves as they can know very easily what their main strong and weak points are.

In order to simplify bibliometric analysis, the previous classes were grouped into eight different classes (General Classification 2) as well as into a broader scheme with only three classes (General Classification 1) (Table 3).

Table 3. General classificatory schemes of scientists.

General Class 1	General Class 2	General Class 2			General Class1	
		Criteria	No. Scientists	%	No. Scientists	%
TOP CLASS	TOP1	All 3 scores	73	6.86	206	19.36
	TOP2	Two 3/one 2	133	12.50		
MEDIUM CLASS	MC1	Two 2/one 3	170	15.98	596	56.02
	MC2	All 2 scores	217	20.39		
	MC3	Two 3 or 2/one 1	209	19.64		
LOW CLASS	LC1	One 2 or 3/two 1	127	11.94	262	24.62
	LC2	All 1 scores	90	8.46		
	LC3	Any blank	45	4.23		
Total researchers			1064			

As it can be seen in Table 3, “General Classification 1” is composed by 3 main classes (Top Class, Medium Class and Low Class) and “General Classification 2” is composed by 8 main

classes (Top 1, Top 2, Medium Class1 [MC1], MC2, MC3, Low Class 1 [LC1], LC2 and LC3).
These different scientific classes have been analysed taking into account personal data such as age, years working at the CSIC, etc., in order to explain some of the main features of scientists.

Results

General description of areas and researchers

The three areas account for a total of 24982 documents: 9660 in Material Sciences, 9318 in Biology & Biomedicine and 6102 in Natural Resources; receiving 80546, 189699 and 56940 citations respectively. In Table 4 a general description of the three areas from the individual perspective is presented by means of the introduced indicators.

Table 4. General indicators at micro-level for the three areas.

Scientific Area	*P*	*C*	*h-index*	*%HCP*	*CPP*	*CPP/FCSm*	*Median IF*	*NJP*	*JCSm/FCSm*
Natural Resources (349)	24.17 ±19.69	242.21 ±282.32	8.03 ±4.55	22.59 ±15.11	7.31 ±5.11	0.89 ±0.54	1.273 ±0.541	0.64 ±0.14	0.99 ±0.36
	21	163	8	19.84	6.63	0.83	1.18	0.67	0.98
Biology & Biomedicine (388)	30.64 ±23.33	627.4 ±610.89	11.82 ±5.73	24.97 ±15.21	19.03 ±16.66	1.17 ±0.89	4.645 ±2.223	0.8 ±0.1	1.39 ±0.55
	25	466.5	11	21.37	14.21	0.97	4.12	0.82	1.34
Material Sciences (327)	47.83 ±38.68	427.44 ±508.4	9.96 ±5.16	20.22 ±11.51	6.3 ±5.13	1.02 ±0.81	1.576 ±0.756	0.72 ±0.11	1.2 ±0.39
	40	261	9	18.68	4.89	0.84	1.44	0.74	1.21
Total (1064)	33.8 ±29.64	441.66 ±518.14	10.03 ±5.43	22.69 ±14.19	11.36 ±12.43	1.04 ±0.78	2.626 ±2.136	0.72 ±0.13	1.21 ±0.47
	27	270	9	20	7.86	0.87	1.81	0.75	1.15

Data expressed as Mean±SD
Median

According to Table 4, researchers in Material Sciences present the highest average number of documents, while Biology & Biomedicine researchers exhibit the highest values of impact, including both absolute and relative indicators (such as the *h-index*, *%HCP*, *CPP*, etc. and also *Median Impact Factor*, *NJP* or *JCSm/FCSm*). Finally, Natural Resources researchers present the lowest scores in all indicators, but the highest increment in relative impact (*CPP/FCSm*) during the last years (Figure 1). Although Biology & Biomedicine presents the highest values in CPP/FCSm, it shows a downward trend at the end of the period.

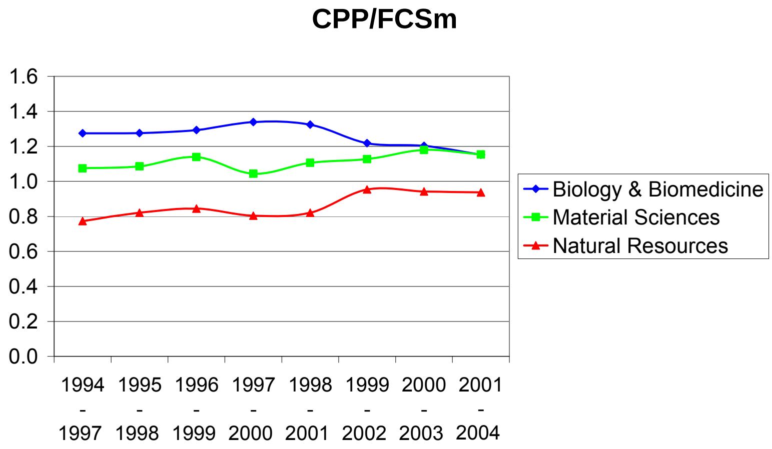

Figure 1. CPP/FCSm evolution in the three research areas.

Who are Top researchers?

To start with, as a preliminary statement it can be said that Top researchers are those scientists with the highest scores in all indicators, not just in one or two, but in all indicators included in the analysis. Then it can be said that they present a high and well balanced research performance (Table 5).

Table 5. General indicators at micro-level by Scientific Class.

Class	*P*	*C*	*h-index*	*%HCP*	*CPP*	*CPP/FCSm*	*Median IF*	*NJP*	*JCSm/FCSm*
Top (206)	47.72 ±36.27	944 ±713.31	15.1 ±5.1	37.82 ±11.98	22.62 ±20.01	1.92 ±1.06	3.776 ±2.702	0.81 ±0.07	1.65 ±0.49
	37.5	716.5	14	36.36	14.56	1.56	2.711	0.81	1.57
Medium (596)	36.95 ±28.01	406.1 ±385.53	10.29 ±4.4	19.42 ±10.62	10.37 ±7.79	0.97 ±0.47	2.589 ±1.968	0.74 ±0.1	1.21 ±0.36
	30	283	10	17.39	7.71	0.88	1.678	0.75	1.15
Low (262)	15.68 ±15.83	93 ±134.22	4.79 ±2.88	10.24 ±12.26	4.04 ±3.34	0.45 ±0.30	1.635 ±1.285	0.6 ±0.17	0.8 ±0.34
	12	60.5	4	6.98	3.11	0.40	1.042	0.63	0.78
Total (1064)	33.8 ±29.64	441.66 ±518.14	10.03 ±5.43	22.69 ±14.19	11.36 ±12.43	1.04 ±0.78	2.626 ±2.136	0.72 ±0.13	1.21 ±0.47
	27	270	9	20	7.86	0.87	1.81	0.75	1.15

Mean±SD
Median

Researchers classified in Top, Medium and Low classes have also been described by means of their age, experience at the institution and time in the same professional category.

- *Age*

The distribution of the age of researchers by scientific class in the three areas analysed is shown in Figure 2. It can be seen how Top scientists are the youngest in all areas.

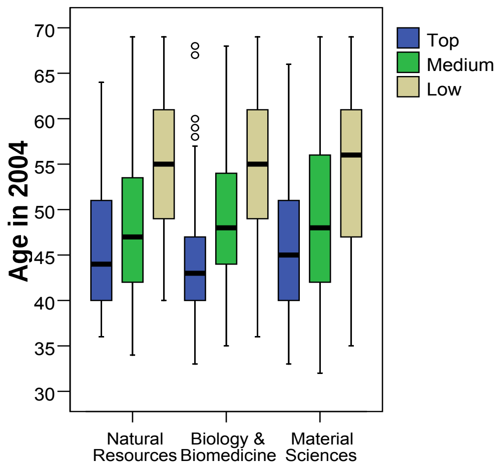

Figure 2. Age distribution of researchers by Scientific Class.

Statistical significant differences were found among scientific classes ($p<0.05$). As we can see Top researchers are around 45 years old, Medium class researchers are between 50 and 45, and Low class researchers are around 55 years old.

- *Experience at the institution and time in the same professional category*

The years of experience at the institution (Years at the CSIC) and the number of years at the same professional category are shown in Figure 3. According to this figure, Top class researchers not only present the shortest experience at the institution but also the shortest permanence at the same professional category. In other words, Top researchers have entered the institution or have been promoted more recently than the other researchers.

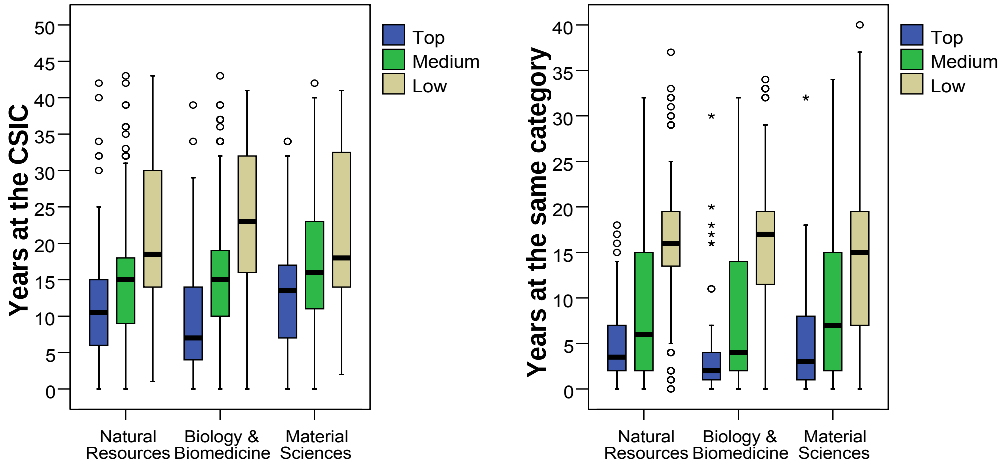

Figure 3. Experience at CSIC and Years at the same category by Scientific Class.

The fact that Top researchers also present more documents published from foreign countries (i.e. without any Spanish address) (Figure 4) can be related with the youth of these scientists, since these documents were mostly published during the postdoctoral period of research in foreign countries as we can deduce from Figure 5 (all areas combined).

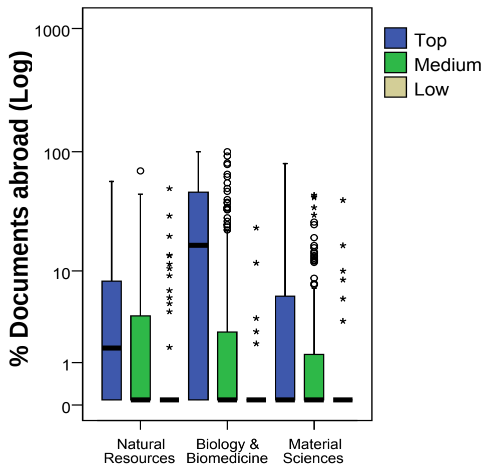

Figure 4. Percentage of documents abroad of researchers by Scientific Class.

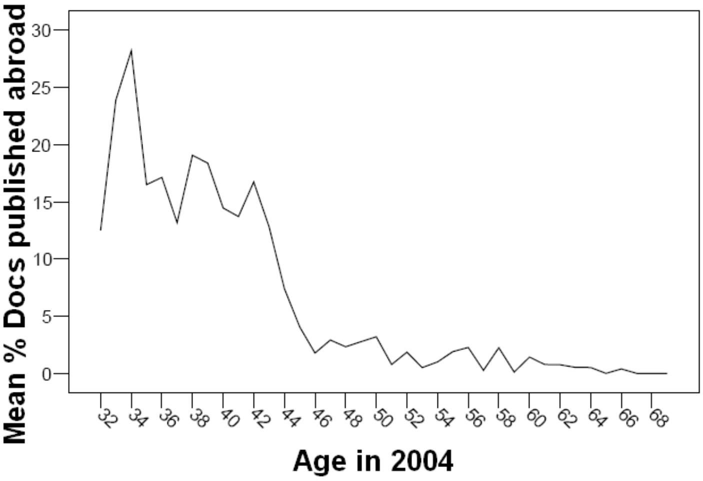

Figure 5. Percentage of documents abroad by age of researchers.

Figure 5 shows how younger researchers present a higher share of their output published abroad. Nowadays, postdoctoral research stays in international centres of prestige constitute an essential stage of the scientific career. These stays may contribute to increase the productivity and impact of researchers and constitute one of the explanations of the better performance of young researchers.

Discussion and Conclusions

The use of bibliometric indicators at macro and meso levels is widely extended among the scientific community. However, their use at micro level for the assessment of research performance of teams or individuals have always been surrounded by controversy and debate, especially due to the limitations that these indicators have at this level (Bordons et al, 2003; Costas & Bordons, 2005). In spite of their shortcomings, bibliometric indicators at micro and particularly at individual level have an especial interest for policy makers and research managers. On the one hand they are useful for assessing the research performance of scientists, and on the other hand they are useful tools for studying the scientific behaviour of researchers, being possible to detect their different strategies of work (Nederhof, 2008) as well as to identify research teams or invisible colleges (Bordons et al, 1995).

However, the use of bibliometric indicators is not free of limitations. Since all indicators present drawbacks and bias, we cannot rely on a single indicator for research assessment (van Leeuwen et al, 2003), this statement being valid even for very new indicators such as the h-index or g-index (Costas & Bordons, 2007b, 2008; Vinkler, 2007; van Leeuwen, 2008). Although the use of several indicators combined has been frequently suggested by different authors (Lewison et al, 2007) up to the moment there are no practical suggestions or concrete methodologies on how to use bibliometric indicators at micro-level. This paper seeks to shed some light on this matter.

The methodology developed in this paper for the classification of scientists according to their bibliometric profile presents three main advantages: completeness of the data, multidimensionality in the analysis and simplicity in its use and interpretation. Moreover, it can hardly be manipulated and encourages better publication habits among researchers. This methodology is useful not only for experts and policy makers but also for researchers themselves, providing information about their main strengths and weaknesses and also allows the development of studies for descriptive ("Top-down") and evaluative purposes ("Bottom-up"). It is interesting to remark that this methodology could also be applied at the research team level, which can be very relevant due to the basic role of teams in the development of research in many disciplines.

However, the methodology is not free of limitations, such as the fact that some dimensions related with scientific performance of individuals are not included (such us innovative activity, locally-oriented production, PhD training, teaching, etc.) aspects that also need to be considered in the evaluation of scientists.

Considering the general classification of researchers developed (Top, Medium and Low), it is possible to identify Top researchers as those who obtain the best results in all indicators, what can be related to balanced strategies of publication. The main characteristics of Top researchers can be described and different determinants of their research success can be explored, being this information very useful for research managers and policy makers in order to create new scientific and management policies.

This study highlights several important features of Top researchers. Firstly, it has been observed that Top researchers tend to be younger than scientists in other classes. Other authors (Rey-Rocha et al, 2006) have also detected that younger researchers at CSIC present the best scientific performance. This fact can be linked to the reduction of new positions offered at the CSIC during last years, which resulted in an increased competitiveness for entering the institution. On the other hand, the most recent CSIC strategic plans stress the importance of recruiting the “best” researchers with the aim of enhancing excellence and consolidating the position of the institution at the international level. This means that newcomer researchers need more competitive CVs in the most recent years; normally including high productivity, high visibility of research and research stays abroad (Sanz-Menendez, 2003). At present, experience abroad is considered a key factor in the professional career of researchers, since scientific mobility has beneficial effects over training and productivity of researchers (De Filippo et al, 2007). Under this assumption, different programs of mobility such as *Acciones Integradas* (Granadino et al, 2005) or Ramon y Cajal (Canibano et al, 2008) have been set up in Spain to help researchers to get international experience, establish valuable contacts and get involved in the international networks within their disciplines.

Another interesting result in our study is that the experience of Top researchers at CSIC is shorter than that of the Medium or Low class researchers. Moreover, Top researchers present the shortest time at the same professional category, what means that they have entered very recently the institution or that they have been promoted during last years. This result suggests that promotion has a positive effect over research performance of scientists, something that has also been suggested by other authors (Allison & Long, 1990; Tien & Blackburn, 1996; Carayol & Matt, 2004).

In relation to the lower performance of older researchers, several explanations can also be considered, such as the following:

- As researchers get older they are involved in more different tasks (administration, teaching, research assessment, project management, funding, supervision of PhD students, etc.), reducing the time that they can devote to conduct research.
- The lack of incentives can also contribute to the lower performance of some scientists (Turner & Mairesse, 2002); in fact Cole (1979) suggested that the relationship between age and scientific performance is more influenced by the reward system than by a real loss of productivity with age.

A final conclusion is that the methodology suggested can be a useful tool to study the main characteristics and determinants of research performance of scientists in the different scientific classes. The information provided can be very helpful for research institutions not only for research assessment purposes but also for implementing research policies considering the different types of researchers.

Future lines of research include in-depth study of determinants of research performance as well as the improvement of the methodology developed, since new dimensions and indicators might provide better understanding of the scientific process on work floor level.

References

Aksnes, D.W. & Taxt, R.E. (2004). Peer reviews and bibliometric indicators: a comparative study at Norwegian university. *Research Evaluation*, 13(1), 33-41.

Allison, P.D. & Long, J.S. (1990). Departamental effects on scientific productivity. *American Sociological Review*, 55(4), 469-478.

Araujo Ruiz, J.A.; van Hooydonk, G.; Torricella Morales, R.G. & Arencibia Jorge, R. (2005). Cuban scientific articles in ISI Citation Indexes and CubaCiencias databases (1988-2003). *Scientometrics*, 65(2), 161-171.

Bordons, M & Barrigon, S. (1992). Bibliometric analysis of publication of Spanish pharmacologists in the SCI (1984-89). Part II. *Scientometrics*, 25(3), 195-206.

Bordons, M.; Morillo, F.; Fernandez, M.T. & Gomez, I. (2003). One step further in the production of bibliometric indicators at the micro level: differences by gender and professional category of scientists. *Scientometrics*, 57(2), 159-173.

Bordons, M.; Zulueta, M.A.; Cabrero, A. & Barrigon, S. (1995). Research performance at the micro level: analysis of structure and dynamics of pharmacological research teams. Research Evaluation, 5(2), 137-142.

Borgman, C.L. & Siegfried, S.L. (1992). Getty's Synoname and its cousins: a survey of applications on Personal Name-Matching Algorithms. *Journal of the American Society for Information Science*, 43(7), 459-476.

Cañibano, C. Otamendi, J. & Andujar, I. (2008). Measuring and assessing researcher mobility from CV analysis: the case of the Ramon y Cajal programme in Spain. *Research Evaluation*, 17(1), 17-31.

Carayol, N. & Matt, M. (2004). Individual and collective determinants of academic scientists' productivity. *Information Economics and Policy*, 18(1), 55-72.

Cole, S. (1979). Age and Scientific Performance. *American Journal of Sociology*, 84(4), 958-977.

Costas, R. & Bordons, M. (2005). Bibliometric indicators at the micro-level: some results in the area of natural resources at the Spanish CSIC. *Research Evaluation*, 14(2), 110-120.

Costas, R. & Bordons, M. (2006). Algorithms to solve the lack of normalization in author names in bibliometric studies. *Investigacion bibliotecologica*, 21(42), 13-32.

Costas, R. & Bordons, M. (2007a). A Classificatory Scheme for the Analysis of Bibliometric Profiles at the Micro Level. In D. Torres-Salinas & H.F. Moed (Eds.), *Proceedings of ISSI 2007: 11th International Conference of the International Society for Scientometrics and Informetrics (ISSI 2007)* (pp. 226-230). Madrid: CINDOC-CSIC.

Costas, R. & Bordons, M. (2007b). The h-index: Advantages, limitations and its relation with other bibliometric indicators at the micro-level. *Journal of Informetrics*, 1(3), 193-203.

Costas, R. & Bordons, M. (2008). Is g-index better than h-index? An exploratory study at the individual level. *Scientometrics*, 77(2), 267-288.

De Filippo, D.; Sanz-Casado, E. & Gomez, I. (2007). Impact of the research stays on the scientific output. In D. Torres-Salinas & H.F. Moed (Eds.), *Proceedings of ISSI 2007: 11th International Conference of the International Society for Scientometrics and Informetrics (ISSI 2007)* (pp. 848-849). Madrid: CINDOC-CSIC.

Fernandez, M.T.; Cabrero, A.; Zulueta, M.A. & Gomez, I. (1993). Constructing a relational database for bibliometric analysis. *Research Evaluation*, 3(1), 55-62.

Granadino, B.; Plaza, L.M. & Vidal, C. (2005). Analysis of Spanish scientific output following the Joing Action Program (Acciones Integradas) of the Ministry of Science and Technology (MCYT). *Research Evaluation*, 14(2), 97-102.

Hirsch, J.E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America*, 102(46), 16569-16572.

Lewison, G.; Thornicroft, G.; Szmuler, G. & Tansella, M. (2007). Fair assessment of the merits of psychiatric research. *British Journal of Psychiatry*, 190, 314-318.

Martin, B.R. (1996). The use of multiple indicators in the assessment of basic research. *Scientometrics*, 36(3), 343-362.

Nederhof, A.J. (2008). Policy impact of bibliometric ranking of research performance of departments and individuals in economics. *Scientometrics*, 74(1), 163-174.

Nederhof, A.J. & van Raan, A.F.J. (1987). Peer review and bibliometric indicators of scientific performance: a comparison of cum laude doctorates with ordinary doctorates in physics. Scientometrics, 11(5-6), 333-350.

Rey-Rocha, J.; Garzon-Garcia, B. & Martin-Sempere, M.J. (1999). The role of domestic journals in geographically-oriented disciplines: the case of Spanish journals on earth sciences. *Scientometrics*, 45(2), 203-216.

Ruiz-Perez, R.; Delgado Lopez-Cozar, D. & Jimenez-Contreras, E. (2002). Spanish personal name variations in national and international biomedical databases: implications for information retrieval and bibliometric studies. *Journal of Medical Library Association*, 90(4), 411-430.

Sanz-Menendez, L. (2003). *Coping with researchers' labour market problems through public policy: The Spanish Ramon y Cajal Programme*. Working Paper 03-15. Retrieved January 12, 2009 from: http://www.iesam.csic.es/doctrab2/dt-0315.pdf

Tien, F.F. & Blackburn, R.T. (1996). Faculty Rank System, Research Motivation, and Faculty Research Productivity. *The Journal of Higher Education*, 67(1), 2-22.

Turner, L. & Mairesse, J. (2002). Explaining individual productivity differences in public research: How important are non-individual determinants?: An econometric study of French physicists' publications (1986-1997). Cahiers de la MSE, 66. Retrieved January 12, 2009 from: ftp://mse.univ-paris1.fr/pub/mse/cahiers2002/V02066.pdf

Van Leeuwen, T.N. (2007). Modelling of bibliometric approaches and importance of output verification in research performance assessment. *Research Evaluation*, 16(2), 93-105.

Van Leeuwen, T.N. (2008). Testing the validity of the Hirsch-index for research assessment purposes. *Research Evaluation*, 17(2), 157-160.

Van Leeuwen, T.N.; Visser, M.S.; Moed, H.F.; Nederhof, T.J. & van Raan, A.F.J. (2003). The Holy Grail of science policy: exploring and combining bibliometrics in search of scientific excellence. *Scientometrics*, 57(2), 257-280.

Van Raan, A.F.J. (2004). Measuring Science. In H.F. Moed & W. Glanzel (Eds.) *Handbook of Quantitative Science and Technology Research* (pp. 19-50). The Netherlands: Kluver Academic Plubishers.

Van Raan, A.F.J. (2005). Fatal attraction: conceptual and methodological problems in the ranking of universities by bibliometric methods. *Scientometrics*, 62(1), 133-143.

Vinkler, P. (2007). Eminence of scientists in the light of the h-index and other scientometric indicators. *Journal of Information Science*, 33(4), 481-491.

Weingart, P. (2005). Impact of bibliometrics upon the science system: inadvertent consequences? *Scientometrics*, 62(1), 117-131.

Wooding, S.; Wilcox-Jay, K.; Lewison, G. & Grant, J. (2006). Co-author inclusion: A novel recursive algorithmic method for dealing with homonyms in bibliometric analysis. Scientometrics, 66(1), 11-21.