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Reference density trends in the major disciplines

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ABSTRACT

The aim of this study was to determine whether different areas of knowledge presented different behaviour with regard to the number of references cited per journal document or if, conversely, they shared the same reference density practices. Bibliometric and bibliographic data were collected from 27,141 journals (indexed between 2001 and 2015 in the SCImago Journal & Country Rank (SJR)) and the growth rates in reference density and number of documents and journals in each category were calculated at different levels of aggregation.

Our analysis identified that (a) mean reference density values in some Social Sciences and Arts and Humanities categories were equal to or higher than those in the "hard sciences"; (b) reference density growth rates in these disciplines were not as high as those in the hard sciences and, in general, did not correspond with growth rates in the number of documents produced; (c) this can be considered an indication that citation-based evaluation practices affect publication habits; and (d) no significant differences were found in mean values or growth rates between Gold Open Access and Non Gold Open Access journals.

1. Introduction

The advancement of science relies on the effective communication of the knowledge generated by members of the scientific community. As part of this process, the rapid exchange of knowledge and experience is a significant factor in the production of new research and, therefore, development of the different areas of knowledge. Publication of research results is the main output of research activity (Gross, Harmon, & Reidy, 2002). There are several formal channels through which to communicate research results, such as oral presentations at conferences, monographs, patents, research reports and scientific journals. The latter predominate in the scientific system (Pacheco-Mendoza & Milanés, 2009) because they publish the latest advances in science, constitute the most rapid means of disseminating research results and, in the majority of cases, are indexed in the major scientific databases. It would be useful here to indicate the differences between areas of knowledge and subject categories. Traditionally, areas such as the Social Sciences and Humanities have tended to publish a higher number of monographs and book chapters, whereas in Engineering it is more usual to communicate knowledge through conference proceedings and scientific articles (which predominate in the hard sciences) (Gumpenberger, Sorz, Wieland, & Gorraiz, 2016; Moed, 2005; Nederhof, 2006; Rovira, 2007; REF, 2014; Sanz-Casado et al., 2002).

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The publication of research results enhances a researcher's reputation and brings greater recognition and esteem within his or her scientific community (Sanz-Menéndez, 2003) to the extent that, today, it has become a case of 'publish or perish'. This enhancement of a researcher's reputation, recognition and esteem is closely linked to the evaluation of the research activity. Scientific production *per se* is not an end in itself; impact and visibility are also very important aspects (Gorraiz, Wieland, & Gumpenberger, 2012), so it is of high interest to develop approaches that can be correctly measured and quantified. Consequently, it is necessary to construct and apply indicators that are tailored to evaluate the different processes or aspects (Costas-Comesaña, 2008). These should be designed to be simple to use while still being sensitive to the complexity of the research, standardised within the knowledge area and specific to the subject categories (Gorraiz & Gumpenberger, 2015; Gorraiz, Wieland, & Gumpenberger, 2016; Hicks, Wounters, Waltman, de Rijcke, & Rafols, 2015).

Recent decades have not only witnessed an upsurge in the number of scientific publications (OECD, 2015) but also in the density of citations and references that these receive and contain. According to Moed (2005), and in line with the theories proposed by Merton, references serve two functions. The first is related to content, since they can be used as descriptors of the document they support, and the second is a symbolic payment of intellectual debts or merit recognition (Small, 2004). Citations are also used as a proxy for impact assessment and are commonly used in research evaluation processes.

Citations are generated in the form of literature references and they are usually listed at the end of the publication. Undoubtedly, citations and/or references shape the structure of scientific communication and modern papers contain an abundance of knowledge and information, compiled in their References

Evaluation practices that are largely based on quantitative methods, unquestionably influence the publication habits and practices of researchers. However, it is still a matter of debate as to whether they do so in a manner that is positive or negative for scientific communication. Naturally, scientists tend to follow the rules imposed by the evaluation system in order to increase the worth of their publications, consolidate their prestige and achieve greater recognition (Ellison, 2002; Lange, 1985; Seglen, 1997; Sánchez-Gil, 2014).

Our starting point is the hypothesis that citation habits in different areas of knowledge, and their component categories, can exert a significant influence on the size of a document's reference lists and, therefore, on the mean reference density values.

In this study, we have analysed trends over time regarding the density of references that are cited in articles published in journals. In this context, the term 'references' should be understood to mean the publications listed in the reference list (as well as named literature in some journals or books). In this paper, we use the term *reference density* to refer to the number of references cited per document, which could equally be termed 'citation density' (Garfield, 2007; Van Raan, 2008). However, we have employed this terminology to distinguish between cited and citing papers.

This paper considers whether evaluation systems that are based primarily on citations, lead to an increase in the number of references cited by authors in order to trigger a cumulative effect; thus increasing or inflating the number of citations of each publication, particularly of their own work.

Several earlier studies have analysed references from different perspectives, including the age of the references, the type of document referenced and reference trends in disciplines and journals. Albarrán and Ruiz-Castillo (2011) attempted to determine the distribution of references in an article and the relationship with citations received by articles in different areas of knowledge. Later, Ucar et al. (2014) observed an increase in references in the field of Engineering and related this to greater access to information as a result of the Internet. Finally, Lin and Huang (2012) studied the relationship between co-authorship, self-citing and references; analysing whether a greater number of self-citations is related to lower co-authorship or whether researchers tend to cite their own previous work before that of others.

Behaviour has changed in recent years regarding the number of papers referenced per document, both in different areas of knowledge and in specific subject categories. This change in behaviour has given rise to variability in impact indicators such as the Scimago Journal Rank and the impact factor (IF) (Althouse, West, Bergstrom, & Bergstrom, 2009; Bornmann and Pudovkin, 2017). Consequently, techniques have been introduced to correct these differences, such as the method proposed by Zitt and Small (2008) which formed the basis of the new indicator for measuring journal impact introduced by Moed (2010, 2011), the Source Normalised Impact per Paper (SNIP) which is calculated using data from Scopus (2004) (see also Waltman, van Eck, van Leeuwen, & Visser, 2013).

The aim of this study was to determine whether there were differences in behaviour regarding the density of references generated in different areas of knowledge and at different levels of aggregation, in addition to analysing whether these hypothetical differences were related to an increase in the number of documents available on databases or not.

Given these objectives, we posed the following research questions:

1) How has reference density increased in the 15 years between 2001 and 2015?
2) Are there any differences in the volume and rate of growth between scientific categories and between "hard and soft" sciences?
3) Are reference density growth rates related to an increase in the number of citable documents (i.e. do some categories or fields present a degree of saturation)?
4) Are there differences between Gold Open Access journals and those with more traditional access policies governed by the subscription model?

There is a rationale for this last research question. Due to the fact that authors pay for publication in Gold Open Access journals, these journals have often been discredited regarding the rigour of their peer review process (Barreiro, 2013). This is often perceived as being less severe when compared to traditional journals and authors could benefit from weaker peer review policies by inflating self-references on purpose. This analysis intends to shed a light on the possible undesirable behaviour of Gold Open Access Journals, concerning their citation habits in comparison with traditional journals. This issue is certainly highly relevant for informetricians due to the new challenges posed by the Open Access model.

2. Materials and methods

We used Scimago Journal & Country Rank (SJR) as the data source for our analysis (http://www.scimagojr.com). This platform was created in 2007 (Grupo Scimago, 2007) and continues to develop scientific indicators based on the information included in Elsevier's Scopus database (Codina, 2005; Scopus, 2004). Scopus has wider coverage than its main competitor, the Web of Science Core Collection (WoSCC) which is maintained by Clarivate Analytics (Mongeun and Paul-Hus, 2016), especially in the fields of the Social Sciences, Arts and Humanities (Bartol, Budimir, Dekleva-Smrekar, Pusnik, & Juznic, 2014; Harzing, 2013; Jacso, 2008; Leydesdorff, Moya-Anegón, & Guerrero-Bote, 2010). In this study, we did not examine the advantages and disadvantages of each of the databases since this aspect has already been analysed on multiple occasions. Rather, we considered that Scopus would enable us to conduct a more representative analysis of reference density growth rates in the Social Sciences, Arts and Humanities than the WoSCC, since it includes a higher number of journals (more than 21,950 as opposed to approximately 12,795 in WoSCC) (Elsevier, 2017; Thomson Reuters, 2016). Undoubtedly, the coverage of WOSCC has been expanded by the inclusion of the Emerging Sources Citation Index. This is irrelevant to our study, since this index only began in the year 2015, whereas our study analyses the period from 2001 to 2015. Furthermore, the newly added journals are not included in Journal Citation Reports (JCR), which is the analytical tool providing the required data at journal and category level. The coverage of journals in SJR (more than 20,000 titles via Scopus Content) is significantly higher than in JCR (approximately 13,000 via WoSCC). Therefore SJR has been used as a preferred data source for our study.

The SJR Annual Report comprises the following information (see also http://www.scimagojr.com/journalrank.php):

- *SJR (Scimago Journal Rank) indicator*;
- *SJR Best Quartile*;
- *H-index;*
- *Total Published Documents (the total number of documents published in the three previous years);*
- *Total References*;
- *Number of citations received in the selected year from documents published in the previous three years;*
- *Number of citable documents*[1] *published by a journal in the previous three years (selected year documents are excluded);*
- *Citations per document (2 and 3 years); and*
- *References per document (or average number of references per document) in the selected year.*

In total, we downloaded data from 27,141 journals included in the SJR for at least one year in the period 2001–2015. In order to address our research questions, the journals were analysed on two levels of aggregation: the highest level, consisting of five areas of knowledge (Arts and Humanities, Health Sciences, Life Sciences, Physical Sciences and Social Sciences[2]), and a second level, comprising sixty scientific categories according to the "All Science Journals Classification" (ASJC) code or codes from the Scopus Source List.[3]

The ASJC multidisciplinary category was not included in our analysis due to the high degree of heterogeneity that it represents. Thus, 100 of the journals that were downloaded but classified solely as being in the Multidisciplinary category, were not considered in our analysis.

In each of the five areas of knowledge and the sixty considered categories, all of the bibliometric indicators listed in Table 1 were calculated for all journals and differentiated as either being Gold Open Access (Gold OA) journals or Non Gold Open Access (Non Gold OA) journals (Harnad et al., 2004).

This table considers three main groups of indicators:

1) Journals indicators: the number of journals in the years 2001 and 2015 according to SJR (#J 2001 and #J 2015 in Table 1).

[1] Exclusively articles, reviews and conference papers are considered.

[2] To maintain agreement with levels of aggregation of the All Science Journals Classification (ASJC) of Scopus, the category of Social Sciences in this study is presented in two lists, Social Sciences and Social Sciences (subject).

[3] ASJC codes in the Scopus Source List presents three levels of aggregation. The highest level consists of five areas of knowledge (Arts and Humanities, Health Sciences, Life Sciences, Physical Sciences and Social Sciences), the second level has 27 category headings and the third level lists 307 categories. Last update available at www.elsevier.com/__data/assets/excel_doc/0015/91122/ext_list_June_2017.xlsx or from www.elsevier.com/solutions/scopus/content at the bottom "Scopus Source List".

Table 1
Overview of bibliometric indicators used in this study.

Journals	
Number of Journals in 2015 (#J 2015)	
Number of Journals in 2001 (#J 2001)	
Area or Category Reference Density (Aggregate data)	
Reference Density (RD)	$RD = \frac{References_{yearx}}{Documents_{yearx}}$
Reference Density mean (RD mean)	$RDmean = \left(\sum RD_{n\,year}\right)/15$
Reference Density: Average Annual Growth Rate (RD-AAGR)	$RD - AAGR = \left[\left(\frac{RD_{2015}}{RD_{2001}}\right)^{\frac{1}{14}} - 1\right] * 100$
Documents	
Number of Documents in 2001–2015 period (#P 2001–2015)	$\#P2001 - 2015 = \sum Documents_{nyear}$
Annual number of documents per year (#P year)	
Number of Documents: Average Annual Growth Rate (#P-AAGR)	$\#P - AAGR = \left[\left(\frac{Documents_{2015}}{Documents_{2001}}\right)^{\frac{1}{14}} - 1\right] * 100$

2) Reference Density (RD) indicators: the density of references (i.e. number of references per document) for each area of knowledge and category[4] and for each year (RD indicator), were calculated in static (mean RD indicator) and dynamic (RD-AAGR[5] indicator) form, over the period being analysed. It should be noted that the average annual growth rate (AAGR) is the average increase in the value of a measure over a specific interval of time. It is the result of multiplying the difference between the geometric mean and 1 by 100 (Farris, Bendle, Pfeifer, & Reibstein, 2010). We have used such indicators because we are working at the aggregate level in each category and this is the most common practice (e.g. the category aggregate Impact factor introduced by Garfield and traditionally used in Journal Citation Reports).
3) Documents indicators: the number of documents for a given year (#P indicator) were calculated for the period analysed, in static (#P 2001–2015 indicator) and dynamic (#P-AAGR indicator) form (see Table 1).

To identify Gold OA journals, we used the Directory of Open Access Journals (DOAJ). Launched in 2003 by Lund University and listing approximately 300 open access journals, the DOAJ now provides access to more than 9000 peer-reviewed journals in subjects spanning the Sciences, Social Sciences and Humanities (DOAJ, 2017).

When calculating the results, we did not distinguish between the types of document referenced, although we are aware of the high number of references that a review article can include compared with other document types. Reviews tend to inflate a journal's impact indicators because they usually receive more citations than research articles (Campanario, Carretero, Marangon, Molina, & Ros, 2011; Glänzel, 2008). Consequently, we attempted to estimate the effect of this limitation on our study.

Thus, from among the 27,141 journals included in the SJR, we identified those of a review nature using two different approaches, one semantic and the other more practical.

The semantic approach consisted of identifying all the journals that included the word "review" in their English language title[6]; a total of 1109 journals were obtained, with a reference density (RD) of approximately 48. The reference density growth rate (RD-AAGR) for these 1109 journals was 2.22. When these were excluded from the total number of journals analysed (27,141), the total value for RD-AAGR was 2.13. The RD-AAGR rate for the total number of journals analysed in this study (without differentiating by type or nature of journal) was found to be 2.11.

The more practical approach was the same as that used in the WoS Core Collection database which classifies articles as reviews when they contain more than 100 references (Harzing, 2013). This approach was applied to journals in this instance, i.e. where the mean RD value was greater than 100. In this case, we identified 79 (0.29%) journals with an RD equal to, or greater than, 100 references in at least 14 of the 15 years analysed. Of these 79 journals, 50 also contained the word review in their title and had already been identified using the previous method. The RD-AAGR value for these 79 journals with an RD equal to, or greater than, 100 references was 0.23. Excluding these latter journals from the total number of journals analysed in this study yielded an RD-AAGR of 2.15 instead of 2.11.

These calculations demonstrate that the inclusion of review journals do not significantly distort the results obtained when calculating reference density growth rates.

[4] As with the Aggregate Impact Factor (Thomson Reuters, http://ipscience-help.thomsonreuters.com/incitesLiveJCR/glossaryAZgroup/g4/7769-TRS.htm), the RD was calculated according to the number of references and documents in all the journals in the area or category in question.
[5] In order to avoid nomenclature errors among AAGR (Average Annual Growth Rate) and its synonym CAGR (Compound Annual Growth Rate), AAGR will be used consistently throughout this work.
[6] In other languages, the word "review" refers to journal and does not indicate this specific nature.

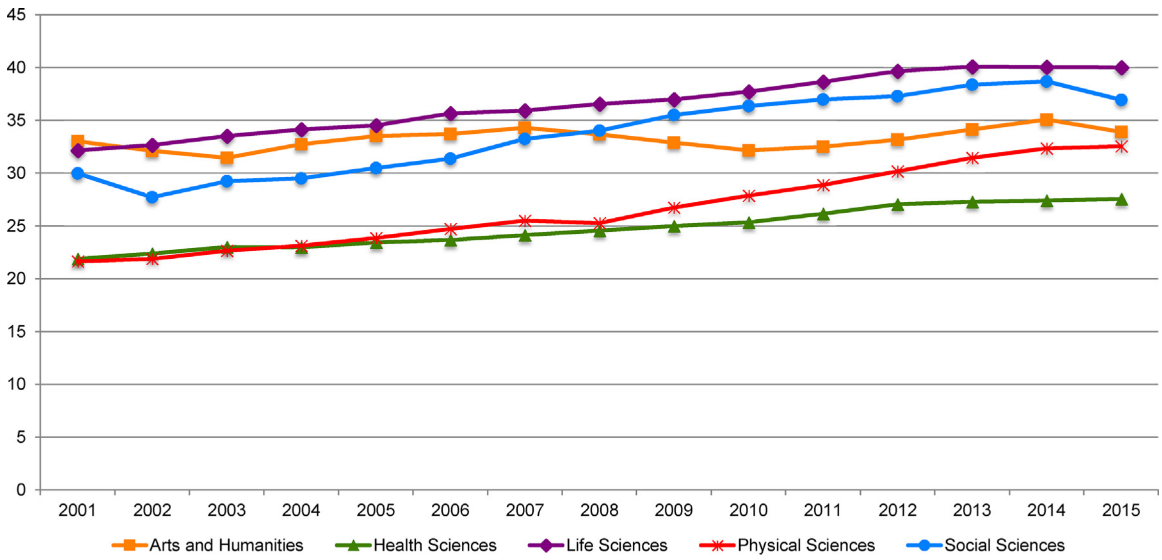

Fig. 1. Evolution of the reference density for all journals in each knowledge area per year.

Table 2
Overview of the journal, document and reference density indicators for each knowledge area (all journals).

Knowledge Area	#J 2015	#J 2001	#P 2001–2015	RD mean	RD-AAGR	#P-AAGR
Arts and Humanities	2874	806	762,237	33.22	0.18	10.20
Health Sciences	6972	5511	9,340,852	24.79	1.66	4.09
Life Sciences	4551	2945	6,590,324	36.55	1.57	4.66
Physical Sciences	7456	4810	10,761,630	26.57	2.95	5.42
Social Sciences	6985	3143	2,922,610	33.71	1.50	7.77

3. Results and discussion

3.1. Knowledge areas

Figures and tables provide the best overview of the most relevant results. The complete data set for each analysis is included as supplementary material.

Fig. 1 shows that the annual RD rose steadily in all areas of knowledge except Arts and Humanities, where it remained relatively static. As shown in Table 2, this area of knowledge presented an extremely high initial RD value in 2001 (32.60) and a high mean annual value (mean RD) over the last 15 years (33.22). This was only exceeded by Life Sciences (36.55) and Social Sciences (33.71) but was higher than Physical Sciences (26.57) and Health Science (24.79, the lowest of all).

These initial results differentiated the behaviours in each area better than those published by Dorta-González and Dorta-González (2013a, 2013b), which analysed the mean number of references in those journals indexed in the WoSCC belonging to each of the 2010 Journal Citation Reports (JCR) editions, i.e. the Sciences and Social Sciences editions. The discrepancy between their results (with slightly higher values) and ours is explained by (a) the different levels of aggregation and classifications employed,[7] (b) the number of journals indexed in both databases, and (c) probable overlapping of journals included in the two JCR editions. Nevertheless, in both studies Life Sciences and Social Sciences were the areas of knowledge with the highest RD.

Table 2 shows that the highest RD-AAGR corresponded to Physical Sciences (2.95), which had one of the two lowest annual mean values, and this was almost twice as high as in other areas such as Arts and Humanities, in which hardly any growth was observed.

Table 2 also shows that the RD-AAGR did not correspond with growth rates for the number of documents (#P-AAGR). Areas with the highest growth in number of publications presented the lowest reference density growth rates. All areas of knowledge showed a clear and strong increase in the number of journals indexed in Scopus.

One of the consequences of the increase in the number of publications in the Arts and Humanities and Social Science domains in these databases is more frequent use for evaluative purposes than before. At the same time, researchers in these

[7] They considered Technology as a separate area, whereas we considered Health Sciences as a separate area, which affected other categories such as Life Sciences and Physical Sciences.

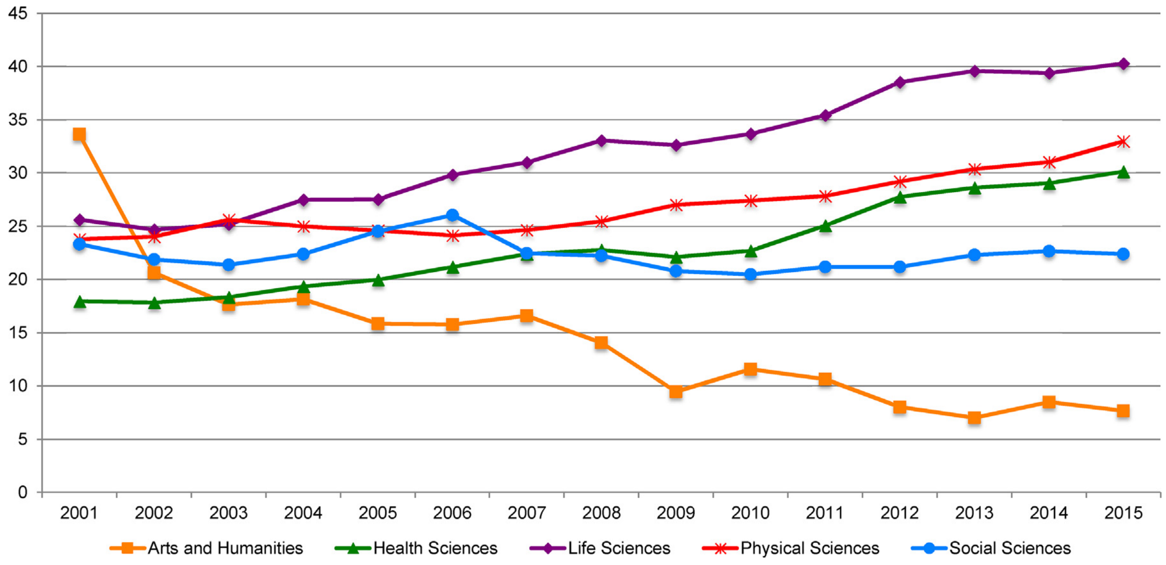

Fig. 2. Evolution of the reference density for each knowledge area per year (only Gold Open Access journals).

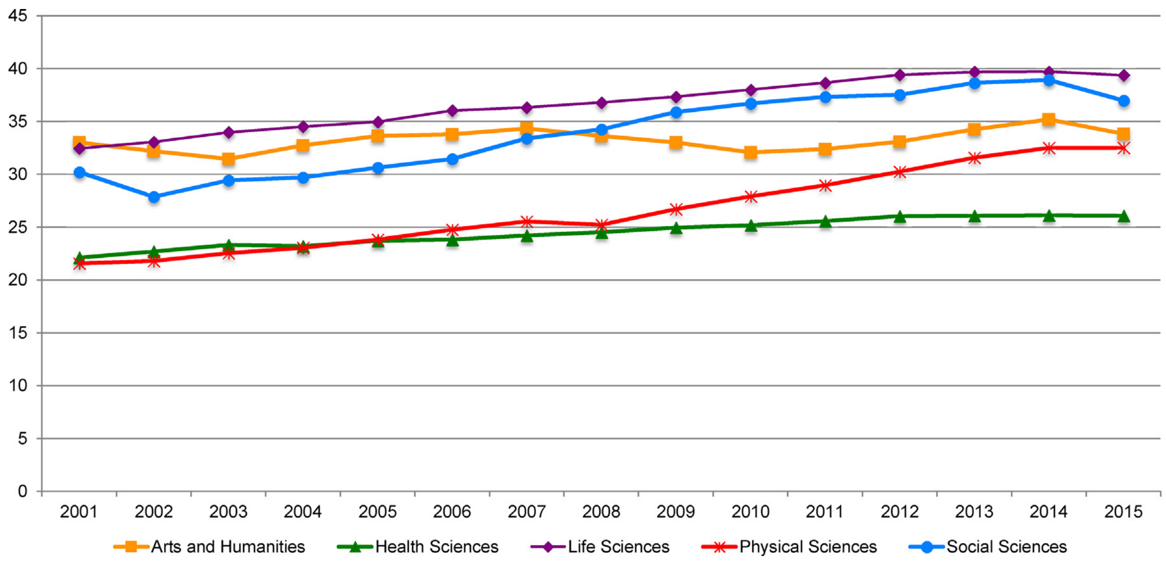

Fig. 3. Evolution of the reference density for each knowledge area per year (non-Gold Open Access journals).

disciplines are becoming more accustomed to publishing in the journals that are indexed in these databases because research assessment exercises (particularly citation analyses) heavily rely on them as the most common data sources.

In addition, the number of journals in these two areas had grown to more than double that in 2001: by 256% in Arts and Humanities and 122% in Social Sciences. This marked increase in the number of journals in Arts and Humanities could be related to the almost negligible increase in the RD mean. As already mentioned above, in 2001 this area of knowledge had the highest RD mean of all the areas analysed but it also had the lowest number of journals (800, five times lower than in other areas). It is possible that the particular focus of the early journals included in the database characterised these values to some extent.

This increase was very clear in the Gold OA journals, where the annual RD mean value for Arts and Humanities fell sharply as the number of journals indexed in Scopus rose (see Figs. 2 and 3). Table 3 shows that the number of publications grew more rapidly in Gold OA journals in all areas of knowledge. In contrast, RD growth rates rose rapidly in the hard sciences but rose more slowly —and in some cases fell— in Social Sciences and Arts and Humanities. This effect will be analysed in more detail below.

A comparison of Tables 3 and 4 shows that there were no differences between Gold and non-Gold OA journals with regard to the mean RD values for the hard sciences. However, annual RD values in Social Sciences and Arts and Humanities were

Table 3
Overview of the journal, document and reference density indicators for each knowledge area (Gold OA journals).

Knowledge Area	#J 2015	#J 2001	#P 2001–2015	RD mean	RD-AAGR	#P-AAGR
Arts and Humanities	300	33	46,859	14.35	−10.02	19.8
Health Sciences	1381	361	1,243,333	23.01	3.78	14.85
Life Sciences	989	232	853,693	32.25	3.29	18.2
Physical Sciences	1037	278	796,037	26.87	2.35	13.87
Social Sciences	821	128	201,061	22.35	−0.29	16.03

Table 4
Overview of the journal, document and reference density indicators for each knowledge area (non-Gold OA journals).

Knowledge Area	#J 2015	#J 2001	#P 2001–2015	RD mean	RD-AAGR	#P-AAGR
Arts and Humanities	2574	773	715,378	33.23	0.17	9.68
Health Sciences	5591	5150	8,097,519	24.50	1.19	2.65
Life Sciences	3562	2713	5,736,631	36.68	1.39	3.03
Physical Sciences	6419	4532	9,965,593	26.58	2.97	4.85
Social Sciences	6164	3015	2,721,549	33.93	1.45	7.23

considerably lower in Gold than in non-Gold OA journals. In the case of Arts and Humanities, the annual RD was more than two times lower in Gold OA journals.

3.2. Categories

The results at category level served to shed light on the degree of contribution of each of the categories to the different areas of knowledge, as well as to identify the categories that generated higher RD values in each area of knowledge.

Table 5 presents the annual RD values. In Arts and Humanities, RD mean varied widely between the different component categories, as can also be seen in Table 6. In this area, the categories with the highest mean RD were Archaeology (52.78), History (52.16) and "History and Philosophy of Science" (47). The categories with the lowest mean RD were Conservation (19.91) and "Visual Arts and Performing Arts" (22.12), which had fewer than half the number of references per article than in the three categories with the highest values. It should be noted that, according to Scopus Classification, Archaeology lies within the "Arts and Humanities" category, as well as within the area of the "Social Sciences".

This high degree of heterogeneity was also detected in the area of Social Sciences (see Social Sciences – subject), where the categories with the highest mean RD were Archaeology (51.21), Law (50.05) and Anthropology (42.4). Meanwhile, the categories with the lowest mean RD were "Library and Information Sciences" (23.53) and Transportation (24.11), with values almost 50% lower. Rising to the next highest level of aggregation in Social Sciences, it was the category of Psychology that obtained the highest mean RD value (39.77) whereas the category "Business, Management and Accounting" obtained the lowest, with a mean RD of 27.43.

The area of Physical Science also presented a high degree of heterogeneity, although mean RD values were lower than in the areas reported above. The categories of "Earth and Planetary Sciences" and "Environmental Sciences" obtained mean RD values of 35.85 and 33.76, respectively. In contrast, the category of Engineering presented a mean RD value of 18.78 (about 50% lower than the values observed in the previous categories.)

The area of Health Sciences presented greater uniformity, in terms of reference density, and also obtained the lowest mean values. Of note were the categories of Health Professions (25.60) and Medicine (25.03), with the highest mean RD, while those with the lowest mean value were Dentistry (23.10) and Nursing (23.50).

The area of Life Sciences presented a higher degree of heterogeneity than Health Sciences, although this remained considerably lower than in the first three areas of knowledge analysed. The categories with the highest mean RD were Neuroscience (41.60) and "Biochemistry, Genetics and Molecular Biology" (37.94), while the category with the lowest mean RD was "Pharmacology, Toxicology and Pharmaceutics" (34.31).

The values obtained in this study for reference density in 2010 (for the areas of knowledge and categories analysed from the SJR) presented considerable similarities with the RD values reported in two studies conducted by Dorta-González and Dorta-González (2013a, 2013b) (represented as $r^F{}_t$ in their studies[8]), concerning data obtained from the JCR and Essential Science Indicators (ESI). If we consider the categories used in ESI with a very high degree of similarity, differences were almost negligible (compare for example, Agricultural Sciences – to employ the terminology used in the ESI- and "Agricultural and Biological Sciences" according to Scopus; ($r^F{}_t$ 2010 = 35.93 versus RD 2010 = 36.88). This confirms the similarity of the data regardless of their source (i.e. whichever database is used) or the methodology employed (citable documents based on the WoS, the JCR) and the total number of documents. The most marked differences occurred in categories with a low degree of

[8] Average number of references in studies of Dorta-González and Dorta-González (2013a,2013 was defined as: "Let RFt be the total number of references in journals of field F in year t. Then rFt = RFt/AFt is the average number of references in citable items of field F in year t".

Table 5
Evolution per year of the reference density for each category (all journals).

Category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Arts and Humanities															
Archaeology	72.1	65.5	49.1	49.9	54.4	49.3	52.6	47.7	47.9	50	52.8	53.1	47.8	49.5	49.8
Arts and Humanities (miscellaneous)	29.8	30.5	31.8	31.1	38.3	35.4	35	37	38.6	37.3	37.8	38.4	38.9	35.6	34.3
Classics	35.1	37.7	45	40.8	45.1	45	47.1	46.5	45.5	46.6	49.8	47.9	47.8	49.2	51.7
Conservation	20.3	20.1	16.2	18.6	20.6	17.6	18.2	15.5	17.7	17.4	19.8	20.5	26	24.8	25.3
History	50.1	45.1	49.9	51.9	55.3	55.9	54.9	54	52.3	51.1	51.8	52.2	53.5	53.7	50.8
History and Philosophy of Science	49.3	42.2	41.8	48.9	48	49.2	50.8	50.3	46.4	49.7	46.7	46.8	48.2	46.1	41
Language and Linguistics	34	34.6	35.6	35.5	37.3	38.3	39.3	39.6	39.8	39.8	41	38.2	37.6	39.1	38.9
Literature and Literary Theory	30.8	33.5	28.3	28.1	28.5	28.9	29.2	26.9	28.4	27.2	26.8	26.6	26.7	27.7	27.9
Museology	43	35.3	28.6	48.7	54.4	47.8	50.6	23.3	25.9	26.5	27.4	25.8	35.8	38.4	35.8
Music	34.2	32.8	27.8	25.3	26.2	25	26.9	25	27.1	19.8	21.5	23.3	25.3	24.5	28.6
Philosophy	27.6	26.6	26.3	28.7	27.5	28.1	30.2	29.3	29.7	30	30.2	29.9	31.3	32.7	29.2
Religious studies	34.5	37.1	39	36.5	38.2	38.1	42.2	40.8	42	39.7	38.4	37.1	38.1	40.4	39.5
Visual Arts and Performing Arts	27.2	30	23.8	22.5	22.9	24	22.5	18.4	17.9	16.5	18.5	19.9	21.1	24.2	22.5
Health Sciences															
Dentistry	18.5	20.2	21	21.7	22.5	22.8	23.9	23.5	23.5	23.9	24	25.1	25.3	25.8	24.8
Health Professions	22.7	22.8	22.6	22.5	23.4	23.7	24	25.4	25.5	26.3	26.6	27.9	28.2	28.9	28.5
Medicine	22.1	22.7	23.3	23.2	23.7	23.9	24.4	24.8	25.2	25.6	26.4	27.3	27.5	27.6	27.7
Nursing	21.7	21.4	22.5	22.7	22.9	22.7	20.6	21.4	23	23.5	24.4	26.2	26.7	26.5	26
Veterinary	21.4	19.6	20.8	21.2	22.3	23	23.5	24.8	24.7	24.8	26.3	26.6	26.6	27.3	28.3
Life Sciences															
Agricultural and Biological Sciences	31.2	31.3	32.5	32.8	33.1	34.1	34.3	35	35.8	36.9	38.1	39.6	40.3	40.4	40.6
Biochemistry, Genetics and Molecular Biology	33.7	34.3	35.1	35.8	36.1	37	37.5	37.9	38.4	39.2	40	41.1	41.2	40.8	40.9
Immunology and Microbiology	32.5	33.3	34.3	34.9	35.1	34.8	35.2	36.2	36.4	37.7	38.2	39.4	39.5	40.2	41.5
Neuroscience	36.7	37.2	38.3	39.5	40.1	40.6	40.9	42.3	42.3	42.7	44.2	44.9	45.2	45.4	43.8
Pharmacology, Toxicology and Pharmaceutics	27.7	29.1	29.7	30.7	32	34.4	34.8	36.1	36.3	36.1	36.8	37.4	38.1	37.6	37.9
Physical Sciences															
Chemical Engineering	21.8	21.8	23.5	24	25.6	26.7	27.5	26.2	27.9	29.2	30.6	32.5	33.9	35.6	36.2
Chemistry	26.4	27.4	28.2	28.5	29.5	30.3	31.3	31.8	33.6	34.9	36.2	37.4	38.6	39.9	40.2
Computer Science	18	18.4	19.2	19.6	20.1	21.2	22.5	23.3	24.6	25.5	26.4	27.1	28.8	29.6	28.8
Earth and Planetary Sciences	30.4	30.2	31.4	31.1	31.7	33	34.4	34.9	36.3	37.8	38.5	41	42.4	42.8	41.9
Energy	12.4	12.1	12.9	13	13.8	15.6	16.6	17.3	19.3	21	22.9	25.4	27	29.1	30.9
Engineering	13.9	13.9	14.7	15.3	15.8	16.9	17.8	17.3	19	20	21	22.3	23.8	24.9	25.1
Environmental Science	27.4	28.6	29.4	29.7	30.9	31.7	32.4	32.8	34.3	36	36.9	37.8	39.2	39.9	39.3
Materials Science	19.2	19.7	20.3	20.5	21.5	22.2	22.5	22.8	24.4	26	26.9	28.4	29.6	31.2	31.9
Mathematics	18.9	19.2	19.4	19.6	20.1	20.7	21.2	21.8	22.6	23.4	24.1	24.5	25.4	26	25.3
Physics and Astronomy	22.6	22.6	22.9	23.2	24	24.3	24.9	25.6	26.7	27.9	28.5	30	31.3	32	32.9
Social Sciences (subject heading)															
Business, Management and Accounting	21.8	20.3	23.1	22.3	22.4	24	25.8	23	27.7	29.2	31.6	33	34.9	36.3	36
Decision Sciences	22.9	23.2	23.9	24.7	25.5	25.8	26.9	27.7	28.9	30.8	32	33.6	34.6	35.4	33.3
Economics, Econometrics and Finance	28	28	28.3	28	28.8	26.9	28	29.9	32.2	32.9	33.9	34.6	35.8	35.8	33.5
Psychology	35.5	35.2	36.8	36.5	37.4	38.5	39.1	40.3	40.2	41.4	42.4	43.3	44.2	44.4	41.3
Social Sciences (subject)	33.3	29.5	30.6	31.6	33	33.8	36.3	39	39.2	39.6	39.3	39	39.8	39.7	37.7
Social Sciences (subject)															
Anthropology	44.7	42.2	41.6	43.3	43.2	44.1	43.4	41	42.2	41.4	43.1	41.9	41.3	41.1	41.5
Archaeology	53.6	52.5	48.6	50.5	53.9	50.6	50.9	49.2	47.8	51	53.1	53.8	51	50.7	51.1
Communication	38.8	35.1	35.9	36.5	34.7	34	33.4	36.3	35.1	36.4	38.6	38.6	37.1	37.5	38.3
Cultural Studies	40.2	38.5	36.9	36.2	37.1	37.4	32.8	34.4	34.7	33.8	34.9	35.5	37.4	37.8	36.7
Demography	31.2	30	39.2	38.6	40.6	39.8	40.8	43.1	43.5	43.7	43.9	44.6	42.5	44.6	39.1
Development	33.4	33.8	34.5	32.8	35.3	34.8	36.7	36.1	35.8	37.9	39.2	40	42.5	42.4	42.3
Education	26.4	25.1	25.8	26.7	27.1	28.7	29.6	30.8	31.6	31.9	32.7	33.1	34.3	34.9	32.7
Gender Studies	39.4	33.8	35.5	36.7	39.1	36.3	38	37.6	39.8	38.2	39	43.5	43.2	41.3	40.1
Geography, Planning and Development	33.3	33.8	34	33.4	36.7	37.1	36.2	37.1	36.8	39.1	40.4	40.8	43	42.6	41.7
Health(social science)	27.1	27.2	27.8	29.1	29.5	32.4	31.3	32.4	33.4	33.1	33	31	32.9	33.2	32.1

Table 5 (*Continued*)

Category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Human Factors and Ergonomics	29	28.9	30.1	31.3	31.6	34.6	34.5	35.8	38	38.9	38.9	41.3	40.4	42.2	36.8
Law	43.7	22.2	19.2	20.9	27	36.1	60.3	80.8	78	77.7	65.2	58.2	56.3	55.2	49.9
Library and Information Sciences	18.9	17.3	18.6	20.8	23.5	23	22.6	22.6	24.1	24.7	25.5	26.6	27.1	27.9	29.8
Life-span and Life-course Studies	25.8	26.8	37.2	38.3	38.2	36.2	37.4	36.7	43.6	41.8	41.8	41.2	39.9	42.5	39.3
Linguistics and Language	34.3	34.8	36.9	35.4	37	38.2	39.6	39.4	40.3	40.5	41.4	39.2	38.5	40.1	39.3
Political Science and International Relations	41	29.2	30.5	32.9	35.7	34.8	37.2	40	41	42.2	42.4	41.9	41.9	40.7	39.9
Public Administration	30.4	30.3	29.6	31.5	29.3	31.9	28.8	28.8	30.8	32.4	30.5	32	36.2	38	35.7
Safety Research	32	20.5	22.1	26	32	32.8	38.2	38.5	35.2	38.4	36.7	37.7	39.3	39.3	36.1
Social Sciences (miscellaneous)	39.8	32.7	34	34.4	35.1	33.7	34.9	37	37.1	38.4	38.8	40	41	39.9	35.3
Sociology and Political Science	41.5	34.8	35	37.4	38.1	38	39	39.6	40.3	40.4	41.3	42.5	43.5	42.8	41.1
Transportation	10.9	11.8	14.1	17.9	19.7	21.5	22.9	24.7	24.6	26.9	29.3	30.8	33.9	36.5	36.3
Urban Studies	37.2	36.4	35.4	32.7	40.3	36.6	38.5	36.7	39	39.3	38	38.5	40	39.6	36.5

similarity, such as Clinical Medicine from the JCR ($r^F{}_t$ 2010 = 38.84) as opposed to Medicine, the category employed in the present study and SJR (RD 2010 = 25.27).

Very similar results were reported by Dorta-González and Dorta-González (2013a) for Social Sciences and Arts and Humanities, especially when comparing JCR categories closely related to the ones used in our study. In this case, the reference densities calculated in our study were lower than those in the mentioned study. This is probably due to the fact that we considered in our analysis all document types and not only citable ones (articles, proceedings and reviews). However, the reference densities showed an equivalent distribution (for example, the highest values were obtained for Law).

In terms of growth rates (Table 6), negative values were only observed in some Arts and Humanities categories, such as Archaeology, "History and Philosophy of Science" (which had very high initial values), "Literature and Literary Theory", Music, Museology, and "Visual Arts and Performing Arts". The same can be said for some Social Science categories, including Anthropology, Communication, Cultural Studies, "Political Science and International Relations", "Social Sciences (miscellaneous)", Sociology, and Urban Studies. The growth values in these latter categories were so low that they were virtually undetectable. The highest RD-AAGR rate was found in the category of Classics.

Far more striking was the drop in values observed in Archaeology, a category halfway between Arts and Humanities and Social Sciences; in 2003, Archaeology obtained an RD of 49.12, compared with 65.52 in 2002 and 72.09 in 2001. Therefore, the RD for this category has fallen by up to 22.28 references over the last fifteen years. This could be due to the large increase in the number of journals indexed in this category. In addition, this category also presented the highest growth rate in the number of documents (#P-AAGR) detected in all the areas of knowledge and categories analysed.

In Social Sciences, the category of "Business, Management and Accounting" presented the highest increase in RD values, up to 14 points more than in 2001. In contrast, the category of Psychology presented the highest values over the study period, reaching 48.8 references in 2014. With regard to Social Sciences (subject), a very heterogeneous category comprising 22 more specific −categories, RD grew most in the categories of Transportation and "Library and Information Sciences".

Turning to RD-AAGR growth rates (Table 6), the categories of Transportation and "Business, Management and Accounting" presented the highest rates (8.99 and 3.64, respectively), whilst the lowest rates occurred in categories that are very diverse, such as "Social Sciences (miscellaneous)" (-0.85) and "Social Sciences (subject)" (0.90).

In the area of Health Sciences, all of the categories showed growth, notably the Health Professions and Veterinary categories (obtaining the highest RD values in 2015). With regards to the RD-AGGR rate (Table 6), Dentistry and Veterinary presented the highest values (2.13 and 2.00, respectively), whilst Nursing presented the lowest (with a rate of 1.30).

In the area of Life Sciences, growth was almost linear in all categories and for all types of journal, being slightly steeper in "Agricultural and Biological Sciences", "Immunology and Microbiology", and "Pharmacology, Toxicology and Pharmaceutics". In addition, Neuroscience obtained the highest RD throughout the study period but especially in 2011, 2012, 2013 and 2014, Although RD fell again in 2015, Neuroscience remained the category with the highest density.

The most notable values of RD-AGGR rate (Table 6) in this area of knowledge occurred in the category of "Pharmacology, Toxicology and Pharmaceutics" (2.26), while the category with the lowest rate was Neuroscience (1.28).

In the case of Physical Sciences, we detected a wide disparity between the categories, although all of them presented strong annual growth (including Mathematics and Engineering). In this area of knowledge, "Earth and Planetary Sciences" and Chemistry obtained the highest annual RD (more than 40), while the lowest occurred in Mathematics and Engineering (approximately 25). The category with the highest growth in RD during this period was Energy, rising from 12.43 references in 2001–30.89 in 2015.

In Mathematics and Engineering, proceedings are the type of document most frequently employed to publish research results. This type of document requires a maximum extension (lower than the original article) and that is why the number of references in proceedings is usually reduced to meet is requisite. Dorta-González and Dorta-González (2013a) found that

Table 6
Overview of the journal, document and reference density indicators for each category (all journals).

Category	#J 2015	#J 2001	#P 2001–2015	RD mean	RD-AAGR	#P-AAGR
Arts and Humanities						
Archaeology	207	19	31,188	52.78	−2.61	19.35
Arts and Humanities (miscellaneous)	51	41	28,739	35.31	1.01	2.36
Classics	91	14	21,928	45.38	2.81	9.09
Conservation	45	7	9208	19.91	1.59	13.77
History	831	334	180,472	52.16	0.1	9.26
History and Philosophy of Science	95	50	31,882	47.03	−1.32	7.14
Language and Linguistics	512	112	112,670	37.92	0.96	9.29
Literature and Literary Theory	635	110	172,953	28.35	−0.7	14.64
Museology	33	7	7019	36.48	−1.31	8.75
Music	101	25	25,234	26.22	−1.28	11.94
Philosophy	432	155	118,593	29.16	0.39	8.99
Religious studies	348	86	65,656	38.78	0.97	11.67
Visual Arts and Performing Arts	370	51	106,584	22.12	−1.32	16.48
Health Sciences						
Dentistry	157	95	165,903	23.1	2.13	4.08
Health Professions	379	239	315,005	25.26	1.64	5.41
Medicine	6330	5113	8,679,508	25.03	1.62	4.08
Nursing	526	315	483,240	23.5	1.3	5.47
Veterinary	210	135	271,410	24.1	2	3.35
Life Sciences						
Agricultural and Biological Sciences	1874	1136	2,013,371	35.73	1.88	6.84
Biochemistry, Genetics and Molecular Biology	1810	1201	3,495,514	37.94	1.4	6.84
Immunology and Microbiology	497	357	838,234	36.61	1.76	6.84
Neuroscience	484	304	738,871	41.6	1.28	6.84
Pharmacology, Toxicology and Pharmaceutics	709	452	981,624	34.31	2.26	6.84
Physical Sciences						
Chemical Engineering	540	420	1,091,246	28.19	3.67	7.22
Chemistry	789	612	2,525,230	32.95	3.04	4.92
Computer Science	1329	649	1,145,982	23.55	3.43	7.86
Earth and Planetary Sciences	1038	812	1,089,728	35.85	2.32	4.91
Energy	361	228	588,132	19.3	6.71	8.77
Engineering	2445	1527	3,338,430	18.78	4.31	6.32
Environmental Science	1184	761	1,209,473	33.76	2.6	7.16
Materials Science	1068	736	2,402,728	24.48	3.69	4.86
Mathematics	1237	677	1,242,636	22.16	2.09	5.85
Physics and Astronomy	956	711	3,032,492	26.64	2.7	3.64
Social Sciences (subject heading)						
Business, Management and Accounting	1144	481	559,446	27.43	3.64	7.49
Decision Sciences	291	146	191,288	28.62	2.71	6.96
Economics, Econometrics and Finance	812	339	366,540	30.98	1.28	8.88
Psychology	1056	633	593,614	39.77	1.07	6.46
Social Sciences (subject)	5004	2147	1,737,893	36.09	0.9	8.62
Social Sciences (subject)						
Anthropology	247	96	63,131	42.4	−0.53	8.95
Archaeology	214	36	42,186	51.21	−0.34	11.9
Communication	238	60	58,352	36.42	−0.09	12.22
Cultural Studies	657	181	154,662	36.29	−0.65	13.3
Demography	67	42	22,245	40.36	1.62	7.25
Development	187	137	79,484	37.16	1.69	6.12
Education	901	311	331,037	30.1	1.55	9.8
Gender Studies	105	44	31,347	38.77	0.12	9.37
Geography, Planning and Development	594	451	235,362	37.73	1.61	6.68
Health(social science)	210	96	113,766	31.02	1.22	8.93
Human Factors and Ergonomics	33	20	21,216	35.5	1.71	6.38
Law	485	217	171,656	50.05	0.95	6.96
Library and Information Sciences	190	89	92,434	23.53	3.32	5.97
Life-span and Life-course Studies	37	13	14,219	37.78	3.04	10.52
Linguistics and Language	589	144	128,527	38.33	0.97	9.37
Political Science and International Relations	382	143	123,864	38.08	−0.19	10.22
Public Administration	101	43	43,819	31.76	1.14	8.28
Safety Research	57	12	17,585	33.64	0.85	17.19
Social Sciences (miscellaneous)	190	116	76,472	36.8	−0.85	8.09
Sociology and Political Science	890	416	328,561	39.68	−0.08	8.32
Transportation	76	44	36,030	24.11	8.99	5.4
Urban Studies	119	47	33,346	37.64	−0.13	8.44

Mathematics and Engineering documents habitually included no more than 20 references per article. In our studies, the mean RD did not exceed 19 references in Engineering and 22 references in Mathematics. These data are very similar to those obtained by Ucar et al. (2014) in an analysis of eight journals in the category of Engineering.

In Physical Sciences, the categories of Energy and Engineering had the highest RD-AGGR growth rate (6.71 and 4.31 respectively, see Table 6), while "Earth and Planetary Sciences" presented the lowest rate (2.32).

3.3. Differences for gold OA and non gold OA journals at category level

One of our research questions was whether there are differences between Gold OA journals and those with more traditional access policies, termed 'Non Gold OA journals' here. Therefore, we calculated all of the indicators for both types of journal in order to identify any differences between them. The results for Gold OA journals and Non Gold OA journals are presented in Tables A4 and A5 as part of the Supplementary Material.

We found that the Gold OA initiative exerted a different influence on some categories (Table A4 in the Supplementary Material). In the areas of Arts and Humanities and Social Sciences, this type of journal has emerged much later than in the other areas of knowledge analysed. This applies to the categories of Museology, "Life-span and Life-course Studies", Communication and Conservation and, to a lesser extent, Archaeology and Gender Studies. This aspect was most marked in the category of Arts and Humanities (miscellaneous), where this type of journal did not appear until 2011. In the case of some of the other categories (such as Museology) this finding may be due to the influence of associations, which also tend to be publishers, adhering to the traditional journal subscription model.

The highest growth rates in the number of documents (#P-AAGR) (Table 7) in Gold OA journals occurred in the area of Arts and Humanities and, in particular, in the categories of Religious Studies (27.41) and Philosophy (24.79). Equally high were some of the rates observed in Social Sciences, for example in "Economics, Econometrics and Finance" (26.97) and Safety Research (25.59). In the hard sciences, #P-AAGR values in Gold OA journals were somewhat lower but still considerable, especially in the category of Health Professions (with the highest value, 22.24) and in the Life Sciences categories of Neuroscience (21.84) and "Immunology and Microbiology" (20.82).

In contrast, the lowest #P-AAGR rate values were obtained in the categories of Human Factors and Ergonomics (0.16), "Library and Information Sciences" (5.32), Law (8.25) and Veterinary (9.01), all with a rate below 10 documents.

Table 7 gives the annual RD values for each of the categories comprising the five areas of knowledge, in Gold OA journals. The areas of Arts and Humanities, Social Sciences and Social Sciences (subject) all show highly heterogeneous behaviour.

The highest mean RD values (Table 9) were obtained in the Arts and Humanities categories of History (49.76), Religious Studies (38.26) and "Language and Linguistics" (35.94). The only category that presented behaviour similar to that for the total number of journals was History but, in this case, with slightly lower values. It is striking that the category of "History and Philosophy of Science" presented a much lower mean RD than the total number of journals, with up to 25.7 fewer references than the mean. "Visual Arts and Performing Arts" presented a mean of 10 references more in Gold OA journals.

Mean RD values (by category) in the area of Social Sciences (subject) were very similar to those for the combined total of the journals analysed. The most notable categories were Law (50.91) and Archaeology (42.73), although in this case Social Sciences (miscellaneous) also presented high values (38.67) for mean reference density. Conversely, as with the total number of journals, the lowest values were obtained for Transportation (18.71) and "Library Information Sciences" (20.62). Rising to the next highest level of aggregation in Social Sciences, it was the category of Psychology that obtained the highest mean RD value (37.50). Lower values were observed in Decision Sciences and "Business, Management and Accounting" (22.35 and 23.58, respectively).

In the areas of Social Sciences, Social Sciences (subject) and Arts and Humanities, mean RD values were lower in Gold OA journals than in the total number of journals analysed. It seems that an open access policy for periodicals neither encourages authors to cite a higher number of papers to support their research findings nor fosters disparate citation habits, with respect to papers published in traditional access journals.

In the area of Physical Sciences, the annual RD indicated an increase over the fifteen years analysed, as was the case with the total number of journals, but this growth was less marked in Gold OA journals than in the total number of journals. The highest reference densities in this area were observed in "Earth and Planetary Sciences", Chemistry and Environmental Science. RD values for scientific categories such as Chemistry, Energy, Materials Science and "Physics and Astronomy" doubled over the period analysed. Finally, the category that showed the greatest growth differences between 2001 RD and 2015 RD was Energy, increasing from 12.43 to 30.89 in all journals, from 17.49 to 35.70 in GOA journals and from 12.31 to 30.62 in Non GOA journals.

The mean RD value obtained for "Earth and Planetary Sciences" and Environmental Science was 36.35 whereas, once again, Engineering and Mathematics obtained a maximum of 21.60 references. These data are similar to those reported by Dorta-González and Dorta-González (2013b) and, in this case, they correspond to Gold OA journals. The category of Materials Science presented the lowest mean RD value, with 18 References

The area of Health Sciences presented higher homogeneity in RD values than the previous areas of knowledge and we observed a greater similarity between mean RD values in Gold OA journals and in the total number of journals. It is noteworthy that RD values increased the most in the category of Nursing, rising from 11.25 in 2001–30.33 in 2015. We also observed this behaviour in Medicine, albeit not as pronounced.

Table 7
Overview of the journal, document and reference density indicators for each category: Gold OA versus non-Gold OA journals.

	Gold OA journals						non-Gold OA journals					
Category	#J 2015	#J 2001	#P 2001–2015	RD mean	RD-AAGR	#P-AAGR	#J 2015	#J 2001	#P 2001–2015	RD mean	RD-AAGR	#P-AAGR
Arts and Humanities												
Archaeology	24	0	2051				183	19	29,137	53.08	−2.49	18.1
Arts and Humanities (miscellaneous)	1	0	94				50	41	28,645	35.37	1.03	2.31
Classics	9	0	919				82	14	21,009	45.24	2.91	8.23
Conservation	8	0	863				37	7	8345	19.4	1.4	12.55
History	70	15	9508	49.76	−1.13	17.59	761	319	170,964	52.41	0.2	8.82
History and Philosophy of Science	9	1	1781	21.3		19.61	86	49	30,101	47.99	−1.28	6.67
Language and Linguistics	90	6	10,320	35.94	−0.42	18.62	422	106	102,350	38.2	1.13	8.44
Literature and Literary Theory	54	4	8234	27.36	−2.72	19.55	581	106	164,719	28.4	−0.59	14.36
Museology	4	0	310				29	7	6709	36.69	−1.09	8.28
Music	7	1	923	15.79	17.1	14.01	94	24	24,311	26.6	−1.55	11.8
Philosophy	51	5	8392	24.51	−0.71	24.79	381	150	110,201	29.46	0.41	8.39
Religious studies	20	3	4762	38.26	2.22	27.41	328	83	60,894	38.77	0.93	11
Visual Arts and Performing Arts	25	1	2652	32.36	−0.68	21.14	345	50	103,932	21.88	−1.43	16.32
Health Sciences												
Dentistry	40	10	22,591	19.85	4.09	11.38	117	85	143,312	23.51	2.03	3.13
Health Professions	49	7	21,905	24.33	1.02	22.24	330	232	293,100	25.38	1.74	4.59
Medicine	1250	327	1,156,381	25.25	4.48	15.09	5080	4786	7,523,127	24.72	1.12	2.6
Nursing	54	9	26,837	22	7.34	16.74	472	306	456,403	23.48	1.12	4.96
Veterinary	57	19	47,567	24.26	1.58	9.01	153	116	223,843	24.14	2.07	2.27
Life Sciences												
Agricultural and Biological Sciences	437	107	388,675	34.03	3.57	19.41	1437	1029	1,624,696	35.69	1.61	4.62
Biochemistry, Genetics and Molecular Biology	383	95	498,798	35.29	3.3	20.21	1427	1106	2,996,716	37.96	1.23	2.28
Immunology and Microbiology	109	23	99,363	33.82	5.07	20.82	388	334	738,871	36.48	1.36	2.17
Neuroscience	105	11	72,002	36.66	4.07	21.84	379	293	666,869	41.64	0.98	3.28
Pharmacology, Toxicology and Pharmaceutics	145	30	101,652	28.21	3.61	14.61	564	422	879,972	34.9	2.3	3.41
Physical Sciences												
Chemical Engineering	68	20	47,524	29.15	4.91	16.2	472	400	1,043,722	28.14	3.62	6.86
Chemistry	99	36	173,552	25.36	4.5	12.71	690	576	2,351,678	33.48	3	4.47
Computer Science	176	35	96,089	26.23	4.52	18.27	1153	614	1,049,893	23.33	3.24	7.12
Earth and Planetary Sciences	178	78	90,525	36.35	3.32	10.59	860	734	999,203	35.79	2.23	4.45
Energy	35	11	18,605	24.45	5.23	15.08	326	217	569,527	19.16	6.72	8.54
Engineering	246	47	130,194	21.6	4.2	18.65	2199	1480	3,208,236	18.7	4.29	5.85
Environmental Science	188	54	101,979	33.48	4.04	13.2	996	707	1,107,494	33.76	2.49	6.66
Materials Science	112	29	115,247	18	4.6	16.28	956	707	2,287,481	24.8	3.69	4.53
Mathematics	164	40	102,830	21.47	3.89	18.32	1073	637	1,139,806	22.2	2	5.05
Physics and Astronomy	120	39	266,800	25.69	1.09	12.21	836	672	2,765,692	26.82	2.79	3.01
Social Sciences (subject heading)												
Business, Management and Accounting	66	9	17,878	23.58	5.78	12.72	1078	472	541,568	27.53	3.61	7.33
Decision Sciences	31	5	6794	22.35	3.69	15.22	260	141	184,494	28.82	2.72	6.72
Economics, Econometrics and Finance	72	4	16,043	23.19	4.23	26.97	740	335	350,497	31.22	1.27	8.41
Psychology	105	12	33,495	37.5	2.34	20.58	951	621	560,119	39.76	0.96	5.86
Social Sciences (subject)	637	102	144,011	30.16	2.9	15.61	4367	2045	1,593,893	36.57	0.87	8.03
Social Sciences (subject)												
Anthropology	33	5	9099	30.33	3.76	13.16	214	91	54,032	44.13	−0.79	8.27

Table 7 (*Continued*)

Category	Gold OA journals						non-Gold OA journals					
	#J 2015	#J 2001	#P 2001–2015	RD mean	RD-AAGR	#P-AAGR	#J 2015	#J 2001	#P 2001–2015	RD mean	RD-AAGR	#P-AAGR
Archaeology	23	1	2288	42.73	10.01	17.72	191	35	39,898	51.66	−0.53	11.4
Communication	28	0	4546				210	60	53,806	36.89	0.04	11.26
Cultural Studies	61	11	11,400	31.89	3.02	14.62	596	170	143,262	36.62	−0.88	13.17
Demography	10	2	2117				57	40	20,128	40.55	1.55	6.26
Development	15	2	2590	31.27	1.82	15.92	172	135	76,894	37.36	1.72	5.85
Education	138	19	38,298	24.55	3.15	17.25	763	292	292,739	30.7	1.51	8.98
Gender Studies	7	0	1960				98	44	29,387	39.21	0.26	8.71
Geography, Planning and Development	79	25	19,744	32.02	4.02	14.89	515	426	215,618	38.18	1.53	5.92
Health(social science)	27	4	7715	27.57	7.42	16.39	183	92	106,051	31.2	1.09	8.5
Human Factors and Ergonomics	1	1	677	25.59	−2.08	0.16	32	19	20,539	35.85	1.8	6.59
Law	44	8	7514	50.91	3.07	8.25	441	209	164,142	50.07	0.89	6.9
Library and Information Sciences	32	11	9379	20.62	4.96	5.32	158	78	83,055	23.89	3.13	6.06
Life-span and Life-course Studies	3	0	250				34	13	13,969	37.83	3.08	10.25
Linguistics and Language	93	7	10,999	35.5	−0.1	17.39	496	137	117,528	38.65	1.12	8.68
Political Science and International Relations	33	3	4561	36.75	1.61	19.31	349	140	119,303	38.12	−0.23	9.93
Public Administration	10	2	3242	35.92	3.33	15.67	91	41	40,577	31.49	0.94	7.77
Safety Research	11	1	2434	26.44	4.12	25.59	46	11	15,151	34.02	0.73	16.1
Social Sciences (miscellaneous)	14	4	3905	38.67	−1.79	13.42	176	112	72,567	36.76	−0.79	7.79
Sociology and Political Science	85	10	15,290	32.88	1.64	14.53	805	406	313,271	39.96	−0.1	8.05
Transportation	8	1	1444	18.71	6.45	20.27	68	43	34,586	24.33	9.14	4.9
Urban Studies	27	3	3894	35.56	0.77	16.64	92	44	29,452	38.08	−0.15	7.53

The area of Life Sciences mirrored the behaviour observed for the total number of journals analysed; it presented a lower degree of homogeneity than Health Sciences but not as marked as that observed in Arts and Humanities, Social Sciences (subject included) and Physical Sciences. In addition, mean RD values presented only negligible differences between Gold OA journals and the total number of periodicals.

In relation to the RD-AAGR growth rate in Gold OA journals (Table 9), negative values only occurred in Arts and Humanities and Social Sciences (including subject) categories such as “Literature and Literary Theory”, “Human Factor and Ergonomics”, History, “Social Sciences (miscellaneous)”, Philosophy, “Visual Arts and Performing Arts” and “Language and Linguistics”. All of these initially presented very high RD values that subsequently declined over the study period, In addition, the last three categories did not present a mean increase of a single reference in the period studied.

Within Arts and Humanities, Religion and Music were the only categories with positive RD-AAGR values (2.22 and 17.10, respectively). Furthermore, in the category Music, the highest RD-AAGR value was observed.

In Social Sciences and Social Sciences (subject), the highest RD-AAGR rates were observed in Archaeology (10.01), Health (social sciences) (7.42), Transportation (6.45) and “Business, Management and Accounting” (5.78).

In Health Sciences, the category of Nursing obtained the highest RD-AGGR rate (7.34), while the lowest values were observed in Veterinary (1.58) and Health Professions (1.02). Notably, the category of Nursing obtained a RD-AGGR rate approximately equal to 1 in the total number of journals, whereas this figure was 6 times higher in Gold OA journals.

In the area of knowledge of Life Sciences, the most notable RD-AGGR rate values occurred in the categories of Immunology and Microbiology (5.07) and Neuroscience (4.07) (Table 9). Neuroscience was particularly striking because the rate of growth in Gold OA journals was three times higher than in the total number of journals. The category with the lowest rate was Biochemistry, Genetics and Molecular Biology (3.57).

In Physical Sciences, the categories of Energy and Chemical Energy obtained the highest RD-AGGR rates (5.23 and 4.91, respectively, see Table 9. The lowest rate was detected in “Physics and Astronomy” (1.09). In this area, the RD-AGGR rate was lower in the total number of journals for higher and lower values alike. In Gold OA journals, it was the category of Energy that showed most growth.

4. Conclusions

There are three main conclusions that can be drawn from this study:

1) In contrast to general assumptions,[9] mean reference density values in some categories in the areas of Social Sciences and Arts and Humanities are equal to, or higher than, those in the hard sciences. For example, some Arts and Humanities and Social Sciences categories obtained higher mean reference density values than the highest such value obtained in the hard sciences (e.g. in the category of Neuroscience). In other words, citations to references occur at least as often (or even more often) in these two knowledge areas as they do in some of the hard sciences, despite potentially lower journal impact factors (see SJR or JCR). This is mainly because they cite types of publication other than journal articles (for example, in the category of Law), show different obsolescence behaviours (age of the cited documents) and they also cite contributions in journals that are not indexed in the database.

This study also shows that closer scrutiny at category level reveals a high degree of heterogeneity in terms of publication and citation habits in each area of knowledge. Only the areas of Health Sciences and Life Sciences maintained some degree of homogeneity at category level, whereas Arts and Humanities presented a higher degree of heterogeneity.

2) Reference density is increasing in all scientific areas and categories, except in some Arts and Humanities categories, which is to be expected since the number of citable documents is constantly rising, illustrated by the continuous increase in documents and journals indexed in Scopus.

Although an increasing number of documents and journals in Scopus is not necessarily evidence of an increasing number of citable documents and could just be due to an increasing degree of the coverage of the database, the number and availability of potentially citable documents is increasing worldwide in all disciplines.

In line with this reasoning, it would be logical to assume that the highest increases in reference density would occur in those areas or categories which also present a higher increase in the number of documents. However, our results show that growth rates in reference density do not correspond with growth rates in the number of documents. In fact, the areas with the highest increase in the number of publications showed the lowest rates of growth in reference density; in other words, the correlations were generally negative, except in Physical Sciences, which obtained a Pearson correlation value of 0.6.

One possible reason for the low correlation could be that some categories or areas of knowledge had very high initial reference density values, due to scant indexing of journals in the Scopus database. Another possible reason could be that mean reference density values have already reached a maximum value and present a level of saturation that precludes further growth.

[9] It is well accepted in the community that citation counts are insufficient for evaluation of the Arts & Humanities. There are only two logical explanations. Firstly, the number of citations is too low. Secondly, the framework for citation collection is not yet as developed as in the hard sciences, which results in a low number. One of the most important reasons is the low coverage of publication channels like books, book chapters, etc. in the current citation databases (Dorta-González and Dorta-González, 2013a, 2013b; Gumpenberger et al., 2016; Nederhof, 2006).

However, we detected wide differences in behaviour in each area of knowledge. For example, in Life Sciences and Physical Sciences, growth rates were higher in the categories with the lowest mean density values, suggesting the adoption of evaluation practices (especially in the case of "Pharmacology, Toxicology and Pharmaceutics" and of Energy). The same trend was detected in Health Sciences, with the exception of the category of Nursing.

This finding suggests that other factors must be exerting an influence and one of these is undoubtedly the effect of citation-based evaluation practices on publication habits. The fact that all hard sciences, where these evaluation practices are more established, were the only areas of knowledge that coincided with the above assumption seems to add further support to our initial hypothesis.

Reference density growth was also clearly evident in Social Sciences at the highest level of aggregation, where the categories of "Business, Management and Accounting" and Decision Sciences presented the most growth, as if these scientific fields would try to make up for lost time. A more detailed analysis at a lower level of subject aggregation confirmed that, generally, the categories with lower mean values showed the highest growth rates.

This could hint at the increasing adoption of evaluation practices in this discipline.

It is only in the area of Arts and Humanities, where neither growth nor saturation are so clearly visible. Thus, categories such as Music and Visual Arts and Performing Arts seem impervious to these practices and perpetuate their own publication dynamics, while others such as Archaeology, History and History and Philosophy of Science appear to have reached a degree of saturation.

3) In general, we did not find that mean annual reference density values for Gold OA journals differed notably from those for Non Gold OA journals, although they tended to be somewhat lower in most categories. In other words, Gold OA journals do not cite references more than subscription-model journals, and so neither inflate nor distort bibliometric analyses based on citations. It would be interesting to conduct a more detailed analysis of this aspect, including the proportion of self-citations in both types of journal.

We did not observe significant differences between Gold and Non Gold OA journals in terms of reference density growth rates in the hard sciences either, as evidenced by the high correlations. Mean values tended to be slightly lower and growth rates somewhat higher, but no correlation was detected with growth rates in documents.

We identified a similar but somewhat more pronounced trend in the area of knowledge of Arts and Humanities, with a few exceptions such as the Visual Arts and Performing Arts category. This category was the only one that presented an extremely high value, albeit offset by a very low, negative growth rate.

Our study also reflects a clear increase in the number of articles in Gold OA journals in almost all categories. In addition, we observed that Gold OA journals were indexed later by Scopus in areas such as Arts and Humanities and Social Sciences than in the other areas of knowledge analysed. In some cases, this may be due to the influence of associations, who also tend to be publishers adhering to the more traditional subscription-model, their members comprising the largest group of users or readers of a journal.

Lastly, findings in this study were in agreement with previous results (Dorta-González & Dorta-González (2013a, 2013b). The Scopus database did not differ much from the WoSCC in terms of results obtained (see comparisons) and our results were not affected by the use of all types of document rather than analysing solely citable documents and/or excluding reviews.

5. Limitations

This study was conducted on different hierarchical levels (areas of knowledge, categories and sub-categories) but focused on the narrow sub-categories for the Social Sciences and Humanities. However, the results show a very high degree of heterogeneity for almost all categories. The investigation of the behaviour on the lowest level for the natural and exact sciences would be an interesting area for future research.

It should also be stressed that this study has been undertaken on publications in journals without any differentiation of document type. This decision was based on the outcome of an additional analysis performed during this study, which confirmed that a consideration of review articles in review journals would not significantly distort the results obtained when calculating reference density growth rates.

A similar study for other publication channels, (e.g. book series, conferences and proceedings and trade journals) can also be carried out from SJR, particularly in such disciplines where these play an important role.

Author contributions

Susana Sánchez-Gil: Conceived and designed the analysis; Collected the data; Contributed data or analysis tools; Performed the analysis; Wrote the paper.

Juan Gorraiz: Conceived and designed the analysis; Collected the data; Contributed data or analysis tools; Performed the analysis; Wrote the paper.

David Melero-Fuentes: Conceived and designed the analysis; Collected the data; Contributed data or analysis tools; Performed the analysis; Wrote the paper.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.joi.2017.11.003.

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