Referencing Patterns of Individual Researchers: Do Top Scientists Rely on More Extensive Information Sources?

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This study presents an analysis of the use of bibliographic references by individual scientists in three different research areas. The number and type of references that scientists include in their papers are analyzed, the relationship between the number of references and different impact-based indicators is studied from a multivariable perspective, and the referencing patterns of scientists are related to individual factors such as their age and scientific performance. Our results show inter-area differences in the number, type, and age of references. Within each area, the number of references per document increases with journal impact factor and paper length. Top-performance scientists use in their papers a higher number of references, which are more recent and more frequently covered by the Web of Science. Veteran researchers tend to rely more on older literature and non-Web of Science sources. The longer reference lists of top scientists can be explained by their tendency to publish in high impact factor journals, with stricter reference and reviewing requirements. Long reference lists suggest a broader knowledge on the current literature in a field, which is important to become a top scientist. From the perspective of the “handicap principle theory,” the sustained use of a high number of references in an author’s oeuvre is a costly behavior that may indicate a serious, comprehensive, and solid research capacity, but that only the best researchers can afford. Boosting papers’ citations by artificially increasing the number of references does not seem a feasible strategy.

Introduction

Bibliometric indicators describe properties of the scientific communication process through the use of mathematical and statistical analyses. They are frequently used to support research assessment at the macro-, meso-, and microlevels (e.g., Braun, Glänzel, & Grupp, 1995; Costas & Bordons, 2005; Vinkler, 2006), but also to obtain a better understanding of the behavior and dynamics followed by researchers when communicating new knowledge (Budd & Magnuson, 2010).

This study focuses on the analysis of the referencing practices of scientists, which may provide interesting information about communication in their field as well as about scientists themselves. Different aspects of the referencing process have been studied in the literature, such as how researchers cite other papers, the median age of their references, and the different typologies of cited literature according to the different fields (Amat & Yegros-Yegros, 2009; Clements & Wang, 2003; Larivière, Archambault, Gingras, & Vignola-Gagné, 2006); scientists’ ways of searching and using bibliographic material (Budd & Magnuson, 2010; Shanmugam, 2009); attitudes and reasons for citing (Clarke & Oppenheim, 2006; Oppenheim & Smith, 2001); and limitations and bad uses of referencing practices (Kidd, 1990; Roth & Cole, 2010). However, there is still an important lack of knowledge about the conceptual relationship between citations and references (Wouters, 1999) as well as about the referencing behavior of researchers at the individual level (Nicolaisen, 2007).

Within the bibliometric scientific community, there also is an important debate about the reasons for the frequently observed correlation between the number of references and the number of citations (Alimohammedi & Sjjadi, 2009).
The discussion about this relationship goes back in the bibliometric literature. In 1965, Price claimed that “we know little about any relationship between the number of times a paper is cited and the number of bibliographic references it contains” (p. 512). In 1983, Stewart reported that articles in Geology and Plate Tectonics were “more likely to be cited if they (…) have more references, or more recent references” (p. 180). Since then, several papers have addressed the topic, offering different theories and answers. For example, Steele and Stier (2000) suggested that a higher level of references can be related to more interdisciplinary approaches; Uzun (2006) related it to higher degrees of authorship; and Abt (2000) and Abt and Garfield (2002) associated it to the length of the articles, among other aspects. According to Moed and Garfield (2004), the reference conventions in a discipline, individual styles, the amount of information contained in the papers, the paper’s length, or the limits imposed by journals editors may influence the frequency with which researchers cite other literature. In addition, a possible “network effect” or “reciprocal altruism,” according to which by citing others you get cited by them, has been suggested: “I cite you, you cite me” (Webster, Jonason, & Schember, 2009). More recently, it even has been argued that the impact of papers could be “boosted” just by including more references in the bibliographic list of publications (Corbyn, 2010).

From our perspective, another plausible hypothesis to explain this phenomenon is that a large reference list could be a characteristic of “top” researchers since they could have a broader knowledge of the literature in their disciplines, and as a result, they could document their papers more thoroughly, being able to satisfy the peer-review standards of the “best” journals, therefore gaining more visibility and receiving more citations.

As suggested by Moed (2005), a reference list in a paper marks the “socio-cognitive location” (p. 219) of that paper. Small (1978) also suggested that cited documents can be seen as “concept symbols” (p. 327) of the ideas contained in the cited works. Taking these ideas from a more general perspective, it can be assumed that the body of references used by individual authors in their “œuvres” signals their “socio-cognitive location” or “socio-cognitive environment” as well as the set of “concepts” that they are using for developing their own research. In other words, references used by scientists indicate their conceptual framework, their influences, and knowledge they manage about their respective fields of work. From this point of view, longer reference lists in the œuvres of researchers might suggest a broader knowledge of the field and a firm grounding in the preexisting literature.

1According to the hypothesis suggested by Webster et al. (2009), if an author cites one of your papers, “You might be more likely to cite [the papers of this author] in the future, provided it is on a related topic. Thus, the more references an author includes, the greater the likelihood that more authors will in turn cite his or her work.” (p. 358)

In this context, the present article addresses the study of referencing patterns at the individual level. A recent article by Frandsen and Nicolaisen (2012) “digs the first spit” in this line of research focusing on the effects of experience and prestige of researchers on their citing behavior in the field of econometrics and provided some initial results and hypothesis (p. 65). Their article concluded with a call for further empirical research and theoretical analyses on the topic since only two journals in a single specialty were studied. In this article, we adhere to this research line by extensively analyzing different aspects related to the use of information by individual researchers in three different research areas and with a different methodology. Thus, this study represents a step forward in the analysis of the referencing patterns of scientists at the individual level, assuming the perspective that referencing (i.e., citing) is a human behavior that is better analyzed from the point of view of individuals, and with the aim of gaining new insights into the topic.

Objectives

The main objective of this article is to analyze the use of references in the œuvres of individual researchers, focusing on the number and type of references that they include in their papers; on how it changes by areas; and whether it could be related to individual factors such as age and research performance.

The main research questions addressed can be summarized as follows:

- Are there inter-area differences in the use of scientific literature (cited references) by scientists?
- Does the use of references vary according to individual factors such as age and research performance? In other words, do “top” researchers use more references in their publications as compared to other scientists? What about more veteran researchers?
- Is there any relationship between the number of references that a scientist uses in his or her papers and other bibliometric indicators (e.g., scientific production, impact, collaboration)? If so, what are the most influential factors?

The answers to these questions will provide important insights into the referencing behavior of researchers, useful for policy makers and research managers, but also for library policies, editors of scientific journals, and scientists themselves.

Method

This study is based on the bibliometric analysis of the scientific publications of 1,064 researchers who were employed with a permanent position (“civil servants”) at the Spanish National Research Council (CSIC) in 2004. These researchers are organized in the institution in three main scientific areas: Biology & Biomedicine (n = 388), Natural
Resources (n = 348), and Materials Science (n = 327). The classification of the researchers in these three main scientific areas corresponds to the disciplinary organizational scheme at the CSIC, in which eight different scientific areas are distinguished with a certain degree of homogeneity in their research profiles and scientists’ behaviors.

For each researcher, the scientific production published in journals covered by the Web of Science (WoS) during the period 1994 to 2004 was downloaded and correctly assigned to authors (several methodologies for the proper matching of authors and documents were considered; Costas & Bordons, 2006). Documents published from Spanish centers, but also from abroad during the stay of scientists in foreign countries, were considered to build the bibliometric profile of each person.

Indicators Based on Research Performance

The bibliometric profile of a scientist comprises the number of publications, citation-related indicators (citations per publication, number of citations, %highly cited papers, h-index), journal impact factor based indicators (median of impact factor and normalized journal position), and relative measures of impact. A detailed description of these indicators is provided in the Appendix A.

To assess whether there is a relationship between research performance and use of references, scientists were classified following a classificatory methodology (described in Costas, van Leeuwen, & Bordons, 2010) for the analysis and research evaluation of individual scientists. Based on this methodology, scientists are grouped in three classes (“top,” “medium,” and “low”) according to their “balanced” performance across three bibliometric dimensions (Production, Observed Impact, and Journal Quality). Top researchers are those with a “high” performance in at least two of the three dimensions; researchers in the “medium” class include an intermediate performance in two of the three dimensions, and researchers in the “low” class have a low performance in at least two of the three dimensions described (cf. Costas et al., 2010).

Indicators Based on the Cited References

For each scientist, a set of indicators based on the number of cited references included in their documents was obtained. Indicators based on cited references were calculated with a window of 11 years. This window is set considering the year of publication of the source papers and goes 11 years backward in the cited references. Thus, for papers published in 1994, only cited references between 1994 to 1984 are considered, 1995 to 1985 for papers in 1995, 1996 to 1986 for papers in 1996, and so on. With this reference window, possible biases due to differences in the age of researchers and/or in the years of publication of documents are minimized. In any case, also note that almost all researchers under analysis (91%) had publications already in the 1994 to 1995, so we can assume a quite homogenous population in terms of publication age during the whole period of analysis (1994–2004).

- References per document: mean number of references included in the source documents of each researcher. It is calculated as the total number of references divided by the total number of publications.
- References per article: mean number of references per WoS-document-type article.
- External references per document: mean number of references to documents that do not belong to any of the coauthors of the source documents (In this indicator, only references to 1994–2004 WoS documents were considered since they could be identified with no error only in these cases.)
- Total distinct references: total number of unique references cited by each researcher.
- Distinct references per document: For each scientist, the number of total unique references is divided by the number of publications.
- Average publication year of the cited references: the mean value of the publication year of the cited references.
- Percentage of references to non-WoS literature: the percentage of references to documents not included as source documents in the WoS (i.e., books, non-WoS journals, reports, theses, etc.).

Indicators Based on Paper Length and Coauthorship

In previous studies, the number of references per publication also has been linked to the degree of authorship (Uzun, 2006) and to the length of the articles (Abt, 2000; Abt & Garfield, 2002). In this study, the mean number of authors per document at the individual level (Authors/document) and the mean number of pages per document of individuals (Pages/document) also have been included in some analyses. This last indicator (Pages/document) has been considered only as a “proxy” of the paper length, as the raw number of pages per document can vary depending on the page format of every journal.

*The percentage of cited references within the last 11 years per area is as follows: 80% in Biology & Biomedicine, 66% in Materials Science, and 59% in Natural Resources.

*The number of words per paper could be a more accurate measure of paper length (as in Frandsen & Nicolaisen, 2012). Unfortunately, since we did not have access to the full text of all the publications, we relied on the number of pages as a “proxy” measure of the paper length.
Review Papers Indicator

One additional indicator is the total number of review papers per researcher, assuming that this document type tends to reflect the state of the art in a particular field and that the presence of review papers in the profile of a researcher can be an indication of his or her expertise and esteem among peers (Lewison, 2009) as well as evidence that the author has achieved a noteworthy level of recognition from her or his scientific papers (Ketchman & Crawford, 2007) as a knowledgeable scientist (Weed, 1997). In a way, authors of review papers can be considered also as “trendsetters” with respect to future research (Sagar, Kalyane, Prakasan, Garg, & Kumar, 2009) because they provide not only a comprehensive literature perspective but also establish some (new) order among the facts.

Scientists by Age

Finally, researchers also were classified into three age groups as of 2004:

- **Young**: researchers between 32 and 43 years old.
- **Senior**: researchers between 44 and 56 years old.
- **Veteran**: researchers between 57 and 69 years old.

Age-group limits are determined by the percentile values in the distribution of scientists by age (P25 = 44 years old; P75 = 56 years old). Note that the “young,” “senior,” and “veteran” labels should be understood in relative terms. In this sense, one could argue that a 40-year scientist is not very young; but from the point of view of this study, he or she is young, belonging to the youngest cohort in the population under study. The purpose of categorizing age in a three-class category was to compare differences along three distinct stages in the life of scientists.

Results

The researchers of the three areas account for a total of 24,982 publications: 9,660 in Materials Science, 9,318 in Biology & Biomedicine, and 6,102 in Natural Resources; receiving 80,546, 189,699, and 56,940 total citations, respectively (in this case, including self-citations) (for additional results about this set of scientists, refer to Costas, Bordons, van Leeuwen, and van Raan, 2009, and Costas et al., 2010).

Inter-Area Differences in Reference-Based Indicators

As shown in Figure 1, there are clear inter-area differences in the rate of references per document, percentage of references to non-WoS literature, and average year of references.

Biology & Biomedicine is the area in which researchers use, on average, more references per document, followed by Natural Resources and then Materials Science. Statistically significant differences have been found among the researchers of the three areas, Mann–Whitney U test, \( p < .05 \).

The references used in Biology & Biomedicine tend to be more recent and are more frequently covered by the WoS than those in the rest of the areas. At the other end of the spectrum is Natural Resources, in which the highest percentage of non-WoS literature is observed and the references used are older, on average, than those in the other two areas, differences statistically significant in all the cases at \( p < .05 \).

These data show that the literature used by scientists is area-dependent, and therefore the first element that determines the referencing behavior of a researcher comes from the area in which she or he is working. Accordingly, the stress on the following sections is placed on differences among classes of scientists within each area rather than on inter-area comparisons.

Do “Top” Researchers Use More References in Their Publications as Compared to the Other Scientific Performance Classes?

As seen in the previous part of the analysis, the number of references per document of individual researchers is clearly area-dependent. Within each area, we hypothesize that top scientists may have more knowledge of their research topics than do the rest of scientists; therefore, we expect to find a higher number of references in their papers. To verify this issue, Figure 2 presents the distributions of the rates of references per publication considering different elements of the scientific output of researchers.

As expected, we observe in Figure 2 (top left graph) that top researchers overall include more references per document than do the other two scientific performance classes in the three areas; these differences are statistically significant in all cases, Mann–Whitney U, \( p < .000 \).

The same analysis was performed including only the document-type “article” (graph on the top-right of Figure 2) to avoid possible bias due to specific document types such as “reviews” that will be studied later. Again, top researchers include the highest number of references per article, \( p < .000 \), thus proving that top researchers consistently use more references in their regular articles than do scientists in the medium and low classes.

To control for possible influences produced by the collaboration of researchers (e.g., researchers with a high degree of collaboration might cite more references in their papers because some of them are included by their coauthors), an analysis based only on single-authored articles

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4In the total set of publications, 3% of the publications are review papers. This percentage varies per area as follows: Biology & Biomedicine, 6%; Materials Science, 1%; and Natural Resources, 2%.

7All the analyses included in Figure 2 also were performed considering the total number of cited references (i.e., without any reference window or document-type restriction), and basically the same results as with the 11-year window were obtained. (Data not shown.)
was performed (middle-left graph in Figure 2) (a similar approach also was followed by Frandsen & Nicolaisen, 2012). In this analysis of the single-authored articles, it can be fairly assumed that the researchers only use the references and literature that they themselves know. We can see that top researchers tend to present more references per article in two areas, although the differences are statistically significant only in Natural Resources, $p < .05$. In addition, researchers in the low class present the lowest levels of cited references per article in all cases. The limitation of this approach is that single-authored articles are quite scarce in current scientific publication (Ma & Guan, 2005; van Leeuwen, 2009), especially in experimental sciences. Consequently, the number of researchers involved in the analysis is lower (only 20% of the total in this study), and more than half of them present only one single-authored article, which means that in many cases we are relying on a single paper to know the referencing behavior of an author.

To avoid the potential influence of “self-citing” practices, the number of external references used by the authors is shown (middle-right graph in Figure 2). Again, it can be clearly seen how top researchers include the highest level of external references in their publications, $p < .05$.

Finally, the total number of unique references used by each researcher was obtained and normalized by the total number of publications per person (bottom graph in Figure 2). Again, the distribution of distinct references per paper shows that top researchers include the highest rate, $ps < .000$, in all the cases, thus indicating that top researchers use a broader range of literature in their oeuvres as compared to the other classes of scientists.

**Does the Number of References per Document Vary According to the Age of Scientists?**

We hypothesize that the age of scientists also may be an influencing factor on the number of references since initially, the greater experience and professional careers of veteran scientists might result in a wider knowledge of their research field.

Contrary to the initial expectations, younger researchers tend to present more references per document as compared
FIG. 2. Reference based indicators by scientific performance class and area. (Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.)
to their older counterparts (Figure 3) (left-hand-side figure, \( p < .05 \), in Natural Resources and Biology & Biomedicine). The decreasing trend in the average number of references per document as scientists get older also is observed in the right-hand graph in Figure 3, where age is maintained as an independent quantitative variable.

Following the scheme presented in Figure 2, the analysis of reference-based indicators by age class and area was performed. (Data not shown.) In general terms, younger researchers included more references per article, more external references, and more unique references per document than did veteran researchers, \( p < .05 \), in nearly all cases. The only exception to this pattern was observed in the distribution of references of single-authored publications, where no significant differences by groups of age were observed.

**FIG. 3.** Number of references per document by age and scientific area. (Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.)

**FIG. 4.** Distribution of the percentage of references to non-WoS literature. (Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.)

Does the Use of WoS-Covered Material Vary by Age or Scientific Performance Class of Researchers?

The percentage of references to non-WoS literature (i.e., references to books, non-WoS journals, PhD theses, scientific reports, etc.) is analyzed in relation to the age and scientific performance class of researchers in Figure 4. In this figure, a clear pattern is found: top and younger researchers present the lowest percentages of references to non-WoS literature while the contrary pattern is found for low-class and older researchers in the three areas analyzed, \( p < .05 \).

Does the Age of the References Vary by Age or Scientific Performance Class of Researchers?

Assuming that top researchers do probably work at the forefront of science, we would expect to find that they support
their research by citing the very recent literature in their fields. To explore this issue, the average of the ordinal age (within the 11-year reference window) of the cited references of the papers of every researcher was computed, and the distribution of this variable for the different areas is presented in Figure 5.

Focusing on scientific-performance classes and age groups (top graphs in Figure 5), we can observe how researchers in the low class (left graph) and older researchers (right graph) use older literature as compared to the top class and younger researchers; statistical significant differences were found in almost all cases, \( p < .05 \). This also is supported by the graph on the bottom, where a slight positive correlation between the age of researchers and the age of their references is detected.

**Do Researchers Who Write Reviews Also Include More References in Their Regular Articles?**

Writing review papers is usually considered a sign of prestige, to the extent that authorship of review papers is positively assessed in the evaluation of researchers (Lewison, 2009). Assuming that scientists who write review papers have a comprehensive knowledge of their research field and sometimes even beyond the regions of one’s own expertise (Ketcham & Crawford, 2007), we wondered whether these researchers also have a higher number of references per paper in their regular articles (Figure 6).

The latter hypothesis is confirmed in Figure 6. Researchers who write review papers tend to also exhibit a broader use of references in their normal articles, \( p < .05 \); this
outcome supports the hypothesis relating to the usefulness of the number of references as a measure of the knowledge of an author in his or her field(s).

Moreover, our data support the importance of review papers in the academic profile of scientists since researchers in the top class present proportionally more review papers than do researchers in the other two scientific performance classes in the three areas analyzed. In general, it can be stated that at least 50% of top researchers have published one or more review papers while lower reviewing activity is found in the other classes (Table 1).

On the other hand, a somewhat surprising result is observed: The researchers who publish review papers tend to be relatively younger than do those without reviews (Figure 7), statistically significant differences in Natural Resources and Biology & Biomedicine, p < .05. Therefore, it seems that is not necessary to be a veteran scientist to gain the experience and recognition needed to write reviews in a field.

**Does the Number of References per Document Correlate With Other Bibliometric Indicators at the Individual Level?**

Pearson’s correlations of the number of references per document and other bibliometric indicators at the individual level are presented separately in Appendix B for the three research areas. In this correlation matrix, we can see how there is a moderate positive correlation (Pearson’s generally higher than 0.400) between the rate of references per document and almost all other bibliometric indicators. The correlation coefficient is below 0.400 only for the number of publications (P), pages/document, and authors/document.

In particular, a positive correlation between number of references per document and (a) observed impact indicators (C, CPP, CPP/FCSm, etc.); (b) journal impact indicators (Median Impact Factor, NJP, and JCSm/FCSm), and (c) indicators of “citation density” of journals (JCSm) and fields (FCSm) is observed.

“Predictors” of the rate of references per document: Model 1. To analyze in more depth the relationship between bibliometric indicators and the rate of references per document of scientists, a linear regression analysis has been performed to obtain a model that could “predict” the rate of references/document (“dependent variable”) considering the other bibliometric indicators (“independent variables”). Two different models are shown in Table 2.

In Model 1, only indicators related to the impact of journals (i.e., Median Impact Factor, NJP, and JCSm/FCSm), the indicators related to the “citation density” of the publication journals of researchers (JCSm) and their fields (FCSm), and the number of pages/document and authors/document have been included.8 Squared-root values were used for all the variables included in the linear regression analysis. The final solution for this model was accepted when the Durbin–Watson statistic was between 1.5 and 2.5. Redundant variables were omitted to avoid multicollinearity. To reject the presence of multicollinearity, we examined the values of tolerance, variance inflation factor (VIF), and condition index,9 and only those variables not highly correlated were left in the model.

The best predictors for the rate of references per document of individual researchers are the Median of the Impact Factor, together with the pages per document rate and the number of publications—in Natural Resources and Biology & Biomedicine. The citation density of the fields of the researchers (FCSm) also presents some influence over the rate of references per document at the individual level. The relatively high Adjusted $R^2$'s (0.41, 0.68, and 0.53) suggest that the model is reasonably good in the three areas for the “prediction” of the references per document of individual researchers (Table 2).

According to Model 1, it is possible to calculate the “predicted” (or expected) values of references per document for every researcher and calculate the difference between the observed rate of references per document versus the expected rate (“Dif. O-E”). Based on this difference, it is possible to study which researchers have more references than expected as the “predictions” derived from Model 1.

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8The indicators of observed impact (C, CPP, CPP/FCSm) were not included in the model because we considered that the number of references in a document may contribute to explain its subsequent citation rate while the inverse relationship makes no sense. In a way, the number of citations is not a determining factor of the level of references per document but a consequence of it.

9Durbin–Watson statistics between 1.5 and 2.5 generally indicate that autocorrelation is low enough to draw adequate conclusions from the regression analysis (e.g., Milne, 1969). It is usually accepted that tolerance less than 0.10 and VIF greater than 10 suggest multicollinearity. Moderate to strong collinear relations are associated with condition indexes of 30 to 100 (e.g., Belsley, Kuh, & Welsch, 1980).
Given these observed–expected differences in references, the following question can be raised: Do top researchers still tend to include more references than expected according to Model 1? Figure 8 presents the Dif. O-E of scientists by research performance class in each of the three areas under analysis. Here, we can observe that researchers in the top and medium classes tend to include more references per document than estimated by the models, with statistically significant differences observed among the three classes in Materials Science, \( p < .05 \), and also between researchers in the low class and the rest in the other two areas, \( p < .05 \).

Concerning the research performance class, several dummy variables are built to indicate whether the scientist is top (“top_dummy”: 1 = yes; 0 = no) or medium (“medium_dummy”: 1 = yes; 0 = no) (with “low” defined as the reference category). The variable “reviews” indicates whether a given scientist has at least one review among their papers (“review” = yes). The number of reviews was not used because most of the scientists have no reviews. The presence of collinearity was discarded by means of tolerance and VIF tests.

As observed in Table 2, research performance class and age are significant in the three areas. Scientists in the medium and top classes tend to use a higher number of references than do scientists in the low class, and the greater standardized beta coefficients of top scientists indicate the greater weight of this variable on the final number of references in this class of scientists. Age is negatively correlated with the average number of references per document, which means that older scientists tend to use a lower number of references per document in the three areas.

The variable “review” is significant in Biology & Biomedicine and Materials Science, where the number of references per document tend to be higher for those scientists who have review experience. However, the variable is not significant in Natural Resources, where the effect of reviews is subsumed by the effect of other variables such as impact factor, research performance class, and paper length.

Some interesting findings emerge from the comparison of Models 1 and 2. First, the addition of some variables in Model 2 slightly improves the explanatory power of the model (Adjusted \( R^2 \)). Second, note that the impact factor, which is the most influential factor in Model 1 (according to the values of the standardized coefficients, which allow comparison among variables expressed in different units), is less relevant in Model 2. Moreover, the number of publications is significant in Model 1, but it drops in Model 2 in the three areas. The underlying reason for these changes.

### TABLE 1. Crosstab analysis of researchers with and without reviews by scientific performance class.

<table>
<thead>
<tr>
<th>Scientific Performance Class</th>
<th>Top</th>
<th>Medium</th>
<th>Low</th>
<th>Total</th>
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<tbody>
<tr>
<td><strong>Natural Resources</strong></td>
<td></td>
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</tr>
<tr>
<td>Authors of reviews</td>
<td>39 (59.1%)</td>
<td>38 (19.9%)</td>
<td>15 (16.3%)</td>
<td>92 (26.4%)</td>
</tr>
<tr>
<td>Authors without reviews</td>
<td>27 (40.9%)</td>
<td>153 (80.1%)</td>
<td>77 (83.7%)</td>
<td>257 (73.6%)</td>
</tr>
<tr>
<td>Total</td>
<td>66 (100%)</td>
<td>191 (100%)</td>
<td>92 (100%)</td>
<td>349 (100%)</td>
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<tr>
<td><strong>Biology &amp; Biomedicine</strong></td>
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<tr>
<td>Authors of reviews</td>
<td>53 (75.7%)</td>
<td>145 (62.8%)</td>
<td>29 (33.3%)</td>
<td>227 (58.5%)</td>
</tr>
<tr>
<td>Authors without reviews</td>
<td>17 (24.3%)</td>
<td>86 (37.2%)</td>
<td>58 (66.7%)</td>
<td>161 (41.5%)</td>
</tr>
<tr>
<td>Total</td>
<td>70 (100%)</td>
<td>231 (100%)</td>
<td>87 (100%)</td>
<td>388 (100%)</td>
</tr>
<tr>
<td><strong>Materials Science</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authors of reviews</td>
<td>35 (50.0%)</td>
<td>38 (21.8%)</td>
<td>10 (12.0%)</td>
<td>83 (25.4%)</td>
</tr>
<tr>
<td>Authors without reviews</td>
<td>35 (50.0%)</td>
<td>136 (78.2%)</td>
<td>73 (88.0%)</td>
<td>244 (74.6%)</td>
</tr>
<tr>
<td>Total</td>
<td>70 (100%)</td>
<td>174 (100%)</td>
<td>83 (100%)</td>
<td>327 (100%)</td>
</tr>
</tbody>
</table>

*Note.* Percentages in columns. Pearson chi-square \( p < .000 \) in the three areas.

**FIG. 7. Distribution of the age of researchers with and without reviews.** (Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.)
is the weight of the new variables introduced in Model 2. Top scientists usually have a high number of publications and/or tend to publish in high impact factor journals, to the extent that $P$ is no more needed in Model 2. The fact that impact factor is maintained in the second model suggests that even within the class of top scientists there are differences in this value that can be associated to differences in references per document rate.

### Discussion and Conclusions

In this article, different aspects related with the use of information by individual researchers have been analyzed, assuming that bibliographic references are key elements in the communication of scientific research and new ideas.

First, we would like to comment on the methodology followed in this study. As mentioned earlier; Frandsen and Nicolaisen (2012) first explored this line of research, focusing on the effects of experience and prestige of researchers on their citing behavior in the field of econometrics. Note that they analyzed the referencing behavior of authors through the study of their single-authored publications to avoid the influence of coauthors on the referencing pattern of the studied authors. The limitation of this approach is that only those scientists who have single-authored publications can be studied, a fact that can be very restrictive in the hard sciences where very few documents are single-authored. In this article, we have adopted a novel approach by focusing on the total scientific journal publications of researchers during an 11-year period to analyze their referencing practices since we consider the use of references as a characteristic of the behavior of authors in the production of their "œuvres" instead of as a property of individual papers. A limitation of our approach is that we cannot completely

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**TABLE 2. Regression analysis using number of references per document (SQRT) as the dependent variable.**

<table>
<thead>
<tr>
<th></th>
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<th>Model 2</th>
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<tr>
<td><strong>Coefficient</strong></td>
<td><strong>Standard error</strong></td>
<td><strong>Coefficient</strong></td>
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<td></td>
<td></td>
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<tr>
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<td>0.807***</td>
</tr>
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<td>−0.054</td>
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<tr>
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<td>0.174**</td>
</tr>
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<td>−0.131*</td>
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<tr>
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<td>0.516**</td>
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<tr>
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<td>0.519</td>
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<tr>
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</tr>
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<td>52.240***</td>
</tr>
<tr>
<td><strong>Materials Science</strong></td>
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</tr>
<tr>
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<td>−0.374***</td>
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<td><strong>Natural Resources</strong></td>
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<tr>
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<td>0.965**</td>
</tr>
<tr>
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<td>0.075</td>
</tr>
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<td>0.591</td>
</tr>
<tr>
<td>$F$ score</td>
<td>91.51***</td>
<td>59.644***</td>
</tr>
</tbody>
</table>

*Note.* Data expressed as coefficient $(SE)$.

***$p < .001$. **$p < .01$. *$p < .05$. 

DOI: 10.1002/asi
discard the potential influence of coauthors on the referencing practices of a given researcher, but we focus on the “average behavior” of scientists, which is drawn from the study of their individual bibliometric profiles instead of relying only on their scarce single-authored publications.10 In any case, further research on the influence of coauthors on the referencing practices of researchers would be needed in the future.

On the other hand, while the main bibliometric indicators used by Frandsen and Nicolaisen (2012) include the total number of publications and citations (both size-dependent; e.g., Costas et al., 2010; Franceschet, 2009; Waltman & van Eck, 2009); here, a broader set of indicators has been used, including some citation-density indicators (citation density of fields and journals) as well as some indicators about the authors (age and performance level of the researchers).

Also note that both approaches reveal the limitations associated with the populations studied: a sample of papers from two econometric journals in the Frandsen and Nicolaisen (2012) article and the oeuvres of individual researchers in three different research areas in the present article. Although the three areas analyzed in the present article present quite consistent and similar patterns, some organizational or country influences could play a role; therefore, the results here presented would benefit from further research in other populations of researchers.

Inter-Areas Differences in Cited References

From this study, it can be concluded that individuals use references mainly as a function of their journals and fields, something that has been previously suggested in the literature (e.g., Moed 2005).

Our study shows that the distribution of the number of references per document varies by area, with Biology & Biomedicine scholars presenting the longest reference lists, followed by Natural Resources and then Materials Science researchers. The shortest reference list of Materials Science is consistent with the claims of Kidd (1990), who observed that engineering fields have less comprehensive bibliographies in their works.

The three areas under study show differences in the use of non-WoS literature as well as in the age of the cited material. Inter-area differences were previously described in the literature. In particular, in a study on Australian universities by Butler and Visser (2006), the lowest use of WoS sources was observed in Humanities and Social Sciences (<10% in some disciplines such as Architecture or Law and close to 30% in the case of Economics) while the best WoS coverage corresponded to Biology, Physics and Chemistry (80–90%). Main interfield differences were due to the different weight of nonjournal sources (i.e., books, book chapters, conference papers) in the dissemination of research.

In our study, Biology & Biomedicine researchers are the ones who rely more heavily on WoS-covered material and also present the strongest focus on more recent literature, which can be linked to the fact that this is a very internationally oriented area. This is in line with the observation of Tenopir, King, Spencer, and Wu (2009) that medical/health scholars tend to read more and more recent publications than do scholars from other fields.

At the other end of the spectrum are researchers in Natural Resources, who tend to cite more non-WoS publications as well as older literature than do those in the other two areas, which is consistent with the results of previous studies in natural resources related fields (Garg, Kumar, & Lal, 2006; Rey Rocha et al., 1999; Velho & Krige, 1984) and can be partly explained by the more local orientation of the area in some of its research topics (Costas & Bordons, 2005).

Relationship Between Cited References and Other Bibliometric Indicators From an Individual-Level Perspective

A positive correlation between the number of references per document and both indicators of observed impact (CPP, CPP/FCSm, %HCP, C, etc.) and indicators of journal impact (Median Impact Factor, NJP, JCSm/FCSm) is observed. The relationship between references and citations is an issue of great current concern (Alimohammadi & Sajjadi, 2009). A positive correlation between the number of references per article and the number of times it was cited has been observed at the document level (Uzun, 2006; Webster et al.,

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10In our study, only 20% of scientists had single-authored publications, and half of them presented only one such publication, which clearly reduces the usefulness of the single-authored publication-based approaches.

FIG. 8. Distribution of the difference between the observed and the expected reference rate (Dif. O-E) by scientific performance class. (Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.)
2009) and at the journal level (Biglu, 2008). Dependence between reference frequency and impact factor was described in different sciences by Abt (2000), who also observed a positive relationship between the number of references and the normalized paper length. This relation was steeper in high impact factor journals, in which the same increase in paper length produced a higher increase in number of references (higher slope of the regression line). The “stricter” referencing requirements of high impact factor journals can be the underlying reason (Bordons, Fernandez, & Gomez, 2002).

Our regression analysis (Model 1) shows that the impact factor is the most influential variable, followed by the number of pages per document. The influence of the number of pages should be analyzed with caution because this variable was not normalized according to the number of words/page, which can vary from journal to journal. In any case, it shows that the number of references per document has some “predictive” power, in that longer papers tend to include more references (Abt & Garfield, 2002). One potential explanation for this relationship is that longer papers could have more comprehensive content and discuss more varied ideas, thus supporting the hypothesis that a larger number of pages and references in the publications of an author can be an indication of a greater amount of ideas, concept symbols, or knowledge that he or she is managing and discussing in his or her papers. Along this line, note that both number of references and article length have been identified as strong predictors of impact in the field of psychology (Haslam et al., 2008).

All in all, these findings are in agreement with the claim of Nicolaisen (2007) that the “act of citing” is “embedded within the socio-cultural conventions of collectives” (p. 633). As seen in this study, the journals and the fields in which an author is working constitute important determinants on the number of references that he or she includes in the papers, which somehow establish the “sociocultural convention” of the author as a member of a collective. However, the influence of individual factors also is observed in Model 2, where top performance and older age have a positive and negative effect, respectively, on the number of references per document.

Use of Literature and Age of Researchers

From the individual point of view, younger researchers include a higher number of references per document and tend to rely more on recent literature while the contrary holds for older researchers. A possible explanation for this issue was provided by Frandsen and Nicolaisen (2012), who suggested that as authors gain experience and become more respected among their peers, they might feel less need for supporting all their claims by bibliographic references. In addition, the idea of older scientists being more likely than are younger ones to cite older publications was initially mentioned by both Zuckerman and Merton (1973) and Barnett and Fink (2008), who suggested two potential explanations for this phenomenon: (a) an age bias in the receptivity of scholars to new ideas, with younger scientists being more receptive than are older ones to new ideas and publications; and (b) the possible accumulated knowledge of scientists who created their base knowledge when they began their professional careers (i.e., when they were younger). Another complementary explanation is that younger researchers are more likely to access their readings from electronic sources (where normally the newer publications are contained) than are their older counterparts, who proportionally read more printed sources (Tenopir et al., 2009). The increasingly competitive environment of research also may help explain the use of references by younger scientists, who are obliged to demonstrate excellence in internationally oriented research topics to obtain a permanent position at the CSIC (Costas et al., 2010). This relationship between the use of more recent literature and the probability of being in the forefront of research also was suggested by Gingras, Larivière, Macaluso, and Robitaille (2008).

It is important to highlight again that our conclusions are limited to the population of scientists we have studied. Although we distinguish between “young,” “senior,” and “veteran” scientists, these labels should be understood in relative terms since the existence of very young scientists (in absolute terms) is limited because all the researchers considered in the study already have a permanent position, which means that they have been able to demonstrate a relevant scientific track and to compete for tenure. In this sense, exploring whether younger researchers (e.g., PhDs, recent postdoctoral researchers, etc.) show different patterns in their referencing behavior as compared to other, more established colleagues such as the ones studied here remains to be studied in the future.

Use of Literature and Scientific Performance Class

An initial conclusion is that top researchers use a broader range of scientific literature in their papers as compared to other researchers, and also more than expected by their journals and fields. They cite more references per document, tend to cite more references in their single-authored publications, use more external references, and use a wider variety of unique references in their total set of publications. Moreover, top scientists use more recent literature and rely more heavily on WoS-covered material than do the rest of the researchers.

A plausible explanation for this pattern is that top researchers have (or display) a broader knowledge of the current literature existing in their respective fields. This explanation can be supported by the fact that they also tend to more frequently be authors of review papers and that the authors of review papers tend to have more references in their regular publications. Along this line, Ramesh Babu and Singh (1998) indicated that it is almost impossible to be a productive scientist without awareness of what others are doing in your area of specialization and that an acquaintance...
with recent trends of research in the context of a global situation is inevitable for raising one’s own research output.

Besides, top researchers also are younger researchers (cf. Costas et al., 2010), and it has been confirmed in this study that younger scientists also tend to use more references in their papers as compared to their older colleagues. These results are in line with the findings of Tenopir and King (2000) and Tenopir et al. (2009), who observed that in general high achievers and younger researchers read more articles than do other scientists, thus suggesting that reading habits and literature acquaintance are key elements in the success of scientific research.

These conclusions have important implications from the perspective of library and information access policies, as they should provide tools and resources to facilitate access to the new knowledge published in the fields of researchers, thus allowing them to be able to keep up high standards of referencing in their scientific work and publications. Although electronic tools have notably improved accessibility to scientific knowledge in the modern world, the claim for the establishment of adequate information access services (Ramesh Babu & Singh, 1998) is still valid to allow researchers to be aware of the most important ongoing literature in their fields.

**Authorship of Review Papers as a Proxy of the Knowledge of the Researchers in Their Fields**

Authorship of reviews has been considered in the literature as an indicator of the high esteem or experience in which a scientist is held (Frandsen & Nicolaisen, 2012; Lewison, 2009) since reviews are frequently commissioned to experts who are supposed to have a specially broad and up-to-date knowledge of the literature in their fields. The fact that review authors include more references than do the remaining authors in their nonreview publications and that top researchers are among the most prone to write review papers suggests the relevance of the number of references per document in the oeuvres of scientists as an indication of a genuine broader knowledge of the relevant literature in their disciplines.

An interesting finding in this study is that the authors of reviews are not necessarily the more veteran researchers in their areas, something that also was observed by Gingras et al. (2008), who suggested that the production of reviews increases until age 50 and gradually decreases thereafter. This implies that relatively younger scientists also can be experts in their fields and attain enough esteem to become authors of reviews. As Squires (1989) stated about biomedical review articles, “Well-prepared descriptive and evaluative review articles of important topics or questions are always welcome but involve research and preparation efforts that many authors are unwilling to make” (p. 195). In fact, according to Ketcham and Crawford (2007), an editorial invitation to write a review is an important event for a younger or midcareer scientist, as the reviews give opportunity to provide the scientists’ unique appraisal of knowledge in his or her area of expertise while for more senior authors, reviews may or may not have career value. In any case, the study of the determinants of review authorship is an interesting topic which is beyond the objectives of the present article and deserves a specific and detailed analysis in the future.

**Integrating Data Under the Regression Model**

Our regression model shows that scientists who use a relatively high number of references per document tend to be young, top or medium as far as their research performance is concerned, publish relatively long documents in relatively high impact factor journals, and work in fields of high citation density. In the areas of Biology & Biomedicine and Materials Science, these scientists show some experience in writing reviews while this is not significant for the area of Natural Resources. In summary, our results indicate that the number of references per document is partly explained by the characteristics of the field (citation density), characteristics of the paper (article length, review paper), and journal prestige (impact factor). Moreover, some personal factors seem to have some explanatory power, such as the age and the research performance of scientists.

**Theoretical Discussion**

A general explanation for the positive correlation between cited references and observed impact at the individual level can be suggested: Researchers who have a comprehensive referencing behavior (and implicitly also an important knowledge of the literature in their fields) get their papers published in the best journals—as they satisfy the higher standards and more difficult peer-review requirements of these journals (Bordons et al., 2002) — and as a result, they get a higher degree of visibility and receive more citations. From our point of view, a plausible hypothesis is that those scientists who present longer reference lists in their publications rely on more diverse sources of knowledge for their research and write more comprehensive and stronger studies. It can be proposed, then, that the correlation between cited references and observed impact at the individual level is intermediated by the high impact of the journals that these researchers are targeting, which in turn explains the higher impact that they eventually achieve.

Nevertheless, following Corbyn’s (2010) “boosting” argument, it could still be argued that some authors could simply include more references in their papers (in a somehow manipulative or “perfunctory” way) to get them published in more prestigious journals and also obtain more citations. In this regard, it must be taken into account that “stacking” masses of references is not sufficient to appear serious and strong (Latour, 1987). Authors need to
“modalize” or “qualify” the references\textsuperscript{11} to get them adequately attached to the argument of the citing paper (implying also that the citing authors need to “know” the cited papers at some degree). From this perspective, it seems quite unlikely that an author just by “dropping” some more secondary or unrelated references could get a not very relevant paper published in a high impact journal (and becoming highly cited afterward). This possibility appears even less likely if the oeuvres of researchers are considered (as done in this study) since the systematic manipulation of referencing behavior in an oeuvre seems an infeasible task.

The idea that top researchers legitimately include a higher rate of references in their oeuvres can be framed in the theory of the “handicap principle” or the “theory of costly signaling” (p. 625) (Nicolaisen, 2007; Nicolaisen & Frandsen, 2007). This theory has been recently used in information science (e.g., Small, 2010\textsuperscript{12}), where its potential validity for the understanding of the reference behavior of authors has been noted (Frandsen & Nicolaisen, 2012).

This principle was described by Zahavi (2003) in the context of sociobiological studies and is of use to explain the evolution of all communication systems. From this perspective, different aspects of social behavior can be explained, such as the relevance of social prestige, which is understood as the respect awarded to an individual who has demonstrated his or her strength and abilities. According to Zahavi,

If an individual is of high quality and its quality is not known, the individual may benefit from investing a part of his/her advantage in advertising that quality, by taking on a handicap, in a way that inferior individuals would not be able to do, because for them, the investment would be too high.\textsuperscript{13} (p. 860)

Besides,

the selective process by which individuals develop their handicap increases their fitness, rather than decreases it. Only cheaters would decrease their fitness if they were to take on a handicap that does not match their qualities, hence the efficacy of the handicap in discouraging dishonest signaling. (p. 861).

Along this line of reasoning, Nicolaisen (2007) suggested that references are a sign of confidence and that a stack of references is a “handicap” (p. 628) that only an honest author can afford. Authors who are uncertain of themselves will usually not risk the potential loss of reputation that the discovery of fraudulent citation habits would carry (especially if done systematically in their oeuvres). Accordingly, without proposing that all references are always honest, Nicolaisen (2007) also suggested that the handicap principle ensures that authors honestly credit their inspirations and sources to a tolerable degree. In other words, in light of the results presented in this article, it can be concluded that the ability to include more references in papers is a costly signal primarily preferred by stronger (or top) researchers, who genuinely manage more ideas and knowledge, and as a result are able to publish in higher impact journals, thus obtaining more visibility and citations from their colleagues. In addition, systematically dishonest long reference lists, should be avoided by scientists because they can make the work of readers, reviewers, and journal editors more difficult; and will hardly contribute to the final quality of documents.

Finally, further research on this topic is still necessary. This type of analysis should be extended to other sets of researchers (from other research organizations, countries, and fields) to corroborate and/or discuss some of our results and conclusions presented here. In addition, the analysis of other factors and variables that also could have an influence on the type and amount of knowledge managed by researchers (e.g., interdisciplinarity, network effects, working conditions, etc.) will be an important line of development in this area of research. Such analyses would help to improve our understanding of the scientific communication and referencing patterns of researchers and how they transfer their knowledge and ideas through their scientific publications.

Acknowledgments

We are grateful to the two anonymous referees, whose comments contributed to the improvement of the quality of the original manuscript, and especially for drawing our attention to a recent publication of Frandsen and Nicolaisen (2012).

References


\textsuperscript{11}According to Small (1978), scientists are “creating a link between a concept (…) and a document” (p. 337) and “the work cited (…) cannot be appended without some explicit or implicit context” (p. 337).

\textsuperscript{12}According to Henry Small (2010), the “generosity” of citing also may entail differentiation of one’s works from the work of others to establish one’s own niches by showing that what one presents is original and unique by comparing it with others with similar ideas.

\textsuperscript{13}Note that Zahavi’s observations referred initially to animals, although afterward extended to explain the social behavior of humans.


Moed, H.F., & Garfield, E. (2004). In basic science the percentage of “authoritative” references decreases as bibliographies become shorter. Scientometrics, 60(3), 295–303.


Appendix A

Bibliometric Indicators Used for the Analysis of Scientists’ Performance

For each individual researcher, a bibliometric profile comprising several indicators was produced. Some of said indicators are based on the CWTS14 standard methodology (van Raan, 2004).

(a) Total number of publications (P) during the period 1994 to 2004 considering only articles, letters, and reviews. Full counting has been used for the calculation of this indicator when multi-authored papers are considered.

(b) Total number of citations (C) received by publications (P) during the period 1994 to 2004. Note that the citation window is variable and shorter for the most recent publications (e.g., for publications in 1994, citations from 1994 to 2004 are considered while for publications in 2004, only citations in 2004 are taken into account).

(c) Citations per Publication (CPP). This is the citation-per-document rate for each researcher. This indicator is again slightly different from the original CPP by CWTS because it is based on C, as defined before (excluding self-citations), divided by P.

(d) Percentage of Highly-Cited Papers (%HCP). Highly-Cited Papers (HCP) are those publications (Only articles and reviews are included here.) cited above the 80th percentile in their respective CSIC research areas (Biology & Biomedicine, Materials Science, and Natural Resources). In other words, HCP are those papers among the 20% most cited within each of the three CSIC areas.

(e) h-index. A scientist’s h-index is the highest number of papers that he or she has published which have each amassed at least the same number of citations (Hirsch, 2005).

(f) Median Impact Factor of publications (IF med). Considering all the papers published by each researcher, the median value of the publication journal impact factor (as defined by Garfield, 1955) distribution is calculated. The median has been preferred to the mean due to the reported “skewness” of this indicator (Solari & Magri, 2000). The impact factor is obtained through the Journal Citation Reports (JCR) as published by Thomson Reuters.

(g) Normalized Journal Position (NJP). This is a measure of the average position of the publication journals in their scientific categories (Thomson subject categories) according to their impact factor (Bordons & Barrigón, 1992). Unlike the IF med, it allows for interfield comparisons because it is a field-normalized indicator.

(h) CPP/FCSm. This indicator measures the impact of a research unit (in this case, individual researchers) compared to the world citation average in the fields in which the unit is active (van Raan, 2004). The rate of citations per publication (CPP) (self-citations removed) is compared with the Field Citation Score mean (FCSm) that is the field-based worldwide average impact used as reference; this indicator (FCSm) also measures the “citation density” of the field(s) of publication of a given unit. Here again, we use the definition of fields based on the classification of scientific journals into categories developed by Thomson Reuters. Although this classification is not perfect, it provides a clear and “fixed” consistent field definition suitable for automated procedures within any given data system.

(i) JCSm/FCSm. This indicator measures the impact of the publication journals within their scientific fields. The journal-based worldwide average impact (Journal Citation Score mean—JCSm—thus, this indicator also measures the “citation density” of the publication journals or a unit) for an individual researcher is compared to the average citation score of the fields (FCSm).

Note that for the last indicators (CPP/FCSm, JCSm/FCSm, JCSm, and FCSm), only articles, letters, and reviews (excluding book reviews) are considered, and only external citations (citations that are not produced by any of the authors of the source document) were taken into account.

14CWTS—Center for Science and Technology Studies (Centrum voor Wetenschaps-en Technologie Studies) in Leiden University.
## Appendix B

### Correlation Between Number of References per Document and Other Bibliometric Indicators

<table>
<thead>
<tr>
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<th>Refs/Doc</th>
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<th>C</th>
<th>h-index</th>
<th>CPP</th>
<th>CPP/FCSm</th>
<th>%HCP</th>
<th>JCSm/FCSm</th>
<th>IF Mdn</th>
<th>NJP</th>
<th>JCSm</th>
<th>FCSm</th>
<th>Pag/Doc</th>
<th>Auth/Doc</th>
</tr>
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<td></td>
<td></td>
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<td></td>
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<td></td>
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Note. SQRT normalization for all bibliometric indicators; loadings > 0.40 for Refs/Doc are boldface.

**significant at the .01 level (two-tailed). *significant at the .05 level (two-tailed).