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Productivity and impact of Spanish researchers: reference thresholds within scientific areas

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Abstract: Reference thresholds for the scientific production and impact of internationally visible Spanish research within the areas defined by the Spanish National Agency for Evaluation and Prospective (ANEP) are presented. These percentile reference tables are constructed from the population of researchers who applied for a project within Spain's National R&D Plan 2007 (*n* = 3.356) and are to serve as benchmarks, permitting comparisons between researchers' bibliometric behavior and mean performance in their respective scientific disciplines. Data relating to mean production, impact and visibility for each ANEP area are also presented. The internationalization of these areas between 2000 and 2006 is discussed, with special emphasis on the Social Sciences. Finally, we suggest funding agencies and research institutions use these reference thresholds as assessment tools in their selection processes.

Keywords: Bibliometric indicators, reference thresholds, benchmarking, Spanish National Agency for Evaluation and Prospective (ANEP), science, scientific research, Spain.

Productividad e impacto de los investigadores españoles: umbrales de referencia por áreas científicas

Resumen: *Se presentan umbrales de referencia de producción e impacto científico de la investigación española con visibilidad internacional para las áreas definidas por la Agencia Nacional de Evaluación y Prospectiva (ANEP) en sus convocatorias. Tomando como población los solicitantes de proyectos del Plan Nacional de I+D 2007 (n = 3.356) se construyen tablas de referencia por percentiles que funcionan a modo de benchmarks, permitiendo efectuar comparaciones entre el comportamiento bibliométrico de un investigador y los registros de referencia en su área científica. Igualmente se ofrecen los datos de producción, impacto y visibilidad promedios para las áreas ANEP, y se discute el proceso de internacionalización de dichas áreas en el período 2000-2006,*

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con una especial atención a las Ciencias Sociales. Finalmente, se sugiere el uso de umbrales de referencia como método de evaluación tanto para agencias financiadoras como para instituciones de investigación en sus procesos selectivos.

Palabras clave: *Indicadores bibliométricos, umbrales de referencia, benchmarking, ANEP, ciencia, investigación científica, España.*

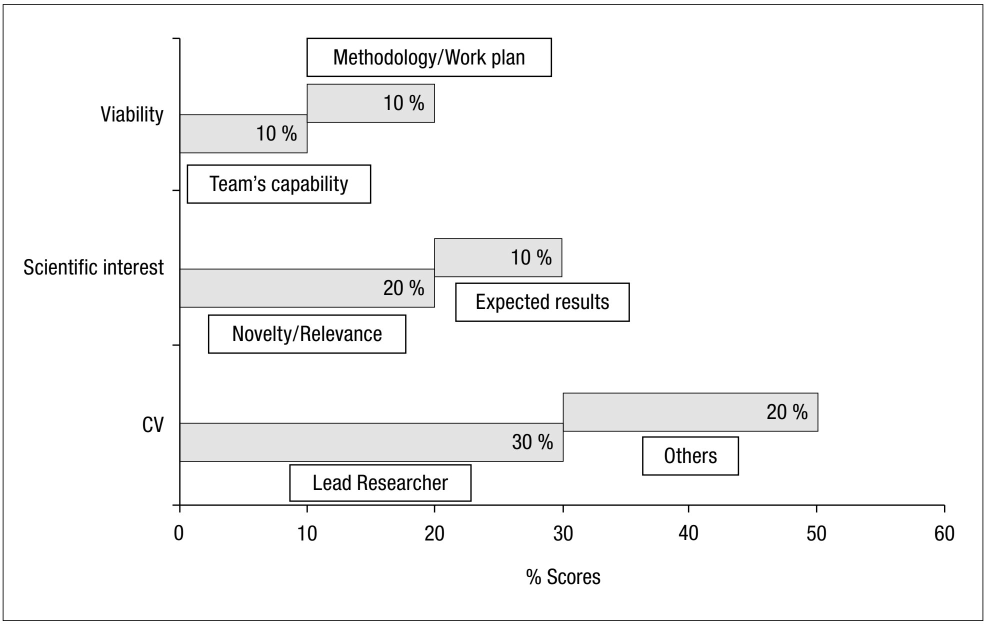
1. Intr oduction

In Spain, the growing importance of bibliometric parameters in University selection and promotion procedures or in awarding grants or funding for research projects has meant the public sector agencies involved need sound indicators, adapted to the different aspects of assessment, that guarantee the fair assessment of competing applications. Over the last 25 years, the Spanish scientific community has become increasingly professional (Sanz-Menéndez, 1997; Cruz-Castro and Sanz-Menéndez, 2007) and a number of national and regional public sector agencies charged with managing scientific activity have appeared. These include the assessment agencies among which one of the most important is the National Agency for Evaluation and Prospective (*Agencia Nacional de Evaluación y Prospectiva,* hereafter ANEP), which has been developing an assessment system that delimits and assesses aspects of content, budget and curriculum vitae (CV) as separate entities. Since its creation in 1986, peer-review has been the preferred method of assessing proposals. Each application is assessed by two expert reviewers chosen by the scientific discipline coordinator. They make independent written reports that include the corresponding score for each section and a final total (Gordillo et al., 2004). Although ANEP assesses competitive funding proposals for the Ministry of Science and Innovation and other public bodies, its most important activity concerns applications to the National R&D Plan (PN). The single most important source of public finance for most Spanish researchers, the PN constitutes an opportunity to obtain financial support to conduct research for a period of three years. Essentially, the criteria used to award funding are based on an assessment of the lead researcher's CV (30%) and of those of the other research team members (20%) (figure 1). In this process, sound experience, together with a good team or a technically acceptable proposal ensure success. In the exact and experimental sciences and, increasingly, the social sciences too, reviewers frequently assess CV quality —defined as the value and repercussion of publications–- through the number of international publications (i.e., those found in the ISI Web of Science [WoS]), and the impact factors (IFs) of the journals in which they appear. In other words, they resort to bibliometric indicators.

In Spain, it is standard practice to turn to IFs when offering incentives for productivity. In fact, they are practically the only criterion used. In the late 1980s, the Ministry of Education's National Research Activity Assessment Commission (*Comisión Nacional Evaluadora de la Actividad Investigadora*, hereafter CNEAI)

FIGURE1

ANEP assessment criteria scores. 2009 funding round



established 6-yearly productivity bonuses to provide one such incentive. The essential criterion for awarding bonuses were standards applied in the pure sciences —together with factors such as a legal framework favoring state sector universities— that led to the increased internationalization of Spanish science in the 1990s (Jiménez-Contreras et al., 2003). In the last decade this has continued largely because researchers have adapted to the pattern of international publication. Moreover, more recently, the citation level of Spanish scientists has converged on international figures following years of under-performing by comparison with their international counterparts (Delgado-López-Cózar et al., 2009). However, the use of these criteria has generated widespread controversy (Camí, 1997; Bordons et al., 2002; Lawrence, 2002) because journal IFs do not represent the impact of the individual studies or that of their authors (Seglen, 1997). This is due to specific methodological and conceptual limitations of the indicator: e.g., the citation window is only two years; an asymmetric relation exists between the number of citation studies received and the IFs of the journals that publish them (van Leeuwen and Moed, 2005). However, despite these limitations, agencies, reviewers, and scientists themselves base a substantial proportion of their scientific decisions on this indicator. Ultimately, the reason for this success (not forgetting the saving in costs) is the assumption that the IF, although it may not predict the impact a specific article will achieve, *does* represent the visibility, prestige and total sum of obstacles authors have to overcome to finally see their work in print. In other words, the IF spotlights study quality in a way that is reasonably proportionate to the journal's impact (Garfield, 2003).

Given this is the case, it has become fashionable to use IFs as a research and assessment tool in empirical studies (e.g., Alonso-Arroyo et al., 2006; Buela-Casal et al., 2004; González-de-Dios et al., 2009). Notwithstanding, some authors have made proposals or reflected on the methodology of using the IF or real or observed citations in attempts to resolve some of their limitations, especially those related to inter-category comparison (Schubert and Braun, 1996). A further issue is that posed by the need for a normalization procedure to permit cross-disciplinary comparisons, for which alternatives exist. One of the simplest procedures uses direct rankings and applies one or various criteria: production, funding, impact or whatever (Torres-Salinas et al., 2009b; Buela-Casal et al., 2010), although special care must be taken due to the many methodological factors involved in constructing the rankings (van Raan, 2005). Another alternative is percentile range, which involves rating the aggregates being assessed on a scale that permits inter-category comparisons (Lewison et al., 1999; Costas et al., 2010). Finally, another option is to develop methods based on production-related reference indicators —such as impact or collaboration— which are normalized to facilitate comparisons between disciplines. The Centre for Science and Technology Studies at the University of Leiden, The Netherlands (hereafter CWTS) proposed just such a set of indicators, which constitutes an appropriate means of assessing institutional compliance with scientific policy and has been successfully applied in different institutions, geographic areas and thematic fields (Moed et al., 1985; van Raan and van Leeuwen, 2002).

Beyond the methods used, our review of international publications revealed several studies aimed at drawing up bibliometric profiles of different constructs. These include, at the level of mesoanalysis, topic-based profiles of academic institutions and researchers in Great Britain (Carpenter et al., 1988), Mexico (Macías-Chapula et al., 2004), or Spain (Moya-Anegón et al., 2005; Torres-Salinas et al., 2009a), and at European research institutions (Thijs and Glänzel, 2009). Much has been written about the individual assessment of researchers by establishing discipline-based rankings. In the field of Information Science, authors have used criteria such as the h index (Cronin and Meho, 2006; Oppenheim, 2007) or production and citations received (Meho and Spurgin, 2005; Jiménez-Contreras et al., 2006). At a micro level, more complex approaches to the development of bibliometric profiles have recently been reported by Abramo and D'Angelo (2011), in the context of national assessment, and by Costas and his coauthors (Costas and Bordons, 2005; Costas, 2008; Costas et al., 2010). These studies establish profiles or levels of excellence that distinguish between three levels of analysis (production, impact and visibility) in order to place researchers on scales or within ranges of excellence or research quality. Typically, this bottom-up method (van Leeuwen, 2007) requires highly careful data collection and indicator-processing and development because search and processing errors can substantially distort the final results. In general, we can say that the closer the analysis is to the authors, the wider-ranging the battery of indicators should be and, the more cautious we should be both in data-collection and indicator-processing and development, which should be in consonance with the final use the data will be put to.

As subject matter experts, reviewers doubtless know the standard parameters of productivity and quality in their discipline but they lack of any reference frame or accurate threshold to enable them to place the researchers being assessed in a productivity context constructed from empirical data and bounded by national research standards. We encounter the same scenario when looking at the impact of the studies these scientists publish. Frames of reference that permit comparative analysis or assessment of production and citation would provide reviewers with benchmarks against which to «measure» the CVs of researchers under assessment, thus enhancing the objectivity of the process. Hence, the peer review assessment process would gain objectivity in response to some of its current defects (Gordillo et al., 2004), favoring what in the literature is known as «informed peer review» (Lewison et al., 1999; van Raan, 1996).

Whether resorting to standard indicators has modified scientific practice and favored deviant or fraudulent behavior has been discussed (Butler, 2003). To overcome these problems and avoid the use of «formulaic» researcher assessment (Moed, 2005), the combined use of bibliometric indicators and expert reviewers has been proposed (Weingart 2005). In the context of reference frame construction for scientific disciplines, Thomson Reuters' Essential Science Indicators (ESI) represent a tool that —although not widely used— proves of inestimable value when establishing thresholds and citation means as a function of the category studies belong to and the date when they were published, thus neutralizing the two main variables that can influence the measurement of an article's impact. The ESI provide baselines: means and percentiles that enable us to establish the relative position of a research article within its field according to the number of citations received and the time since its publication. These indicators give us the mean citations of an article, and the percentile range, by year and category in both cases. The ESI tables, divided into 22 different-sized disciplines and excluding the Humanities, are constructed from the total number of WoS journals. They undergo bimonthly updates (Ruiz-Pérez et al., 2008) and, therefore, are dynamic time frames.

2. Objectives

The primary objective of the present study is to construct bibliometric profiles of applicants to Spain's National R&D Plan for project funding and, on the basis of this data, construct reference thresholds to aid reviewers when taking decisions on the basis of bibliometric evidence. In other words, we aim to establish the standards of publication and impact of those Spanish researchers who actively seek funding.

Specifically, we aim to:

- Construct a reference table similar to the ESI but adapted to the Spanish context, and related to performance in both production and impact.
- Define the main bibliometric indicators of production, productivity, impact and visibility by discipline.
- Test the validity of our proposed method for further use —with or without any relevant modifications— to ensure maximum objectivity in assessing researchers' CVs.

3. Materials & method

A retrospective descriptive analysis of the bibliometric performance of the lead Spanish researchers who applied for research project funding through the Spanish PN funding round for 2007, is conducted. We included 3356 researchers from the ANEP disciplines, excluding Law, Philology and Philosophy, and History and Art. All data were provided by the ANEP. The disciplines that received most applications were Fundamental Biology (12%), followed by Chemistry and Economics. To calculate the indicators and validate our study design, we calculated the percentage of researchers in each discipline with at least one article published during the study period. Data was collected by searching for these researchers' scientific production on the Thomson Reuters on-line WoS databases: the Science Citation Index-Expanded (SCI), Social Sciences Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI), Conference Proceedings Citation Index-Science (CPCI).

Information Science experts conducted a manual search for each researcher, retrieving all records dated between 2000 and 2006. Special care was taken to allow for the different forms of Spanish surnames appearing in ISI databases (Ruiz-Pérez et al., 2002) and the affiliations a researcher may have had during the study period (e.g., due to study leave spent in international centers). Researcher production was initially stored in text format and later exported to *ProCite 5* bibliographic management software. Once all production data had been collected, it was transferred to a purpose-built *MS Access 2003* relational database together with the corresponding biographical data (researcher name, surname, project code number, researcher type, institution and center). The document types analyzed were article, review, letter, editorial material and proceedings paper. Information relating to the journal of publication's IF was downloaded from Thomson Reuters *Journal Citation Reports (JCR)* and added to the database. We also included the number of citations received by each article retrieved using the *Create Citation Report* function on the online WoS results page. Once any given author's production had been identified, this option enabled us to download the citations received for each record as a function of the year of the citing article. The time frame for citations was 2000-2008. Finally, we connected citing documents with documents cited in the database. Data collection took place between February 2009 and May 2010.

We subsequently calculated each ANEP discipline indicator with *Access 2003*. The ANEP discipline categories have remained relatively stable over time although the Life Sciences have recently been modified. The categorization by disciplines presented here (table I) is that which was in use at the time of the 2007 PN.

TABLE I

ANEP disciplines and acronyms

Acronym	Discipline
AGR	Agriculture
BMED	Biomedicine
CEA	Civil engineering and architecture
CHE	Chemistry
CHT	Chemical technology
CLIM	Clinical medicine and epidemiology
CSI	Computer science and information technology
ECO	Economics
ECT	Electronic and communication technology
EDU	Education science
EEC	Electrical, electronic and control engineering
ESC	Earth sciences
FSB	Fundamental and system biology
FST	Food science and technology
LFF	Livestock farming and fisheries
MNA	Mechanical, naval and aeronautic engineering
MST	Materials science and technology
MTM	Mathematics
PHY	Physics and space sciences
PPH	Physiology and pharmacology
PSY	Psychology
SSC	Social sciences
VAB	Vegetable and animal biology, and ecology
Not analyzed	Law
Not analyzed	Philology and philosophy
Not analyzed	History and art

Statistical analysis was conducted with *SPSS 15.0 for Windows*. The indicators calculated were:

- ***Production***
  - ***Productive researchers.*** Researchers with at least one document published during the study period.
  - ***Ndoc/res.*** Mean documents per researcher.
  - ***RV Rate of variation.*** Percentage difference between production recorded in the first (2000) and last (2006) years of the study.
  - ***Baselines (production thresholds).*** Cumulative frequency of production per researcher by percentile This indicator informs us of the number of articles needed for a researcher to be placed in the 90-, 75- and 50-percentiles of the distribution of scientific production by year of publication.
- ***Visibility***
  - ***IFAve.*** Mean Impact Factor.
  - ***Top3.*** Publications in the top 3 journals by JCR category.
  - ***Q1.*** Publications in journals in the first quartile by JCR category.
- ***Impact***
  - ***CitAve.*** Mean citations per document.
  - ***% Ndoc cited.*** Percentage of documents cited.
  - ***Baselines (citation thresholds).*** Cumulative frequency of citation by percentile. This indicator informs us of the number of citations needed for an article to be placed in the 90, 75 and 50 percentiles of the distribution of scientific production by year of publication.

4. Results

4.1. Production

Some 3356 researchers (excluding those in the Humanities) participated in the PN funding round for 2007, grouped by discipline as shown in table II.

The data obtained range from 99.58% of productive researchers in Chemistry to 29.45% in Social Sciences. Most categories have a ratio of productive researchers of >90%. The exceptions are the four Social Science disciplines, which present clearly-defined patterns. Economics and Psychology have higher year-on-year productivity (with spectacular growth in Economics); Education (also with very high relative growth) and Social Sciences remain at <35%. Civil Engineering sharply contrasts with other fields of Engineering having one third of researchers with no production. Disciplines like Physics, Fundamental Biology or Mathematics,

TABLE II

Total number of researchers, productive researchers, and rate of variation 2000-2006 by ANEP discipline

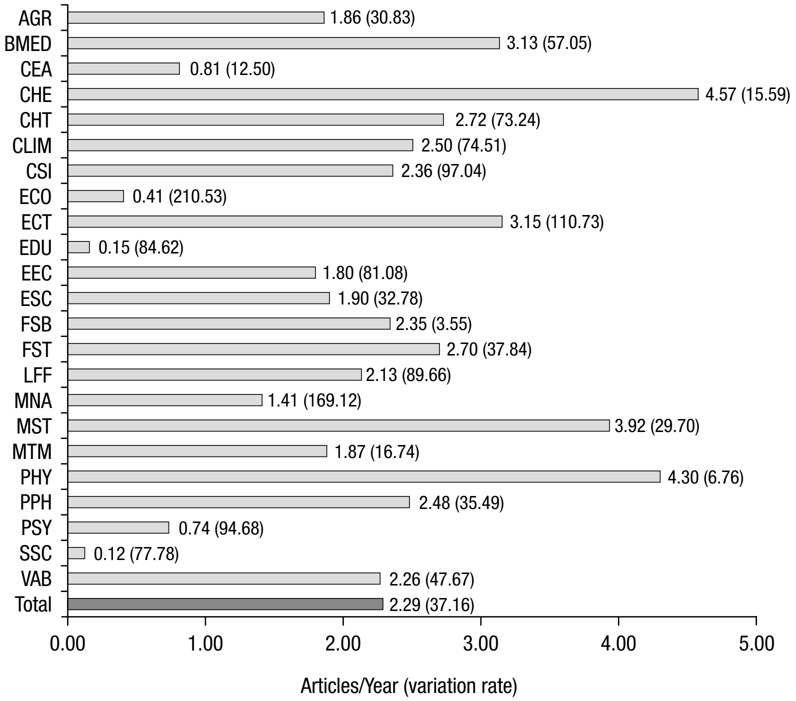
Discipline	Resear chers	Pr oductive	% Pr oductive	RV 00-06
AGR	132	127	96.21	24.39
BMED	124	123	99.19	16.13
CEA	61	40	65.57	33.33
CHE	237	236	99.58	9.00
CHT	106	100	94.34	31.75
CLIM	51	49	96.08	11.43
CSI	152	143	94.08	45.68
ECO	182	131	71.98	157.14
ECT	139	131	94.24	40.00
EDU	119	41	34.45	112.50
EEC	86	84	97.67	36.17
ESC	141	130	92.20	17.44
FSB	405	400	98.77	0.64
FST	128	126	98.44	9.38
LFF	96	92	95.83	34.43
MNA	91	85	93.41	60.00
MST	171	167	97.66	17.74
MTM	131	130	99.24	5.38
PHY	180	178	98.89	1.31
PPH	145	144	99.31	10.53
PSY	169	136	80.47	56.86
SSC	146	43	29.45	35.71
VAB	164	160	97.56	25.00
Total	**3356**	**2996**	**89.27**	**19.94**

which have adopted a solid, international pattern of publication, show minor rates of variation. However, some technologies and fields of Engineering show high growth, probably due to the wider coverage of conference papers in the reference database.

We calculated the mean number of documents produced per researcher and the annual mean by ANEP category. To observe the chronological tendency, we calculated the rate of variation and found researchers increasingly adopt the international publication pattern. This makes inter-disciplinary differences in productivity clear, ranging from 4.3-4.6 documents per researcher per year in Physics and Chemistry to barely 0.1 documents in Social Sciences and Education. The extremely low starting figures in these disciplines explain the high relative increase and simultaneously low ISI productivity of these researchers. The greatest rates of variation occur in some fields of Engineering and Technology and in Economics (figure 2). One factor that influences the different discipline-related rates of productivity is the rate of collaboration in the studies published. The coauthorship index —i.e. mean signatories per article— ranges from 8.2 in Physics (excluding articles with >250 signatories) to 2.5 in Economics. The highest mode is 6 authors in Biomedicine, Clinical Medicine and Epidemiology, and Livestock farming and Fisheries; the lowest, 1 author, is in Social Sciences.

FIGURE2

Mean production per researcher per year, and rate of variation for 2000-2006 (in parentheses) by ANEP discipline



Given that productivity means may be biased by the asymmetric distribution of research productivity, we also calculated the production thresholds per year of the study period and for the whole period. We selected 50-, 75-, 80-, 90- and 99-percentiles and found two very different trends: on the one hand, the results for most disciplines are consistent, and growth between percentiles is exponential– i.e., the productive effort needed for a researcher to enter the higher distribution percentiles is substantially greater, hence these benchmarks are thresholds only surpassed through greater effort, in terms of reviewer criteria. Figures tend to hold in the long-term, with productivity growing towards the end of the study period. In disciplines like Chemistry or Physics, >20 articles (in 7 years) are needed to reach the category median. In contrast, in the Social Sciences (and Civil Engineering) the high number of non-productive researchers conditions results and performance is abnormal. For example, a researcher with no production can be placed in the three-year 75-percentile for distribution in disciplines like Education. Table III shows percentile data for researcher CV assessment at 3.5 and 7 years.

TABLE III

Production thresholds (baselines) by ANEP discipline for the 50-, 75- and 90-percentiles at 3.5 and 7 years

Discipline/ Per centile	3 years			5 years			7 years		
	P50	P75	P90	P50	P75	P90	P50	P75	P90
AGR	4	7	12	7	11	21	10	16	29
BMED	7	12	18	12	20	29	17	28	41
CEA	1	3	8	1	4	13	2	6	18
CHE	10	17	27	17	29	46	24	40	64
CHT	6	9	16	9	16	27	13	22	38
CLIM	5	9	17	8	15	29	11	21	40
CSI	6	9	15	9	15	24	13	21	34
ECO	1	2	3	1	3	5	2	4	7
ECT	7	14	21	11	24	35	16	33	49
EDU	0	0	2	0	1	3	0	1	4
EEC	4	8	12	7	13	20	10	18	28
ESC	3	6	11	6	11	19	8	15	26
FSB	6	9	14	9	15	24	13	21	33
FST	7	11	17	11	19	28	16	26	39
LFF	5	9	10	9	16	17	12	22	24

TABLE III *(cont.)*

Discipline/ Per centile	3 years			5 years			7 years		
	P50	**P75**	**P90**	**P50**	**P75**	**P90**	**P50**	**P75**	**P90**
MNA	3	6	10	6	10	17	8	14	24
MST	9	16	26	14	27	43	20	38	60
MTM	5	7	11	8	12	19	11	17	26
PHY	10	18	25	16	31	42	23	43	59
PPH	6	10	14	10	16	24	14	23	33
PSY	1	3	6	2	5	9	3	7	13
SSC	0	0	1	0	1	1	0	1	2
VAB	5	9	13	9	14	22	12	20	31
Total	**5**	**9**	**16**	**8**	**15**	**26**	**11**	**21**	**37**

* *Example:* A researcher in the field of Agriculture with a production of 12 articles in 5 years would be placed among the 10-25% most productive researchers of the discipline (in the P75-P90 range).

4.2. Visibility and impact

Impact and visibility indicators in relation to articles in journals with an IF and articles cited parallel the ratio of productive to non-productive researchers. The greatest imbalance occurs in the Social Sciences where 11% of researchers published in journals with no IF for the year of publication, which reflects publications recently incorporated into the WoS database. In Education, this affects 8.4% of researchers. In Civil Engineering and, to a lesser extent, in other engineerings, there is also a certain imbalance due to publications in conference papers, a document type with no IF. The same occurs if we compare those productive researchers who are cited and those who are not. In this case, Economics and Psychology are also included in the group. Overall, 4% of productive researchers have non-cited production. Food Technology and Earth Sciences are the only disciplines in which all productive researchers have achieved at least one citation for one of their publications (table IV).

The indicators measuring performance as visibility in top3 and 1st quartile (Q1) journals differ greatly between categories. In Chemistry, Physiology or Fundamental Biology practically all researchers have published one or more articles in Q1 journals. The Social Sciences are ranked at the lower end of this indicator. Overall, 3 out of 4 researchers published at least one article in a Q1 journal during the study period. Nearly half of the researchers also published in one of the top3 journals in their discipline. Values range from 77% in Biomedicine to 0% in Education, where no applicant published in a top3 journal.

TABLE IV

Percentage of researchers by visibility and impact indicators by ANEP discipline

Discipline	% productive	% IF	% Q1	% Top3	% cited
AGR	96.21	93.18	79.55	50.00	92.42
BMED	99.19	99.19	95.16	77.42	97.58
CEA	65.57	55.74	40.98	19.67	52.46
CHE	99.58	99.58	97.89	62.03	98.73
CHT	94.34	93.40	88.68	51.89	93.40
CLIM	96.08	96.08	82.35	70.59	92.16
CSI	94.08	90.13	58.55	21.05	88.16
ECO	71.98	66.48	29.67	13.74	62.64
ECT	94.24	91.37	69.06	33.81	90.65
EDU	34.45	26.05	10.08	0.00	24.37
EEC	97.67	91.86	58.14	25.58	89.53
ESC	92.20	91.49	82.98	49.65	92.20
FSB	98.77	98.77	97.78	68.15	96.05
FST	98.44	98.44	97.66	72.66	98.44
LFF	95.83	95.83	93.75	57.29	93.75
MNA	93.41	89.01	67.03	31.87	86.81
MST	97.66	97.66	92.40	69.01	95.91
MTM	99.24	99.24	71.76	16.03	96.95
PHY	98.89	98.33	95.00	71.11	97.22
PPH	99.31	99.31	97.93	72.41	98.62
PSY	80.47	77.51	46.15	20.12	73.37
SSC	29.45	18.49	8.90	3.42	17.12
VAB	97.56	97.56	90.85	54.27	96.95
Total	**89.27**	**87.10**	**74.82**	**46.51**	**85.40**

Article performance was >50% in Q1 journals, falling to 12% in top3 journals (table V). In Q1 journals, the performance of Fundamental Biology and Physics researchers was excellent; in top3 journals, Biomedicine and Food technology stood out with approximately 20% ratio. The highest percentages of articles cited are found in Chemistry, Physiology and Fundamental Biology. These disciplines, together with Biomedicine, also attain the highest mean of citations per document. Electrical Engineering and the two fields encompassed by Information and Communication Technology had the highest levels of non-cited documents, possibly due to the importance given to conference proceedings. With a mean 2 citations per document, Education is the least cited discipline.

TABLE V

Visibility and impact indicators by ANEP discipline

Discipline	Mean IF	% Q1	% Top3	Mean citations	% cited
AGR	1.70	45.69	12.53	7.60	74.56
BMED	3.86	59.49	20.06	17.14	87.21
CEA	0.95	47.78	12.96	5.75	66.57
CHE	2.89	58.95	8.33	14.16	93.56
CHT	1.90	59.76	14.31	10.58	90.05
CLIM	2.82	48.56	16.07	11.13	84.66
CSI	0.72	14.62	2.99	3.07	49.70
ECO	0.71	21.97	6.78	3.47	70.04
ECT	1.31	37.83	9.74	4.12	51.58
EDU	0.79	23.53	0.00	2.21	60.94
EEC	0.93	30.95	9.89	2.97	47.65
ESC	1.94	55.63	14.59	11.05	86.38
FSB	4.82	67.44	14.62	21.43	92.14
FST	1.82	63.11	19.36	10.61	90.10
LFF	1.87	57.69	11.57	9.41	87.10
MNA	1.09	44.30	8.19	5.83	73.70
MST	1.98	56.16	13.69	9.94	85.75
MTM	0.67	23.52	1.97	4.02	71.79
PHY	3.09	65.29	14.49	12.31	79.62
PPH	3.72	58.29	10.69	15.39	92.70
PSY	1.57	26.29	7.99	6.93	81.54
SSC	2.11	38.82	12.94	3.94	61.60
VAB	2.22	45.59	9.02	9.43	87.07
Total	**2.63**	**53.46**	**11.96**	**11.59**	**82.02**

We calculated 50-, 75-, and 90-percentile figures for citation. Given that time is a factor that influences citation, we calculated the indicators as a function of years since publication. Table VI shows 50-, 75- and 90-percentiles corresponding to a 9-year time frame for articles recorded in 2000; a 3-year time frame has been used for articles published in 2006 (citations were recorded until 2008). If we take the 9 years of the longest period calculated as our reference, an article usually needed 9 citations to reach the distribution median. This rose to 16 citations in Fundamental Biology; however 0 citations were needed in Social Sciences and Electrical Engineering. The 9-year results (production was lowest in 2000) are based on samples that included abnormal cases. For example, in some categories articles (published in 2002) that had 7 years to be cited show citation thresholds above those of articles that had a wider time frame to be cited (9 years).

TABLE VI

Citation thresholds (baselines) with 3-, 5-, 7- and 9-year time frames for 50-, 75- and 90-percentiles, by ANEP discipline

Discipline/ Per centile	3 years			5 years			7 years			9 years		
	P50	**P75**	**P90**	**P50**	**P75**	**P90**	**P50**	**P75**	**P90**	**P50**	**P75**	**P90**
AGR	1	4	9	4	9	15	7	16	28	7	15	30
BMED	4	10	18	8	18	38	11	24	44	10	28	57
CEA	0	2	6	3	6	11	5	9	21	5	20	33
CHE	4	8	15	8	15	28	11	20	34	13	24	42
CHT	3	6	12	6	13	25	9	17	31	10	18	40
CLIM	3	6	10	7	17	24	6	15	30	9	23	48
CSI	0	1	3	0	2	7	1	3	10	2	7	17
ECO	0	1	2	2	4	7	2	9	14	4	7	13
ECT	0	2	6	1	5	11	1	6	15	1	6	15
EDU	1	2	3	2	4	7	1	7	11	1	2	7
EEC	0	1	4	1	5	11	0	6	13	0	5	10
ESC	3	7	11	7	13	34	7	15	30	10	19	35
FSB	5	11	20	10	21	41	14	30	60	16	36	75
FST	3	6	10	7	14	22	9	18	30	11	22	42
LFF	3	5	8	7	11	18	5	11	22	9	18	33
MNA	1	3	6	3	8	17	4	11	17	5	10	20
MST	2	6	12	5	11	20	6	13	28	7	16	30
MTM	1	2	4	2	5	9	3	7	14	3	8	16
PHY	3	7	15	5	14	27	7	17	35	10	21	40
PPH	4	8	14	9	18	37	13	25	43	12	27	55
PSY	2	4	6	5	9	17	5	11	23	4	12	23
SSC	1	2	4	3	6	12	4	8	17	0	2	8
VAB	2	4	8	5	11	21	7	14	22	8	23	43
Total	**2**	**6**	**12**	**5**	**13**	**24**	**7**	**17**	**33**	**9**	**21**	**42**

* *Example:* An article in the field of Mathematics with 4 citations received in 3 years would be situated among the 10% most cited articles in the discipline (P90). The same article (with 4 citations) in Molecular Biology would not enter the 50% most cited articles.

5. Discussion

On the basis of the data analyzed we can confirm the existence of three types of disciplines: the first consists of those that from the outset have been fully integrated into international research. These are Science disciplines (AGR, FSB, BMED, VAB, ESC, PPH, PHY, LFF, CLIM, MTM, CHE, FST, MST, CHT). All match the pattern of international production and the vast majority of funding applications were from productive researchers. In disciplines like FSB or PHY, the percentage of productive researchers held steady during the study period. In this group, disciplines like Agriculture, Animal and Plant Biology and Ecology, or Livestock Farming and Fisheries, have become fully internationalized during the study period. These disciplines stand out for productivity levels of 1.9-4.6 documents per researcher per year, and (except in Mathematics) for publishing >45% of articles in Q1 journals. Moreover, production and citation thresholds held relatively stable year-on-year, although they appear to have been more demanding towards the end of the study period, probably due to less experienced applicants joining the funding round and the general increase in productivity in Spain.

Secondly, we have the group comprising the Engineering and Information and Communication Technology disciplines (ECT, CEA, MNA, EEC, CSI), which have clearly distinguishable profiles. The study period saw the incorporation of more researchers into the system, with productivity ranging from 0.8 (CEA) to 3.1 (ECT) documents per researcher per year. Visibility indicators describe 14%-48% of Q1 documents and 3-5.7 mean citations per document. The results for Civil Engineering are unusual in that within the second group this discipline has the best visibility and impact indicators despite the fact that one third of applicants were non-productive during the study period. This may indicate the existence of highly applied researchers, for whom more academic bibliometric indicators like citations may be inappropriate tools to assess activity and performance. Moreover, in Engineering the dissemination of results through conference proceedings is very important (63% in EEC; 60% in ECT; 31% in MNA) —in contrast with other disciplines where this document type accounts for approximately 4.5% of production— so any study that excludes them cannot assess these highly applied disciplines adequately.

Thirdly, the Social Sciences group (SSC, ECO, EDU, PSY) comprises two clearly distinctive trends. Economics and Psychology have 72% and 80% ratios of productive researchers, respectively; in Economics the rate of variation was 157%, rising from 15% of active researchers in the first year of the study to 40% in the last. In 2000, Economics had figures similar to those of Education or Social Science; at the end of the study period its profile looked more like that of Psychology. Economics and Psychology had production rates of 0.4 and 0.7, respectively. However, if we only include productive researchers, mean production for 2006 was 1.6 and 2.3, respectively. If this trend continues, in production both disciplines would become fully integrated into the experimental sciences' pattern of publication, although in terms of visibility indicators, they remain far behind the levels of the fully established disciplines. While we might expect the Social Sciences and Education to follow the pattern demonstrated by Economics, the fact is that the indicators do not show substantial improvements over the study period. The heterogeneous thematic classification of the Social Sciences, which includes researchers in departments of Anthropology, Sociology, Geography or Library and Information studies, makes it difficult to reach conclusions applicable to all the disciplines. Less than a third of researchers have had one international publication during the study period and, moreover, the rates of variation are limited (from 9.6% of productive researchers in the first year to 13% in 2006). In Education, the productive researchers do increase substantially (112%), although the very low initial figures facilitate this, showing a pattern of behavior that practically parallels that of the Social Sciences. In this category, the impact and visibility indicators present somewhat better figures. It is highly indicative that not one single article was recorded in the top3 journals in Education during the study period, showing the low international visibility of research in the discipline. These data lead us to reflect on the need to find alternative formulas and data sources with which to construct thresholds in these two disciplines from data gathered prior to 2006, at least, and based on methods proposed elsewhere (van Leeuwen, 2005; Torres-Salinas et al. 2009a). The broader WoS journal coverage of these disciplines in recent years (Thomson Reuters, 2008) could bring up differences in future studies.

The applied nature of the present study —aimed at facilitating the review process— led us to take the methodological decision to expressly reject the use of measures requiring additional calculations. Our final objective is to enable the reviewer to quickly and efficiently determine which productivity and impact thresholds the researcher attains in relation to the other applicants for project funding in any given discipline, and with a satisfactory degree of confidence. Establishing tools that facilitate the reviewers' task and improve the agility and efficiency of the Spanish R&D system does not in any way at all mean that bibliometric measures can or should replace the experts' analytical judgment. The ANEP itself recommends *not* penalizing young or inexperienced researchers, so the thresholds or data presented here should not be interpreted as «formulas» through the application of which x publications or citations would be worth y assessment points. Rather, we hope to provide guidelines that facilitate the fair assessment of the research merits of Spanish scientists. To this end, establishing dynamic time windows as a function of specific discipline-based characteristics or researcher types (junior or senior) is also intended to contribute to the fair assessment of candidates' CVs.

On the other hand, and despite our aforementioned main objective, the thresholds or reference tables we have constructed can also serve as benchmarks in academic and research institutions, providing frames that are more or less demanding according to specific needs and criteria. We are aware that the sample analyzed here is not necessarily representative of the research conducted in national centers as it is based on applications for project funding–which presupposes a relatively high, or at least above average standard of research for Spanish institutions which are hampered by the high percentage of lecturers not actively involved in research. This is demonstrated by CNEAI data on 6-year research bonuses that highlights the fact that 10% of professors and 30% of tenured lecturers —posts that entail participation in research tasks— have never applied for, or never been awarded a single research bonus (CNEAI, 2005). However, institutions wishing to establish research-oriented careers on the basis of bibliometric parameters can use these data to construct their own reference parameters to meet specific internal needs.

To obtain more statistically robust results for observed production and citation, we suggest enrolling a wider-ranging study population that would include researchers applying in future funding rounds. In those categories with little production, or with a high number of non-productive researchers, this is practically obligatory, although alternative data sources —e.g., the National Research Council (CSIC) ISOC database, or the University of Granada IN-RECS database— could be used to evaluate the Social Sciences more fairly. An update of the present study would also provide more recent information on the internationalization of these disciplines as the WoS is including more Spanish journals, especially in the Social Sciences, perhaps making the use of alternative sources unnecessary. We suggest future studies should involve the coverage of document types such as monographs, which are especially important in some branches of the Social Sciences and the Humanities. In the latter, a count of international articles is clearly insufficient to assess researchers' merits.

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