An investigation of open access citation advantage through multiple measures and across subject areas for articles published from 2005 to 2014

By

Isabel Basson

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Supervisor:
Prof. Heidi Eileen Prozesky
Co-supervisors:
Prof. Johann Mouton
Dr Jaco Petrus Blanckenberg

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Isabel Basson
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Abstract

Advocates for open access (OA) practices proclaim it to have several benefits, for researchers, for science and for society at large. One of the proposed benefits is that the increased visibility provided by gratis access to research leads to OA publications receiving more citations than those publications of which no OA versions are available. This study investigated the veracity of this claim, by determining whether OA journal articles (defined in this study as gold OA articles) experience a citation advantage when compared to non-OA journal articles. To do so, an analysis was conducted of all articles and reviews published from 2005 to 2014 and indexed in the Clarivate Analytics Web of Science™ (WoS). This study included a description of the presence of OA journal articles in comparison to non-OA journal articles to provide context for the citation analysis. Three different measures of citation advantage were applied, as formulated in the following research questions:

1) Do OA journal articles attain a higher mean normalised citation score (MNCS) than non-OA journal articles?
2) Do a higher percentage of OA journal articles than non-OA journal articles receive at least one citation within two years after publication?
3) Is there a higher percentage of OA journal articles than non-OA journal articles among the most frequently cited 1%, 5%, and 10% of articles?

These questions were explored firstly for all the articles, and then for articles published in each of the years separately. Secondly, the data were disaggregated by subject area and analysed for all the articles, and then only for those published in 2014. In addition, the percentage of articles that were published in OA journals was ascertained. Whether OA journal articles experienced a citation advantage was determined through a three-fold process. Firstly, it was determined whether OA or non-OA journal articles had a higher score or percentage in terms of the measure of the citation advantage in question. Following that, the statistical significance of the difference was tested, and, lastly, the effect size was determined as an expression of the variability in the measure that access status accounts for.

This study found that the percentage of articles published in OA journals had increased considerably, from 3.3% in 2005 to 13.1% in 2014. This is likely due to the launch of new OA journals, considering the retroactive assignment of the OA tag in WoS. While the vast majority of subject areas exhibited an increase in the percentage of articles published in OA journals, seven displayed a decrease. By 2014, the majority of articles, in all but three subject areas (of 274), had been published in non-OA journals.

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This study determined that there is no general OA or non-OA journal citation advantage, as access status accounts for little of the variability in the number of citations articles receive. This was the case for the majority of subject areas as well. OA journal articles experienced a definite citation advantage in only a few subject areas. It is therefore misleading to claim that publishing in an OA journal will necessarily lead to a citation advantage. It is likely that other factors, such as whether the journal is established and the practices of OA journals, have a stronger effect on the number of citations articles receive.

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Opsomming

Voorstanders van oop toegang (OT) praktyke voer aan dat dit geassosieer word met verskeie voordele vir navorsers, die wetenskap en die samelewing oor die algemeen. Een van die voorgestelde voordele is dat die addisionele sigbaarheid wat verkry word deur gratis toegang tot publikasies te verskaf, tot gevolg het dat sodanige publikasies meer aanhalings sal ontvang as dié waarvan geen OT-weergawes beskikbaar is nie. Hierdie ondersoek het die geldigheid van hierdie stelling bestudeer, deur te bepaal of artikels in OT-vaktydskrifte (in hierdie ondersoek omskryf as goue OT artikels) bevoordeel word ten opsigte van die aantal aanhalings wat hulle ontvang in vergelyking met artikels in nie-OT-vaktydskrifte. Om te bepaal of OT-vaktydskrifartikels voordeel trek, is 'n sitaat-analise gedoen van alle artikels en resensies wat vanaf 2005 tot 2014 gepubliseer is, en in Clarivate Analytics se *Web of Science*™ (WoS) geïndekseer is. As deel van die ondersoek is 'n beskrywing van die teenwoordigheid van OT-vaktydskrifartikels in vergelyking met nie-OT-vaktydskrifartikels ingesluit om konteks te verskaf vir die sitaat-analise. In hierdie ondersoek is drie metings van aanhalings-voordeel ondersoek, aan die hand van die onderstaande navorsingsvrae:

1) Het OT-vaktydskrifartikels 'n hoër gemiddelde genormaliseerde aanhalingstelling as nie-OT-vaktydskrifartikels?
2) Ontvang 'n hoër persentasie OT-vaktydskrifartikels as nie-OT-vaktydskrifartikels minstens een aanhaling binne die eerste twee jaar ná publikasie?
3) Is daar 'n hoër persentasie OT-vaktydskrifartikels as nie-OT-vaktydskrifartikels onder die artikels wat in 1%, 5% en 10% van gevalle die meeste aangehaal word?

Hierdie vrae is eerstens vir al die artikels ondersoek, en daarna vir elk van die jare afsonderlik. Tweedens is die voordeel ten opsigte van aanhalings ook ondersoek vir elk van die WoS-vakgebiede afsonderlik. Dit is eerstens ondersoek vir al die publikasies; daarna slegs vir dié wat in 2014 gepubliseer is. Daarbenewens is die persentasie artikels wat in OT-vaktydskrifte gepubliseer is, ook ondersoek. Drie stappe is gevolg om te bepaal of OT-vaktydskrifartikels 'n aanhalings-voordeel ervaar. Eerstens is bepaal of OT- of nie-OT-vaktydskrifartikels 'n hoër persentasie of telling het wat betref die betrokke meting van aanhalings-voordeel. Daarna is die statistiese beduidendheid van die verskil getoets. Laastens is die effekgrootte bepaal as 'n uitdrukking van die variasie in die meting wat kan toegeskryf word aan toegangs-status.

Die ondersoek het bevind dat die persentasie artikels wat in OT-vaktydskrifte gepubliseer word, oor die jare aansienlik toegeneem het, vanaf 3.3% in 2005 tot 13.1% in 2014. Dit kan waarskynlik

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toegeskryf word aan die loodsing van nuwe OT-vaktydskrifte, aangesien WoS terugwerkend die OT-vaktydskrif-etiket aan alle artikels wat in ʼn OT-vaktydskrif gepubliseer is, koppel. Terwyl die persentasie artikels wat in OT-vaktydskrifte gepubliseer word in die oorgrote meerderheid vakgebiede toegeneem het, het sewe ʼn afname getoon. Teen 2014 is die meerderheid van vakgebiede se artikels, met die uitsondering van drie (uit 274), in nie-OT-vaktydskrifte gepubliseer. Hierdie ondersoek het bepaal dat daar is geen algemene aanhalings-voordeel is vir OT of nie-OT- vaktydskrifartikels nie, aangesien die toegangs-status van ʼn vaktydskrif min invloed het op die aantal aanhalings wat ʼn artikel ontvang. Dit was ook die geval vir die meeste vakgebiede. Slegs in ʼn paar vakgebiede ondervind OT-vaktydskrifartikels ʼn besliste aanhalings-voordeel. Om dus in ʼn OT-vaktydskrif te publiseer, sal nie noodwendig verseker dat die artikel meer aanhalings ontvang nie. Ander faktore, soos hoe gevestig ʼn vaktydskrif is en die praktyke van OT-vaktydskrifte, het moontlik ʼn groter invloed op die aantal aanhalings wat artikels ontvang.

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Stellenbosch University https://scholar.sun.ac.za

Table of Contents

Stellenbosch University https://scholar.sun.ac.za

Stellenbosch University https://scholar.sun.ac.za

Stellenbosch University https://scholar.sun.ac.za

Stellenbosch University https://scholar.sun.ac.za

Stellenbosch University https://scholar.sun.ac.za

List of Figures

Stellenbosch University https://scholar.sun.ac.za

List of Tables

Stellenbosch University https://scholar.sun.ac.za

Stellenbosch University https://scholar.sun.ac.za

Stellenbosch University https://scholar.sun.ac.za

Stellenbosch University https://scholar.sun.ac.za

List of acronyms and abbreviations

AHCI	Arts and Humanities Citation Index
APC	article processing charge
ARC	average of relative citations
ARCI	adjusted relative citation impact
BOAI	Budapest Open Access Initiative
CREST	Centre for Research on Evaluation, Science and Technology
CSV	comma-separated values
CWTS	Centre for Science and Technology Studies (*Centrum voor Wetenschap en Technologische Studies*)
DHET	(South African) Department of Higher Education and Training
DOAJ	Directory of Open Access Journals
EC	European Commission
ERA	European Research Area
EU28	The 28 member states of the European Union
IBM	International Business Machines
ICT	information and communications technology
ISI	Institute for Scientific Information
JCR	Journal Citation Reports
JIF	journal impact factor
MNCS	mean normalised citation score
NRF	(South African) National Research Foundation
NIH	(United States) National Institutes of Health
NCS	normalised citation score
NGO	non-governmental organisation
OA	open access
OAI	Open Archives Initiative
OASPA	Open Access Scholarly Publishers Association
OECD	Organisation for Economic Cooperation and Development
OJS	Open Journal Systems
OT	*oop toegang*
PLoS	Public Library of Science
PMH	protocol for metadata harvesting
PNAS	Proceedings of the National Academy (of Sciences of the United States of America)
ROARMAP	Registry of Open Access Repository Material Archiving Policies
SA	South African
SCIE	Science Citation Index Expanded
SciELO	Scientific Electronic Library Online
SHERPA	Securing a Hybrid Environment for Research Preservation and Access
SMMEs	small, medium and micro enterprises
SPSS	Statistical Package for the Social Sciences
SSCI	Social Sciences Citation Index
STM	(International Association of) Scientific, Technical and Medical Publishers
UDHR	Universal Declaration of Human Rights
UN	United Nations
WoS	Clarivate Analytics' Web of Science™

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CHAPTER 1: Introduction

1.1. Contextualising the study

> For various reasons, this kind of free and unrestricted online availability, which we will call open access, has so far been limited to small portions of the journal literature. But even in these limited collections, many different initiatives have shown that open access is economically feasible, that it gives readers extraordinary power to find and make use of relevant literature, and that it gives authors and their works vast and measurable new visibility, readership, and impact. To secure these benefits for all, we call on all interested institutions and individuals to help open up access to the rest of this literature and remove the barriers, especially the price barriers, that stand in the way. The more who join the effort to advance this cause, the sooner we will all enjoy the benefits of open access (Chan *et al.*, 2002: n.p.).

This statement, made by the Open Society Institute (OSI), forms part of the Budapest Open Access Initiative (BOAI) declaration, which contains one of the first and most definitive definitions of open access (OA). The sentiments in this declaration also lie at the core of the calls made by OA proponents for support of OA. However, do the various forms of OA truly lead to the proclaimed benefits for authors and readers of scientific literature and their institutions? This study aimed to investigate the veracity of one of these proposed benefits, namely whether OA provides a "vast and measurable" increase in "impact" as measured through citations, as suggested in the BOAI declaration (Chan *et al.*, 2002: n.p.). This rationale situates this study in the broader fields of open science and research evaluation.

The following two sub-sections of this chapter provide a description of this wider context and inspiration for the study, before detailing the preliminary readings which refined the research questions. The section thereafter summarises the methodology that was applied to address those research questions. The chapter concludes with an outline of the remaining six chapters of this dissertation.

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1.1.1. Open science and open access

Open science can be defined as "transparent and accessible knowledge that is shared and developed through collaborative networks" (Vicente-Saez & Martinez-Fuentes, 2018: 427). Open science is considered an approach to science that not only assists in addressing global challenges, such as climate change, energy security, and public health concerns, but it is also considered to increase the quality of the research that incorporates this approach (Organisation for Economic Cooperation and Development [OECD], 2015: 18) and to assist in fostering trust in science (Grand, Wilkinson, Bultitude & Winfield, 2012). Open science is emerging across the globe, with organisations such as UNESCO (2018) and the OECD (2018) recognising its importance and promoting its uptake. Methods used to advance open science include citizen science, open-source software (although only to some degree), open notebook science, and OA. OA is a fundamental aspect of this approach to science, as it is arguably one of the mechanisms that provide transparency of, and accessibility to scientific knowledge. Understanding the effect of OA on scientific communication is thus important owing to the growing support for the opening of science.

OA itself has become a particularly prominent topic globally due to various developments. Internationally, the focus on OA intensified with the 2012 press release by the European Commission (EC) stating that all research which receives funding from Horizon 2020 from 2014 onwards needs to be made OA through journals or OA copies need to be made available within 12 months after publishing, depending on the subject areas of the research (Heath, Cain, Jennings & Wcislo, 2012). Similar mandates are applied by other funders such as the Wellcome Trust, the Bill & Melinda Gates Foundation, and research funded by the National Institutes of Health (NIH) in the United States of America (Archambault, Amyot, Caruso *et al.*, 2014: 5; Registry for Open Access Repository Mandates and Policies [ROARMAP], 2015; Suber, 2012: 83&198). The mandates were followed by other initiatives by various funders and countries. A notable recent example is Plan S (Science Europe, 2018). Plan S was launched in 2018 and, at the time of writing, was supported by 11 research funding agencies that together form cOAlition S. These funders include organisations such as the Academy of Finland, the Luxembourg National Research Fund, The Research Council of Norway, the National Science Centre in Poland, UK Research and Innovation, and national funders from a variety of other European nations. The aim of Plan S is not only to ensure that immediate gratis access is provided by 2020 to the research that these bodies fund, but also to support the development of OA platforms and infrastructure. Amongst other initiatives, these funders support OA journals, limit the article processing charges (APCs) they are willing to finance, and do not support the rendering of articles in subscription journals, as OA (Else, 2018a:17). Another initiative, which has promoted OA, specifically

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OA journal publishing, is the Scientific Electronic Library Online (SciELO) project (see Morris, 2006: 7). The SciELO project aims to transform local journals – which are not well represented in bibliographic indexes – into OA journals, in order to increase the presence of these journals internationally. The project also assists local journal publishers with editing and publishing through OA platforms, includes them in the SciELO citation index in the Clarivate Analytics' Web of Science™ (WoS), and aims to improve the financial sustainability of such journals (Packer, 2014). The SciELO project originated in Brazil in 1997, and by 2018, it included journals from Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Spain, Mexico, Peru, Portugal, South Africa, Uruguay and Venezuela (SciELO, 2018).

While this study did not focus on any particular country, it was motivated by the concern with OA journal publishing for South African (SA) scholars and the science system due to the various commitments research institutions and publishers have made to this publication model. Locally, in South Africa, awareness of OA and OA journal publishing has increased, firstly by various South African institutions, starting in 2011, signing the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities (see Max-Planck Gesellschaft, 2003). A second development which led to increased interest in OA is when the South African SciELO portal (SciELO SA) joined the global SciELO portal in 2013. A final example of the commitment of research institutions locally to OA is when, in 2015, the National Research Foundation (NRF) of South Africa made a statement that, from 1 March 2015, all researchers generating articles from NRF funding should deposit their articles to the Foundation's administrating institutional repository. The aim is to provide OA to these articles within 12 months after publication. (NRF, 2015: 1).

Lastly, research on OA publishing has received renewed attention since the launch, in 2016, of Unpaywall, a database maintained by ImpactStory that indexes over 20 million articles that have been legally rendered OA. Unpaywall can be accessed using open-source software either through a browser plug-in or through other databases that incorporate this database. In 2017, WoS incorporated Unpaywall, followed by Elsevier (Else, 2018b: 291). Unpaywall not only assists readers with locating articles that they might otherwise have been unable to read (due to lacking subscription to a journal), but also provides new possibilities for researchers to investigate OA publication.

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1.1.2. Research evaluation and citation analysis

This study is also situated in the field of research evaluation. While citation analysis can be applied to explore various dynamics of scientific communication, as displayed through academic publications, it is often applied to measure the impact of research for the purpose of performance appraisal. This is based on the assumption, as Zhoa and Strotman (2015: 11) state, that:

> [a] citation represents the citing author's use of the cited work. The more citations a document receives, the more influence it has had on research. Evaluative citation analysis examines the evaluation of scholars, journals, institutions, etc., based on this assumption.

Various other factors have an effect on the number of citations articles receive, which go beyond the quality of the articles, as elaborated upon in Chapter 3. The visibility of articles is considered one of these factors, and thus it is in the interest of research evaluation to understand the effect OA has on the number of citations articles receive.

Access to large-scale multidisciplinary citation indexes, which capture both the bibliographic details of publications as well as the citation links between these, is required for evaluative citation analysis. With these citation indexes various aspects of research could be examined, for example, researcher affiliation, research collaboration, citation networks and the connections between subject areas (Zhoa & Strotman, 2015). These feats are achievable, because of the data available for the articles indexed in the large-scale multidisciplinary citation indexes and the relational nature of these indexes. However, until recently, research pertaining to OA publishing could not fully benefit from these features, as the access status of articles was not one of the aspects on which data were captured on the most prominent citation indexes, namely WoS and Scopus. Studies that sought to investigate OA publications therefore had to determine the OA status of articles through other means, for example the Directory of Open Access journals (DOAJ), manual online searches, or through collaboration with the publishers. This inevitably reduced the number of articles investigated by most previous studies, often limiting the investigation to a handful of journals, and thereby reducing the ability of these studies to generalise beyond the journals investigated.

This situation changed in 2014, when WoS included tags in their microdata for the OA journal status of articles (Thomson Reuters, 2014). This study makes use of the resulting new opportunities available to investigate OA journal articles. Through a licence agreement between Clarivate Analytiscs[1], and the

[1] Initially (1960), the citation index was owned by the Institute for Scientific Information (ISI). Then in 1993, it was acquired by Thomson Reuters (De Bellis, 2009: 36&38). It was later renamed Thomson Reuter's Web of

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Centre for Research on Evaluation, Science and Technology (CREST) at Stellenbosch University (South Africa), where the researcher is affiliated, the researcher was able to use the microdata of WoS to conduct the large-scale citation analysis required for the research questions addressed in this study.

1.2. Literature review

Through the initial readings for this study the researcher aimed to gain an understanding of the history of OA and motivations to support it. This led to a refinement of the review to focus on one specific benefit of OA, namely the association between the access status of an article and the number of citations it receives. This highlighted the fact that there are different methods through which gratis online access to academic literature could be obtained. The preliminary readings assisted the researcher not only in understanding the factors (beyond the access status of an article) that have an effect on the number of citations articles could expect to receive, but also why there might be a disagreement in the literature on whether an OA citation advantage exists. Lastly, the preliminary readings assisted with identifying the gaps in the literature, which this study proceeded to explore.

The discussion of the history of OA inevitably includes a discussion of two prominent issues in academic publishing, namely the "journal-affordability problem" and the "access/impact problem" (Harnad *et al.*, 2004: 36). The former, also known as the "serials pricing crisis" (Guédon, 2008a: 43) or 'serials crisis' can be summarised as the costs of subscribing to academic journals increasing at a faster pace than the budgets of academic libraries (Koehler, 2006: 17). The access/impact problem involves the culture of 'publish or perish' in academia according to which researchers and departments are evaluated and awarded promotions or grants on the basis of the number of citations their publications receive, which is considered an indication of the impact of their work (Lee, Lee & Jun, 2010). However, if research is not accessible or not visible to other researchers interested in the topic, it cannot receive any citations. OA is proposed as a solution to both issues, firstly, by introducing a new funding model for journals which proposes that authors pay to publish, potentially lessening the burdens on libraries, and secondly, by allowing anyone who is interested in the work and has Internet access, to access articles without requiring a subscription to do so, increasing the visibility of the articles.

The benefits of free online access to research arguably extend beyond the academic sphere. Outside of academia, research that is freely available online is often the only research to which small, medium and micro enterprises (SMMEs), non-governmental organisations (NGOs) and other members of civil

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Science, and in 2017, Clarivate Analytics acquired the platform. This has led to the index being referred to by various names within the literature.

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society have access, as it is prohibitively expensive for them to subscribe to academic journals (Gray & Willmers, 2009: 14). Without OA, these entities either have to forego the latest research or they have to fund their own research (Swan, Willmers & King, 2014). From an economic standpoint, OA could potentially curb these expenses and increase returns on public and private investment on research and development (Houghton & Sheehan, 2009). Lastly, free online access to research potentially assists with realising the ideal to provide access to publicly funded research to the public (Guédon, 2008a: 47).

While various benefits are arguably associated with OA, as further elaborated upon in Chapter 2, there is a need to determine whether these benefits can be attributed to and derived from OA. Each of these benefits requires a distinct method for determining whether it can be associated with OA, for example cost-benefit-analysis, to determine the economic benefit. This study focuses on the access–impact problem (Harnad *et al.*, 2004: 36), and the related claim by various studies that OA could lead to a citation benefit, as discussed in Chapter 3.

A review of the literature reveals three main postulates why OA articles could receive more citations than articles with no OA versions available, which are summarised as follows:

> [A] general open access effect due to unrestricted ability to read and cite articles (the OA postulate); the early view postulate (which they [Kurtz *et al.*, 2005] term the 'early access effect'), due to articles appearing sooner; and a selection bias due to more prominent authors posting their articles, and/or authors preferentially posting their better works (the selection bias postulate) (Craig, Plume, McVeigh, Pringle & Amin, 2007: 245).

There are also reasons to expect articles not to experience an OA citation advantage. Such reasons relate to social biases involved in the process of citing. For example, while there is a selection bias postulate to explain an OA citation advantage, self-selection could also explain why no OA citation advantage is observed. The difference is that, while authors might self-archive their perceived high-quality articles, the opposite might apply for when they render an article OA through an OA journal, as argued in Chapter 3. Due to the majority of OA journals being newly launched journals, the presence of predatory journals, and the tendency of 'local' journals to be OA journals, there is a possibility of authors self-selecting their lower-quality articles for publication in these journals. According to this explanation, articles in OA journals (which are likely to be less-established journals) tend to receive fewer citations than those published in subscription journals, which tend to be more established (Sotudeh & Horri, 2008: 89).

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By reviewing these postulates for a potential OA advantage or disadvantage, it became apparent that these explanations are sensitive to the type of OA investigated. For example, the early view postulate is not applicable to OA gained through publishing in an OA journal, and the self-selection bias functions differently for self-archived articles and those rendered OA by paying an APC to a journal that is otherwise a subscription journal. The distinction between the different definitions of OA is thus important to consider in any study investigating the OA citation advantage, and thus in this study as well.

With the aforementioned understanding of the OA citation advantage, the preliminary review included previous studies that explored the question whether publishing in an OA journal provides a citation advantage. These studies could be divided into those that investigated an OA citation advantage, without distinguishing between subject areas, and those that either focused on a specific subject area or examined a specific range of subject areas. Those which investigated the OA citation advantage hypothesis regardless of subject area tended to focus on publications by authors from specific countries, such as China (Cheng & Ren, 2008), the Netherlands, Denmark, Sweden (Van Leeuwen, Tatum & Wouters, 2018: 8–9), and Spain (Torres-Salinas, Robinson-García & Aguillo, 2016). These studies not only arrived at different conclusions about whether OA journal articles experience a citation advantage, but also illustrated that there is a possibility that, while previously there might have been a citation advantage for publications by authors from a specific country, this is no longer the case. This highlighted the need to investigate the hypothesis for publications across multiple years.

While reviewing the studies which investigated specific or multiple subject areas and comparing the results, as is reported in Chapter 3, two observations were made. Firstly, not only do only some subject areas experience an OA citation advantage, but those that do, are not consistently the same ones identified across studies. Secondly, studies differ on how they calculate whether OA journal articles receive more citations on average, than non-OA journal articles. These considerations all refined the research questions of this study, as discussed in in the following section.

1.3. Research objectives

The aim of this study was to investigate empirically the claim that articles that have OA versions available receive more citations than those which do not; in other words the study aimed to investigate the OA citation advantage hypothesis. The delineation of this study was informed by the preliminary review of the literature, as follows. Firstly, the number of citations publications receive differs between document types; thus, the document types that would be included in the investigation needed to be clearly defined. Secondly, subject areas differ in terms of citation behaviour (Waltman,

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Van Eck, Van Leeuwen, Visser & Van Raan, 2011) and histories of OA publishing (Antelman, 2004). It was relevant to include this consideration in the current study, as findings for one subject might not be applicable to another. Thirdly, previous studies have already shown that the different types of OA differ in terms of the number of citations they receive (Archambault, Amyot, Deschamps *et al.*, 2014). This study therefore needed to be clear about the type of OA it focussed on and to which it could generalise. Lastly, the number of citations that publications receive is skewed, with a few having exceedingly many citations, while the majority receive few or remain uncited (Schwartz, 1997). The skewed number of citations publications receive is accounted for by investigating three different types of citation advantage, which are formulated as the main research questions of this study, as follows:

1. Do OA journal articles attain a higher mean normalised citation score (MNCS) than non-OA journal articles?
2. Do a higher percentage of OA journal articles than non-OA journal articles receive at least one citation within two years after publication?
3. Is there a higher percentage of OA journal articles than non-OA journal articles among the most frequently cited 1%, 5%, and 10% of articles?

The next section summarises how the research questions and objectives translated into the methodology applied in this study.

1.4. Research methodology

The question whether OA journal articles experience a citation advantage (i.e gold OA citation advantage) required a comparative citation analysis research design (Porter, 1977: 265; Sotudeh & Estakhr, 2018: 563). With the resources available to CREST, the researcher was able to extract the relevant microdata from WoS and conduct citation analysis across, a large set of articles. This included access to the OA tags introduced in the WoS microdata in 2014, which became available to CREST for citation analysis purposes during the year this study commenced (2015). At the time, the tags only distinguished articles that are published in OA journals (specifically gold OA journal articles) from those that are not. The selection criteria that were applied to include documents in the citation analysis are as follows:

- time frame: 2005–2014;
- document type: articles and reviews;
- language: all included; and
- subject areas: all included.

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The presence of OA journal articles was investigated for the dataset as well as for the individual subject areas to provide some context for the interpretation of the results of the citation analysis. The three different measures of citation advantage (as expressed in the three main research questions) are all based on the normalised citation scores (NCSs) of the articles, using two-year citation windows. The methodology chapter details how these were calculated. To determine whether OA journal articles or non-OA journal articles experienced a citation advantage, tests of statistical significance (chi-square tests and independent samples t-tests) and measures of effect size (phi-coefficient and point-biserial correlation) were conducted.

First, a general OA citation advantage was investigated, irrespective of subject area, for all the articles published from 2005 to 2014. The same analysis was also conducted for each of the years separately, to examine whether observations had changed over the years. After the hypothesis of a general OA citation advantage had been investigated, it was also investigated for each of the subject areas separately, first incorporating all the articles in the subject area published from 2005 to 2014, then only for those published during 2014. This was to control for the confounding effect of the variable 'year of publication'.

1.5. Dissertation outline

This dissertation consists of seven chapters, two of which review the literature and two of which presents the results. The structure of this dissertation is as follows:

Chapter 2 ("History of, and motivation for, open access publishing") starts with a discussion of the various methods to provide OA to research. Distinguishing the different methods assisted in delimitating the study. This sets the scene for an elaboration upon the technologies, developments and motivations that have led to the popularisation of OA. Specific attention is given to the various arguments in favour of OA and its potential benefits, as the aim of this study was to investigate one specific proposed benefit of OA. The chapter concludes with a review of previous studies that measured the presence of OA journal articles.

Chapter 3 ("A review of the literature on open access citation advantage") narrows down the discussion on one of the proposed benefits of OA, namely that it leads to a citation advantage. Firstly, the link between citation and visibility is discussed, and then follows a review of the various other factors that influence the number of citations an article receives. During this discussion, it is highlighted that there are alternate measures of citation advantage beyond comparing the average

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number of citations an article receives. The chapter concludes with a summation of the gaps in the literature that led to the research questions addressed in this study.

Chapter 4 (“Methodology for examining the open access citation advantage”) describes the research problem, research design, the research questions and the hypotheses tested by this study. Other methodological details, such as the selection criteria for the documents to be investigated, discussed earlier in this chapter, are elaborated upon in more detail. This chapter comprises the technical details on how the NCS and MNCS are calculated and how it was determined whether OA journal articles experience each type of citation advantage through a three-fold method of comparing differences in terms of percentages and scores, tests of statistical significance, and measures of effect size. The chapter concludes with a discussion of the obstacles encountered during the study.

Chapter 5 (“Results on open access citation advantage for articles indexed in the Web of Science”) presents the results of the investigation of the hypothesis of a general OA citation advantage for OA journal articles, in other words regardless of subject area. The chapter starts by presenting how the presence of OA journal articles had changed over the ten years, and compares results with those found in the literature. Finally, the chapter presents the results for each of the measures of citation advantage, first by investigating all the years, and then for each of the years separately.

Chapter 6 (“Results on open access citation advantage for articles indexed in the Web of Science, disaggregated by subject area”) continues to present the results of the investigation of the OA citation advantage hypothesis. The results for each of the subject areas are reported on separately in this chapter. The results are presented in a fashion similar to that of the previous chapter to highlight the contrast between the results for the dataset as a whole and the results for the individual subject areas. The presence of OA journal articles in the individual subject areas is described for the dataset as a whole and then for the year 2014, and compared with what was found in the literature. The results for the three measures of citation advantage are presented to identify those subject areas in which OA journal articles experience a citation advantage in comparison to non-OA journal articles.

Chapter 7 (“Conclusions and recommendations”) summarises the results of the previous two analysis chapters, and relates these to the topics discussed in the two literature review chapters (Chapters 2 and 3). Topics focused on are the perception of OA journals and the possible effect that megajournals has on the number of citations OA journal articles receive. This chapter also comments on the nature of the new OA tag used in the WoS. The chapter and the dissertation conclude with suggestions for future studies on OA citation advantage.

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CHAPTER 2: History of, and motivation for, open access publishing

2.1. Introduction

The advent of the public Internet in the 1980s made the widespread digital distribution of text, including academic material, possible. Consequently, OA publishing, which relies on the Internet, has had a relatively short history, especially when compared to print-based publishing, with the first OA journals only appearing in the 1990s (Laakso, Welling, Bukvova, Nyman, Björk & Hedlund, 2011: 2; Solomon, 2013: 25). In the case of research articles, OA was at first provided on a small scale, with academics distributing articles through mailing lists, then by placing articles on personal or departmental websites (Cullen & Chawner, 2011: 460; Harnad, 2009: 151). After web standards and web-based technologies had advanced sufficiently in the 1990s, further developments in academic publishing became available, first via online repositories, then in online journals. Digital journals could potentially contribute to reducing distribution costs, and the option brought the current subscription funding model into question, thereby introducing the concept of OA, i.e. cost-free access to academic literature (Chan *et al.*, 2002).

Scholars and librarians worldwide have been advocating for OA since the formation of online repositories, motivated by various potential benefits of OA and OA journals for science and scholars alike (Björk, 2013: 13–14, Chan *et al.*, 2002; Max-Planck Gesellschaft, 2003). Since the early 2000s, research institutions, publishers, governments and research funders have also embraced OA, as reflected in them adopting policies and creating repositories to enable cost-free access to the content of journals and the research they fund. Reasons to support OA range from the presupposition that OA research would reach a wider audience (Davis, Lewenstein, Simon, Booth & Connolly, 2008) and increase the usage of research results (Czerniewicz & Wiens, 2013), to a moral obligation to share the fruits of the scientific endeavour (Lor, 2007). Other motivations are economic and financial reasons, for example, that OA to the latest research is more effective than subscription access in its use of limited funds provided by governments and research institutions, that OA could reduce the financial burden on libraries, and that OA is required in order to reap the socioeconomic benefits associated with access to the latest research. OA has subsequently become a prominent topic in the field of scholarly communication.

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As publications can be rendered OA by various means, this chapter commences with a discussion on the different methods for providing OA to an article. This chapter also discusses developments that have led to OA becoming popular worldwide, i.e. the financial strain that libraries are experiencing, and the development of online infrastructure in support of OA journals. The chapter then presents the arguments in support of OA. These refer to science as a public good, the normative nature of science, and the OA–citation–advantage postulate. The overall aim of the chapter is to indicate that OA is considered an emerging practice amongst journals and an important field of study. Additionally, the content of this chapter serves to delineate the proposed benefit of OA that the researcher examined in the rest of this study.

2.2. Types of open access

OA is often discussed as if it merely constitutes the opposite of the subscription journal model for distributing academic publications, and thereby the term ‘open access’ is incorrectly reduced to OA journals. This is a gross simplification of the term, as OA refers to the much broader notion of barrier-free access to academic research. Subscription fees constitute only one of the barriers, and journals are not the only method for distributing academic research. OA is thus a complex term, which incorporates various aspects of the distribution of research articles, namely the provider of the OA, the types of barriers to articles that are removed for the reader, and the funding model of a journal.

In essence, OA refers to “literature [that] is digital, online, free of charge, and free of most copyright and licencing restrictions” (Suber, 2012: 4). This definition does not refer to any specific method whereby OA may be achieved, but it incorporates the fundamental principles of OA. These are that OA refers to the removal of both cost and copyright barriers to academic literature, and that OA requires the Internet for digital distribution. The first official definition of OA was formulated as follows by the BOAI:

> By “open access” to this literature, we mean its free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. The only constraint on reproduction and distribution, and the only role for copyright in this domain, should be to give authors control over the integrity of their work and the right to be properly acknowledged and cited (Chan *et al.*, 2002: n.p.).

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Again (and intentionally), the definition allows for various methods whereby an article can be rendered OA. In the BOAI declaration (see Chan *et al.*, 2002), two methods are described, namely self-archiving and publication in OA journals. However, other methods have also been proposed by publishers and in the literature (see in this regard, for instance Björk, 2011; McKerlich, Ives & McGreal, 2012). Thus, related terms, which touch on each of the aspects discussed in the definition, have emerged. The sub-sections below elaborate upon various nuances of the term 'open access' or 'OA' and how OA pertains to cost-free access. The aim is not to provide an exhaustive account of all the definitions and types of OA, but rather to illustrate the wide variety of terms that occur in the literature, to clarify those that have relevance to this study, and to discuss how some of these publication types affect the perception of the quality of OA journal publishing. For example, terminology related to the removal of copyright barriers also exists, and collectively fall under the term '*libre* OA', while '*gratis* OA' refers to the removal of cost barriers (Suber, 2012: 6). However, discussing these terms and distinctions, especially those related to copyright terminology, was beyond the scope of this study.

2.2.1. Green open access vs gold open access

Cost-free access to academic research may be achieved in various ways. The two routes most often discussed in relation to research articles are 'gold' and 'green' OA. 'Gold OA' refers to the practice of journals allowing all of their content to be read for free immediately upon publication. These are then referred to as (full) OA journals (Chan *et al.*, 2002). When an article is rendered OA by depositing it in a repository or by placing a copy of the article on a website, before or after publishing it in a journal, and in accordance with the journal's self-archiving policy, the practice is referred to as 'self-archiving', or 'green OA' (Suber, 2012: 49&53). Self-archiving policies comprise stipulations of the embargoes that may apply to the self-archiving of the different document types. Delays and embargoes do not form part of the original definition of OA formulated by BOAI – an intentional exclusion by the BOAI (Laakso & Björk, 2013: 1323; Suber, 2011).

Table 2.1, adapted from Swan *et al.* (2014: 8–9), summarises some of the main differences between gold OA, green OA and subscription journals. The first point of comparison relates to where a document is situated. Both gold OA and subscription journals are journal-based, and therefore the distinction between them is dependent on the funding model of a journal. Green OA relies on repositories (of either an institutional or a subject nature) and websites (of an academic or personal nature), even though the article hosted also appears, or is to appear, in a journal. OA journals (namely gold OA) and subscription journals provide immediate access to their articles for their audiences (in the case of the former, this comprises all readers, and in the case of the latter, the journal subscribers).

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In the case of green OA, there is the potential for delay, depending on the embargo period stipulated by the publisher of the journal in which the original article appears (or is to appear). Content hosted in a repository comprises not only journal articles, but other forms of academic output as well.

Table 2.1: Comparison of characteristics of different types of publishing

Characteristic	Gold OA	Green OA	Subscription access
Situated	OA journal	○ Repository ○ Web sites	Subscription journal
Access	Immediate to all audiences	○ Embargoes apply	Immediately to subscribers
Content	Journal articles	○ Journal articles ○ Books ○ Dissertations and theses ○ Grey literature	Journal articles

Source: Adapted from Swan *et al.* (2014: 8–9).

It is therefore clear that OA journals and subscription journals share many similarities. Although they apply two different types of funding models, these are geared towards the same type of outcome, namely publishing of articles in journal format. Gold and green OA also share many similarities, as they are both methods for providing OA to journal content directly or indirectly. It is thus important to realise that OA to research articles may be achieved through other methods besides publication in OA journals.

More variations of OA exist within the categories of gold and green OA. Even though some do not adhere to the strict definitions of OA described above, they do provide free access to academic research articles. The main distinctions between them can be drawn on the basis of how the journals are funded, and whether there are delays in providing OA. The OA citation advantage postulate, the focus of this study, has previously been investigated for various types of OA, for example, mandated green OA (see Gargouri *et al.*, 2010), delay OA (see Laakso & Björk, 2013), and hybrid OA (see Sotudeh & Estakhr, 2018). It is thus important to define the type of OA focused on in this study, and to elaborate upon the factors which affect the number of citations articles receive, as these differ between the types of OA. The next few sections discuss some of the OA-related terms that are relevant to this study, while Chapter 3 elaborates upon the implications of the different types of OA for citation analysis.

2.2.1.1 Types of gold open access

While this study does not distinguish between different types of OA journals, the differences should be taken note of, as they affect author perceptions of the legitimacy and quality of the OA journals – and thus, potentially, authors’ publication and citation behaviour. Types of gold OA journals can be

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distinguished according to the funding model of a journal, namely who pays for the articles to be accessible at no cost to the readers. Even though digital publication and distribution have the potential to significantly reduce the cost of producing and disseminating articles, and reviewers are not remunerated for their services, the process of publishing an (OA) journal is not cost-free (Brown, 2007: 14; Solomon & Björk, 2012: 1486).

Publishers commonly fund OA journals through APCs, also known as author fees (Brown *et al.*, 2003; Solomon, 2013). These are paid by authors (or their institutions) after an article had been reviewed and accepted for publication. This functions similarly to the page fees some subscription journals charge (Harnad, 2015: 1). The author fees charged by a publisher often differ significantly between fields and depends on the length of the article, while waivers may apply to authors who can demonstrate financial need (Dallmeier-Tiessen *et al.*, 2010: 39; Solomon & Björk, 2012: 1488). In 2011, it was estimated that slightly more than 26% of all journals in the DOAJ[2] make use of an APC to fund their journals (Solomon & Björk, 2012: 1485).

Alternatively, OA journals may rely on other sources of funds, such as sponsorship from government or institutions, advertisements and membership fees to a journal (Polydoratou & Schimmer, 2010; Rodrigues & Abadal, 2014: 2150). A membership fee to a journal is a fee paid by an institution to allow all researchers affiliated with the institution to publish in the OA journal. This may be a once-off payment or an annual payment (Björk & Solomon, 2014: 21). Journal publishers who are able to sustain themselves without requiring subscription or individual publication fees per article, are sometimes referred to as "platinum [OA] publishers" (Graziotin, Wang & Abrahamsson, 2014: 1630).

2.2.1.2 Types of green open access

While this study did not directly investigate green OA, the earliest studies on OA citation advantage investigated self-archived articles, and therefore a brief description of the different types of green OA available is provided in this section. Types of green OA may be distinguished on the basis of whether an article is deposited in a repository or uploaded onto a website, and may be further classified according to the version of an article that is allowed to be uploaded onto a repository. Websites onto which articles are uploaded are typically either personal or institutional (including departmental) in nature (Laakso, 2014: 479). The act of an author depositing an article online is referred to as "self-archiving" (Harnad, 2009: 151).

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[2] DOAJ is further discussed in sub-section 2.3.3.

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Two types of repositories exist. The first is subject (or disciplinary) repositories, which house articles and other documentation related to a specific field of science, for example arXiv for a number of subject areas such as physics, mathematics and computer science, RePEc for economics and related sciences, and CogPrints for research related to cognitive psychology, linguistics and neuroscience (Björk & Solomon, 2014: 43; Cullen & Chawner, 2011: 460; Suber, 2012: 57; UNESCO, 2010: 387). The second type of repositories are institutional repositories, which host research output produced by an institution or funder, and may include datasets, teaching material, dissertations and research reports. An example is the NIH's PubMed Central (Eve, 2015: 83).

Repositories that comply with the Open Archives Initiative's (OAI) Protocol for Metadata Harvesting (PMH) offer the greatest potential for increasing visibility, as such compliance renders the repositories inter-operable, in other words, an article can be searched for without needing to know in which repository it is hosted (Björk, Laakso & Welling, 2014; Page-Shipp & Hammes, 2006; Swan *et al.*, 2014). In comparison, articles that are not deposited in a repository, but uploaded onto a personal or departmental website, are often more difficult to locate. These are also difficult to include in research on OA, as they are not included in the network of repositories (Björk *et al.*, 2014: 254).

Many subscription journals have self-archiving policies that specify embargo periods, as well the versions of articles that are allowed to be self-archived (Suber, 2012: 100). The embargo periods are usually six to 18 months, but could be as long as 48 months. The length of the embargo period differs among publishers, and depends on the research field covered by the journal (Laakso & Björk, 2013: 1325). WoS recently (December 2017) included metadata on their indexed articles, which provides an indication of whether a self-archived version of an article is available online[3].

2.2.2. Hybrid open access

Hybrid OA refers to the practice of rendering articles OA in a journal that, as a whole, is subscription-based, but authors have the option to make their article accessible to non-subscribers in the journal itself, by paying an APC (Archambault, Amyot, Deschamps *et al.*, 2014: 1; Suber, 2012: 140). The hybrid approach was first suggested by Thomas Walker as a method for subscription publishers to transition to gold OA publishing (Swan *et al.*, 2014: 8). However, this is not condoned by university libraries and funding bodies, as it can be considered "double dipping" (Suber, 2012: 210), for both subscription fees and the fees to make an article OA, by the publisher into what are often public funds (Archambault,

[3] While this study made use of microdata from WoS, self-archived articles were not included, as data on these only became available after data for this study had been collected and analysed.

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Amyot, Campbell *et al.*, 2014: 7; Björk & Solomon, 2014: 4). Another term for this model is "author's choice" (Fullard, 2007: 41) – as opposed to the choice of the publisher, or the journal's policy – to provide OA to the content of a journal. It should also be noted that many hybrid journals offer delayed OA to all their content, regardless of whether the authors paid an APC (Suber, 2012: 140). Some studies also refer to hybrid OA as "APC-funded OA" (Sotudeh, Ghasempour & Yaghtin, 2015: 584&585), which unfortunately further confuses the distinction between hybrid OA and gold OA, since APCs are not limited to hybrid OA. At the time of the current study, no citation index was available to identify (in any systematic manner across numerous journals from a variety of publishers[4]) articles rendered OA by means of hybrid OA policy, and therefore a more extensive review of hybrid OA was not warranted.

2.2.3. Delay and temporary open access

According to the BOAI definition (see Chan *et al.*, 2002), 'OA' refers to rendering articles OA permanently and immediately upon publication. Thus, delayed and transient OA are not considered OA, as they do not meet the criteria of this strict definition (Archambault, Amyot, Campbell *et al.*, 2014: 3; Laakso, 2014: 1324). 'Transient OA' refers to making articles available for free, but only for a certain length of time (Van Leeuwen *et al.*, 2018). In the case of subscription journals, the publishers occasionally provide temporary access to, for example, one or a limited number of issues for a select few months (Sotudeh & Horri, 2008: 74). Other instances when the OA status of an article is temporary and not strictly 'transient OA', occur when OA journals review their funding model to become subscription journals, or when a journal is sold to a publisher that implements a subscription model (Archambault, Amyot, Deschamps *et al.*, 2014: 4). Self-archived articles could also become temporary due to authors providing access to an article only for a certain time, or due to the instability of websites and institutional repositories, either as a result of a lack of maintenance or as a result of institutional website overhauls (Archambault, Amyot, Deschamps *et al.*, 2014: 4).

'Journal-delayed OA' commonly refers to a publisher making articles in its subscription journals available for free, either after a set length of time, or due to change in policy of the journal (Archambault, Amyot, Deschamps *et al.*, 2014: 4; Björk & Solomon, 2014: 42; Laakso, 2014: 1323). 'Green delayed OA' is the result of embargo periods stipulated by the publisher, or an author delaying

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[4] It is potentially possible to identify articles rendered OA by means of hybrid OA policy through the new OA tags, which WoS introduced in May of 2018, as discussed in section 7.5.

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placement of a published article online either on a website or in a repository (Archambault, Amyot, Deschamps *et al.*, 2014: 2).

2.2.4. Rogue open access and predatory publishing

The process of providing cost-free access to articles by breaching copyright agreements is referred to variously as 'rogue OA', 'Robin Hood OA' (see Van Leeuwen *et al.*, 2018), 'vigilante OA', 'infringing OA', 'piratical OA', or 'OA without consent' (see Archambault, Amyot, Campbell *et al.*, 2014: 4; Suber, 2012: 22). An example hereof is the website Sci-Hub which hosts journal articles for anyone to download for free, irrespective of the publishers' self-archiving policy (Himmelstein *et al.*, 2018; MacDonald, 2016). However, according to most definitions of OA, rendering articles available for anyone to read by disregarding copyright is not considered OA publishing (Suber, 2012: 22). In keeping with this view, in this study, the term 'OA' will only refer to media that are made available for free with the relevant consent from rights-holders.

Predatory publishing takes advantage of the fact that authors' careers are evaluated according to the number of articles they publish, and the existence of author fees (Berger & Cirasella, 2011). Predatory journals, funded through APCs, publish academic articles, for anyone to read, but after little to no peer reviewing and/or editing (and therefore regardless of quality) (Butler, 2012; Graziotin *et al.*, 2014: 1628; Vardi, 2012). This means authors do not run the risk of their articles being rejected, and their articles are published rapidly – both enticing factors for researchers whose performance evaluations often depend on the number of publications they produce (Weingart, 2016: 266). However, in the absence of a comprehensive peer-review process, these publications hold no scientific credibility, as credibility is only gained after claims have been critically evaluated by other scientists in the field (Merton, 1995: 389). Predatory publishing may be identified by certain suspicious practices of publishers, such as soliciting authors for content, and operating with a false-front editorial team (Beall, 2015; 2016). These practices of predatory journals, operating under the guise of OA journals, have unfairly brought OA journals into disrepute. OA journals are potentially mistaken for, or suspected of, being predatory journals, and are thus associated with unethical behaviour and a lack of quality (Graziotin *et al.*, 2014: 1628). The potential implications of this perception of quality for citation behaviour is further discussed in Chapter 3.

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2.3. Developments contributing to the rise of open access

Having discussed the various definitions of OA, this section elaborates upon the circumstances that have encouraged the development of OA and have led to the popularisation of OA journal publishing. Specifically, an increase in the cost of subscription journals as well as developments in information and communications technology (ICT), have provided the OA movement with considerable momentum (Sotudeh *et al.*, 2015: 582; Torres-Salinas *et al.*, 2016: 18). This section elaborates upon these circumstances by detailing how the serials crisis and open-source software have contributed to the growing popularity of OA journals.

2.3.1. The serials crisis

Generally, university libraries subscribe to journals to provide affiliated researchers with access to the content of those journals in order to facilitate their research. Previously, this meant that university libraries received hard copies of the journals to which they subscribed. Since the 1990s, digital online versions of journals have also become available. However, with the move to digital copies, some of the problematic aspects of the subscription model have become exaggerated.

The "serials crisis" (Archambault, Amyot, Campbell *et al.*, 2014: 16&17) may be summarised as follows. Firstly, journals are primarily subscription-based and controlled by a monopoly of publishers, leaving libraries with little negotiating power to manage their expenses (Sotudeh, Ghasempour & Yaghtin, 2015). Secondly, these publishers use a subscription model when selling their journals by means of journal contracts. These contracts cover a collection of journals, the costs of which are hidden behind non-disclosure agreements (Suber, 2012: 32). Thirdly, publishers also need to manage an oversupply of articles, leading to a need for peer-reviewed publishing avenues, which the publishers provide. Market forces are failing to regulate subscription prices that publisher charge (Fullard, 2007) as the choice of which journals to subscribe is based on prestige and not the cost of subscription (Swan, Willmers & King, 2014). This places a burden on university libraries as they attempt to subscribe to an ever-growing number of journals, while subscription costs increase beyond the means of their budgets (Volkmann, Schimank & Rost, 2014: 206). The inability of libraries to maintain their access to journals due to ever-increasing costs is referred to as the serials crisis. The details of the above summary are described in the rest of this section.

The 'runaway costs' of journal subscription fees and the resulting "serials crisis" (Archambault, Amyot, Campbell *et al.*, 2014: 16&17; Koehler, 2006) have been ascribed to scholarly publishers becoming increasingly commercialised over the years. Three firms (Elsevier, Springer and Wiley-Blackwell) have

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come to dominate the academic journal publication market, as a result of various acquisitions and mergers (Archambault, Amyot, Campbell *et al.*, 2014: 16; Björk, 2004; Brown, 2007: 9; Malakoff, 2003: 550). The publishers have been able to drive high profit margins, and this has led to journal subscription fees increasing at a rate much higher than inflation (Swan *et al.*, 2014: 4). The prices of journals have increased at a high rate in order to respond to profit pressures from investors (Solomon, 2013: 24; Volkmann *et al.*, 2014: 205). This increase in journal subscription prices, combined with university library budgets only increasing moderately, or even shrinking, has left libraries unable to negotiate for lower subscription costs (Archambault, Amyot, Campbell *et al.*, 2014: 16; Harnad *et al.*, 2004; Volkmann *et al.*, 2014: 206). In the absence of market forces regulating prices, new or smaller publishers find it difficult to compete, which leads to take-overs, and, in a vicious cycle, increases the monopoly of the three big publishers (Page-Shipp & Hammes, 2006: 88).

Subscription costs have become even more problematic with the advent of the Internet, which has enabled publishers to easily bundle digital journal subscriptions together into a single contract, referred to as "big deals" (Guédon, 2008a: 46; Koehler, 2006: 17; Suber, 2012: 32). These contracts provide a site licence, which affords all staff members and students at a university access to a range of journals for a set length of time (typically three to five years). However, even though these contracts provide access to a wide range of journals, libraries have little choice regarding which journals are included in the journal package. Often these packages would include many journals that are not in demand, but libraries concede to their inclusion, due to the presence of popular journals in a package (Page-Shipp & Hammes, 2006: 88). These contracts do not allow libraries to subscribe only to the journals they require, or if they do, the prices are inflated (Björk, Welling, Laakso, Majlender, Hedlund & Gudnason, 2010: 1; Guédon, 2008b: 324). Another inadvertent consequence of the digitalisation of journals is the potential risk libraries face of losing access to prior issues when unsubscribing. Previously, when only hard copies were available, unsubscribing to journals would leave libraries with physical copies of previous issues. However, unsubscribing to digital copies of journals could mean the loss of earlier issues (Cullen & Chawner, 2011: 461). This is especially problematic if a journal does not have a self-archiving policy, or have one that authors do not make use of. All of these factors place strain on library budgets and limit the options available to libraries for curbing their expenses.

As a result, libraries cut down on their monograph purchases, and finally on their subscriptions to journals, to sustain subscription to high-prestige journals that are in demand among scholars (Swan *et al.*, 2014: 4). Scholars, the ultimate end users of the journals, demand access to the most prestigious journals to allow them to keep abreast of the most important developments in their fields. However, scholars are not involved in the purchasing of subscription journals, and thus have little reason to

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adjust their preferences based on subscription costs alone, which might have enabled a more competitive market (De Beer, 2005: 21; Fullard, 2007: 43). The academic-journal market functions quite differently from other commercial markets, owing to the pressure that is placed on authors to produce and publish articles (Okubo, 1997: 8). This is due to the culture of "publish or perish" (Wilson, 1942: 63) in which researchers' careers depend on the quantity and quality of the articles they produce. Consequently, there is a demand for outlets for these articles, but not necessarily for the articles themselves. While the aim is to publish high-impact articles, the pressure to produce such articles also leads to an oversupply of both articles and journals, which fuels the serials crisis (Guédon, 2008b: 321; Tomaselli, 2015; Volkmann *et al.*, 2014: 200).

2.3.2. The open access movement in response to the serials crisis

In the previous section it was argued that the situation in academic publishing has changed from one in which articles themselves are in demand, to one in which there is a demand for avenues in which to publish. This change of focus implies that the articles are not the product; rather, the publishers provide a service to the authors to distribute their articles. It is this logic that has brought APC-funded OA journals into being (Björk & Solomon, 2014). Unlike, for example, for book publication in which a high number of sales lead to direct financial profit for the authors, subscriptions to a journal have no such direct benefit for an author (Suber, 2012). While a larger audience, due to more subscribers, could hypothetically lead to more citations, (which authors desire), limiting readers to subscribers reduces the extent of the potential audience. To some degree, APC-funded OA journals could assist in regulating this oversupply of articles, as the paying parties are the producers of the articles, and they, rather than the readers, make use of a publisher's services. Cost-free access could facilitate a wider readership, which is more in line with the authors' interests than subscription access is.

Editors of journals, who are readers and authors themselves, have been applying pressure on publishers to provide more OA options and to switch to an OA journal distribution model (Poltronieri, Bravo, Curti, Ferri & Mancini, 2016). An example is the Elsevier journal *Lingua*: all six editors resigned due to their disagreement with Elsevier's use of a subscription business model, non-disclosure agreements and 'big deals'. The editors launched a new OA journal, *Glossa*, in 2016, with the hope that the editors of other journals would follow suit (Ingram, 2015; Moody, 2015; Ubiquity Press, 2017). Scholars in general are also becoming increasingly aware of the serials crisis, as their access to journals is being progressively constrained by their libraries unsubscribing from journals, due to cost constraints (Cullen & Chawner, 2011: 461; UNESCO, 2010: 307). Likewise, scholars are becoming more aware of OA alternatives (OA journals, hybrid OA, platinum OA, green OA), due to funders' policies requiring OA to articles produced from research funded by them, as well as various initiatives by

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libraries and fellow scholars to inform scholars of OA (Czerniewicz & Goodier, 2014: 8; Page-Shipp & Hammes, 2006: 87–88; Suber, 2012: 130; Swan *et al.*, 2014: 5–6). OA has also become popular among less established publishers as the OA model makes it possible for them to operate without having to depend on libraries to subscribe to their journals as libraries are unlikely to subscribe to unfamiliar journals due to their constrained budgets. The use of open-source software for journal management has also reduced the effort of managing some of the costs involved in producing academic journals, which makes it appealing to new or small publishers (Swan *et al.*, 2014: 7–8; Van Noorden, 2013: 429).

In summary, the rising costs of subscription journals have become particularly problematic in the digital age, with limited options for libraries to reduce their expenses, and an increased risk of losing access to the content of journals when unsubscribing. Consequently, libraries, editors, scholars, and less established publishers have explored OA alternatives to curb costs. OA journals, specifically APC-funded journals have emerged due to this serials crisis, in response to the oversupply of articles as well as the need among new journals to reach their audiences despite the shrinking budgets of libraries.

2.3.3. Online infrastructure for open access journals

Three online developments have contributed to the development and promotion of OA journals. The first is DOAJ. DOAJ assisted with the promotion of OA journals by enabling its users to identify high-quality peer-reviewed journals. It is often used to identify OA journals (Archambault, Amyot, Deschamps *et al.*, 2014; DOAJ, 2017; Solomon, Laakso & Björk, 2013: 643; Sotudeh & Horri, 2007b). The second development is the various open-source journal-managing software (as opposed to proprietary software) that have given academic societies and publishers alike a means by which they can provide readers with a digital copy of their previously hardcopy-only journals. This also potentially reduces the cost of managing a journal and provides academic societies and publishers the opportunity to render their journal OA. One such open-source journal-managing system is Open Journal Systems (OJS), a platform which assists with accepting article submissions, conducting peer reviewing, editing, publishing and distribution (Fenner, 2014: 167).

The third development is the SciELO project, which has assisted in providing OA to local journals not well represented in bibliographic indexes, in order to increase the presence of these journals internationally, by assisting local journal publishers with editing and publishing through OA platforms, and improving the financial sustainability of such journals (Packer, 2014). To be included in SciELO, journals need to adhere to a minimum set of criteria, namely the publications need to be peer reviewed, issues need to appear every three months, and key information (abstract, title, keywords)

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should be available in English (Dallmeier-Tiessen *et al.*, 2010). Citations to these publications can be examined by consulting the SciELO Citation Index in WoS (Packer, 2014).

2.4. Arguments in support of open access

The previous section described the technologies and circumstances that have made OA possible. This section describes three arguments that motivate in favour of OA on grounds other than financial ones. The first argument is based on the notion of science as a public good, and the concomitant concern that the subscription model draws heavily on public funds. The public good argument can be summarised as follows: if journals become OA journals, the content would be available to the public, and thus the funds will be in service of the public. Secondly, it is suggested that OA would be more consistent with the norms of science than the current subscription model is. Lastly, the expectation of increased visibility derived from OA is discussed (albeit briefly, as it is elaborated upon in Chapter 3). These arguments have been selected to highlight why there is a growing concern about the subscription model, and interest in OA publishing. However, it should be noted that OA and OA journals do not, inherently, represent all-encompassing solutions to the issues raised by the subscription model.

2.4.1. Science as a public good

The OA movement can be viewed as the outcome of a convergence of three factors: an economic crisis, enabling technologies, and a moral crisis (Lor, 2007). The economic crisis in the form of the serials crisis and enabling technologies – namely the Internet, the DOAJ, and ease of OA journal creation. The moral crisis component (elaborated upon in this section) refers to the lack of access by the public to science, and science as a public good, with OA viewed as a way to provide the public with access to scientific literature (De Beer, 2005: 22; Lor, 2007; Raju, Smith, Talliard & Gibson, 2012: 5–6).

The public good argument incorporates the notion that science is a public good, and as such, research and its results should be available to the public (De Beer, 2005: 22; Guédon, 2008a: 47; Harnad, 2015: 2; Lor, 2007: 197). The argument has four aspects. Firstly, science as a public good is enshrined in Article 27 of the Universal Declaration of Human Rights (UDHR), which states, "everyone has the right [to] freely participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits" (United Nations [UN], 1948:6). Scientific articles are a codification of scientific advancements and thus, according to the UDHR, civil society should share in the potential benefits they can derive from reading these articles. However, this conclusion is problematic due to

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the vague phrasing of the UDHR, which provides little indication of what it implies by benefits or "scientific advancement" (UN, 1948: 6), and therefore its intention is unclear.

Secondly, the argument continues that publicly funded research (e.g. supported by government grants and public funding agencies) is funded with taxpayers' money, and therefore the research should be freely available for the public to read. This is not the case when research is published in a subscription journal, and/or not uploaded to an OA repository (De Beer, 2005: 22; Malakoff, 2003: 550). While it was previously not feasible to distribute hard copies of research articles to the general public, the advent of the Internet and ICT has made wider distribution more viable through digital media – at least to all who have an Internet connection. As such, it is reasoned that the public can now have access to these publications if these were to be made OA. A counter-argument often raised is that the general public has little interest in, or use for, academic articles, that many facilities and expenses are paid for by the public to which the public should not have direct access, for example military equipment. However, such reasoning overlooks the fact that, in the current situation, not even all researchers who have access to the Internet and are expected to use scientific findings, have access to all research articles (Bonaccorso *et al.*, 2014: 3; Suber, 2012: 119).

Another aspect of the public good argument is that public funds pay for the (substantial) subscription fees of private companies, and there is a growing concern that taxpayers are not the ones benefiting the most from their investment (Guédon, 2008a: 47; Harnad, 2015: 2). This is highlighted by studies that have made use of cost–benefit analysis to illustrate the potential economic benefit of OA to research for industry, government and society (Look & Marsh, 2012; Swan *et al.*, 2014: 17). This potential benefit contributes to the motivation for OA journals, and is particularly relevant to South Africa, considering that the Department of Higher Education and Training (DHET) subsidises research publications[5]. Thus, subscription fees, as well as publication subsidies, are publicly funded, but the product, the research articles, are not available to the public or even to all researchers (Page-Shipp & Hammes, 2006: 101). The argument centred in public funds requires careful consideration, as the expenses involved in rendering research OA make it available on a global scale and not simply for the citizens of the country that funded the research. While science is a global endeavour, the argument regarding public funds is partially based on the idea that the public that funded the research should

[5] The DHET follows a policy that entails an incentives system by which higher education institutions are subsidised for certain categories of research output produced by authors from their institutions in the previous year (DHET, 2015: 3).

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benefit the most from the expense. This is not necessarily the case for OA, as countries which are not involved in the funding of the research also benefit.

Related to the globalisation of science and the moral crisis in science, is the claim that OA to research could narrow the knowledge gap between developed and developing countries, by providing access to research, which contributes to social inclusion and economic empowerment among the latter (De Beer, 2005: 22). Similarly, it is argued that research produced in local journals, which are not indexed in global citation indexes (as these contain mainly English-language journals from the United States of America and Europe) should be made freely available to researchers working in similar contexts and socioeconomic conditions, to increase the ability of those researchers to use and build upon such context-relevant research (Czerniewicz & Goodier, 2014: 8; Czerniewicz & Wiens, 2013: 1; Raju *et al.*, 2012: 2–4). Examples of such benefits are particularly applicable to research on those infectious diseases that were previously geographically limited but are now encountered in other parts in the world due to an increase in international travel. In this case, knowledge from local research can assist with addressing the challenges these diseases pose (Gibbs, 1995: 93). OA, via journals or repositories, could make this research available to researchers who otherwise, either due to subscriptions or the small circulation of local journals, would not have had access.

The counter-argument is that ICT is widening the information gap between developing and developed countries, due to unreliable telecommunication networks in developing countries, particularly in sub-Saharan Africa. The concern is that researchers and universities, which previously depended on hardcopy donations will be left with no, or outdated, scientific literature to draw from if publishers decide to exclusively publish digital journals (Gibbs, 1995: 99; Norris, Oppenheim & Rowland, 2008a: 342; Suber, 2012: 32).

2.4.2. The normative view of science

Science is a collective endeavour, with knowledge collected over multiple lifespans. It requires collaboration between all the entities involved in the creation of scientific knowledge and as such constitutes a social activity (Cronin, 1984: 17). This section discusses the norms and values that govern this social activity, and explain how OA is potentially more in agreement with these than the subscription model of distribution of academic texts.

These norms and values form part of a moral consensus among scientists that certain activities and behaviour are acceptable and in the interest of advancing science. Merton identified four norms or imperatives that define this 'scientific ethos', namely universalism, organised scepticism,

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disinterestedness, and communism, also more recently referred to as 'communalism' (Merton, 1973b: 273–275; Ziman, 2000). Exploring the norms of communalism, organised scepticism and, to some extent, disinterestedness, may be useful to illustrate that subscription access to research is problematic for science, while OA to research, in theory, could serve the interest of science better.

'Communalism' refers to the common ownership of the knowledge produced by science. Merton (1973b: 273–274) argues that science is part of the public domain and it is, therefore, imperative that scientists communicate their findings to other scientists. This formulation only refers to sharing research with other researchers, although OA is often regarded as a means to reach an audience beyond academia. OA would allow more researchers access to research otherwise inaccessible due to it requiring a subscription to access, thus OA reflects this norm. Additionally, the relevance of this norm for citation behaviour and copyright lies in the fact that recognition is the only claim scientists have to their intellectual property. An activity which is a reflection of this norm is giving recognition to previous findings that have influenced a scientist's work by means of citations (Merton, 1973b: 273; Zhoa & Strotman, 2015: 12). This norm is also apparent in the discussions of copyright and OA, as copyright limitations prevent articles from being distributed freely, not because the authors have any wish for secrecy, but because commercial publishers are concerned with financial gain. While these publishers want articles to be distributed, they do so from a business perspective. Their primary motivation is to generate an income by, in the case of subscription journals, collecting subscription fees or other funding methods. Distributing scientific findings is only the method for doing so and thus the breadth of distribution is a secondary concern (Cullen & Chawner, 2011: 461).

'Organised scepticism' refers to the norm that scientists need to question all findings and assumptions, and it is in this regard that peer review is critical (Merton, 1973b: 260–263). With scientific fields becoming more specialised, and the number of articles increasing exponentially (De Bellis, 2009: 11), it has become impossible for a single researcher to have read all the articles related to a topic. It is thus important that reviewers gain access to any article, as required, to enable them to engage with the references in the article they are reviewing (Stodden, 2014: 227). As no single institution can currently provide a reviewer with this access, due to a lack of subscriptions, (see Suber, 2012: 41&42), it could be claimed that OA to research articles would resolve this issue and, as such, assist the peer-review process. By consulting references, any reader could verify claims made in an article, which forms part of the continuous review process by peers reading the published article. OA and open data could facilitate this process (Zhoa & Strotman, 2015: 12).

The last norm discussed is that of disinterestedness, which is often understood as an interest in science for the sake of science, i.e. that research is done for the aim of expanding scientific knowledge, rather

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than for personal and/or economic reasons (Cronin, 1984: 3&17; Merton, 1973b: 275–277). The major academic journal publishers in the commercial sector are not primarily concerned with this norm, as they are essentially interested in profits, as discussed previously. It could be argued that commercial publishers themselves do not share the norms of science (Pooley, 2017), and this distinction could be at the heart of the clash between publishers and scientists, as exemplified through the issues described in this chapter.

2.4.3. The open access citation postulate

An oft-repeated argument for why researchers should render their publications OA, and one which relates more directly to the personal interests of researchers, is the potential of OA to increase the visibility of their work. This was already suggested in the BOAI declaration, which states that OA "gives authors and their works vast and measurable new visibility, readership, and impact" (Chan *et al.*, 2002: n.p.). Visibility, readership and impact are often measured by citations, and therefore these aspects may also be interpreted to lead to a citation advantage. Researchers are often evaluated by the number of citations their publications receive, and thus a citation advantage would be appealing. The OA citation advantage postulate is based on the idea that researchers can only cite articles which they can read; thus an article which is rendered OA (which is easily accessible for anyone who has an Internet connection) would potentially be cited more often than one which is behind a "paywall" (Harnad *et al.*, 2008: 37). Stated differently, an article is more likely to be cited if it is freely available, as this increases the potential audience that would be able to cite the work (Eysenbach, 2006; Swan, 2010).

It should be noted that providing OA to an article does not change its content. The article still needs to report on original, quality research to attract citations (Gargouri *et al.*, 2010). The basis of the OA citation advantage postulate is that quality articles that are made OA will receive more citations than quality articles with limited access, due to the increase in the size of the audience able to cite the articles (Cullen & Chawner, 2011: 463). Admittedly, providing OA to an article could have an influence on perceptions of its quality and thus the citations it receives – a topic further discussed in Chapter 3 (Björk & Solomon, 2012a: 10; Fullard, 2007: 44; Sotudeh & Horri, 2009: 23).

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2.5. A critical perspective on the presumed benefits of open access

Although OA publication highlights and potentially addresses various issues present in the subscription journal model, it faces its own set of obstacles, and if not carefully implemented, may even share some drawbacks with the traditional model of academic publishing. OA implies the removal of financial barriers for the reader. However, some OA journals charge authors to publish their articles. A 2015 review of the APCs of OA journals by the International Association of Scientific, Technical and Medical Publishers (STM) found that APCs differ between publishers and according to the type of documents concerned, but typically range between US$1 000 and US$5 000. The APCs to render an article OA through in a journal that ascribes to a hybrid OA policy are approximately US$3 000 (Ware & Mabe, 2015: 93). Another estimate places the range between US$8 and US$3 900 (Van Noorden, 2013: 428). The more prestigious the OA journal the higher the author fees tend to be (Björk, 2011: 1485; Björk & Solomon, 2015: 373). The practices of requiring APCs to publish places the burden on the researchers who, if situated at an under-resourced university and/or lack funding, have access to other's research, but their own research cannot be rendered OA through OA journals, and thus subscription journals are their only recourse for publishing (Celec, 2004). This issue might be exaggerated by opponents of OA journals funded through author fees, as many OA journals do not charge author fees. Some funders cover these publication costs, and waivers of APCs may apply to researchers who are unable afford them, if the researchers comply with the eligibility criteria of the publisher (Berger & Cirasella, 2011; Solomon & Björk, 2012: 1488).

Even if researchers, for whatever reason, continue to publish in subscription journals, free access to research can still be provided through self-archiving of research content, which some subscription journals allow, albeit often after an embargo period (Laakso, 2014). However, without a mandate to do so, few researchers upload their research on easily searchable repositories (Cullen & Chawner, 2011: 460; Gargouri *et al.*, 2010; Swan & Carr, 2008: 32; Xia, 2007: 648). Although institutional repositories could serve as a method to curb university and library expenses in the long term, they entail substantial investment, especially initially, in the form of technical expertise, acquisition of hardware and human resources dedicated to soliciting content (Swan *et al.*, 2014: 7). Institutional repositories are thus not an investment all institutions can afford, regardless of their potential to curb expenses in the longer term. However, institutions do not need to rely on their own repositories in cases where inter-operable subject or shared repositories exist.

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OA journal publishing is often recommended as a method to distribute scientific publications in a more cost-efficient manner than publishing in a subscription journal, especially from the perspective of institutional libraries. With the development of open-source journal management systems, this cost-efficiency motivation now also applies to journal publishers. It is suggested that with online solutions the costs of publishing may be significantly reduced (or even removed), and are only inflated due to a concern with profit (Solomon & Björk, 2012). However, digitalisation is cost-intensive for reasons similar to those that apply to self-archiving, as well as for other reasons. While digitalisation reduces the cost associated with some activities, such as physical storage, distribution and printing, the costs incurred through other activities, for example software and digital preservation, have increased (Brown, 2007: 4). The challenge for publishers is to find a sustainable funding model that allows readers to have free access to publications, enable the publishers to fund their operations, and render publication in their journals affordable for authors.

APCs is one method for publishers to provide OA to their content and generate an income, although authors are distrustful of journals that request APCs, as they suspect these will accept lower-quality articles simply to sustain themselves or generate income (Fullard, 2007: 44; Taylor, Perakakis & Trachana, 2008: 31). This distrust in journals that require an APC is worsened by the emergence of predatory journals. Predatory publishing is a problematic practice that has taken advantage of the fact that OA journals make use of APCs, and that authors require outlets for their academic articles (Harnad, 2015: 8). This is detrimental to researchers publishing in these journals, as it undermines their reputations due to the lack of proper peer review in these journals. It also undermines trust in reputable OA journals and in science in general (Beall, 2012; Poltronieri, Bravo, Curti, Ferri & Mancini, 2016).

Another concern with APCs is that public funds will have to support both APCs and access to subscription journals (Björk & Solomon, 2014: 12–13; Czerniewicz & Goodier, 2014: 5; Malakoff, 2003: 550). Some authors' funders or their institutions cover their APCs completely, thus once again removing the author from the process of regulating market prices. If funders unconditionally fund APCs, issues similar to those that under-resourced fields or institutions experience with the subscription model, will arise (see Björk & Solomon, 2014).

APC-funded OA journals may be able to regulate market forces because, unlike current subscription contracts, OA journals should be free from non-disclosure agreements. This would enable authors to compare OA journals, and their APCS, in the same field in terms of both the service they receive from a publisher and how much it would cost to publish in such journals. In an OA-journal market, journals may be regarded as substitutes for each other, instead of as complementary to each other, as is the

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case in the subscription market. In a substitute market, authors choose among alternatives that provide the best service, thereby allowing for competition (Björk & Solomon, 2014: 9; 2015: 375). However, nothing inherent in the OA market will guarantee this type of behaviour among authors and publishers. A concern is that author fees and institutional memberships for APC discounts will simply replace the subscription model, with little transparency regarding the calculation of the APC and waivers (Bonaccorso *et al.*, 2014).

It is clear that OA is not a panacea for all the access- and funding-related issues experienced in academic publishing. Not only can OA only reach those researchers with access to the Internet, but OA journal publication is not necessarily viable for all journals and even self-archiving is not necessarily as cost-effective as first suggested. There is the risk that proponents in favour of OA, and especially of OA journals, could mistake the method for the end goal: viewing the increase in OA journal publications as a measure of success in terms of reducing the financial burdens of scientific communication, and increasing the visibility of otherwise neglected works. However, it cannot be denied that the OA movement has highlighted problems of the subscription model and made great strides in providing more free access to research, either through journals themselves, or through repositories. OA also has the potential to be beneficial to the scientific endeavour, and to provide an alternative that makes more equitable use of public funds. While an increase in OA journal publications does not equate to a concomitant increase in benefits that libraries, readers or authors experience, it is still essential to examine the presence of OA journals and OA journal publications to provide context to understand the development of OA journal publishing.

2.6. Presence of open access journals

The extent to which OA journals are indexed in the most prominent citation indexes (WoS and Scopus) differs considerably across the indexes. WoS indexes significantly fewer OA journals than Scopus. In 2016, Scopus indexed a total of 3 625 OA journals, which constituted 10.2% of its indexed journals, whereas WoS indexed 1 253 OA journals, which comprised 5.9% of its indexed journals (Elsevier, 2016; Thomson Reuters, 2017). The dissimilarity between these two citation indexes in terms of the percentage of OA publications indexed is, however, smaller when the percentage of indexed articles published in OA journals is considered. In 2012, 12.8% of all articles indexed in Scopus (Archambault, Amyot, Caruso *et al.*, 2014: 10) and 8.3% of those in the WoS Core Collection were OA journal articles (Thomson Reuters, 2017). Neither of these citation indexes comprehensively covered the titles in DOAJ, which indexed 9 424 journals in 2017 (DOAJ, 2017). However, it needs to be noted that newly launched journals, many of which are OA, are unlikely to be indexed in Scopus or WoS (Archambault,

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Amyot, Deschamps *et al.*, 2014: 17; Solomon *et al.*, 2013: 645) and in general, neither WoS nor Scopus aims to index all of the world's journals[6]. Even the DOAJ does not intend to index OA journals comprehensively, but rather to include only those of a certain standard (Sotudeh & Horri, 2007b: 1580).

The historical trajectory of OA journals and articles for the publication years 1993 to 2009 has been described by Laakso *et al.* (2011). They identify three periods, namely the pioneering years (1993–1999), the innovation years (2000–2004), and the consolidation years (2005–2009). The first period saw selected journals (20 in 2003) using simple technologies and voluntary labour to create OA journals. The innovative years were characterised by a significant increase in OA journal and articles, the introduction of APCs and hybrid OA, and an increase in OA advocacy. The consolidation years, the period which corresponds the closest to the publication years investigated in this study, were characterised by

- a decrease in the year-on-year increase of OA journal articles;
- an expansion of the infrastructure for OA journals through open-source publishing software;
- the DOAJ becoming the primary index of OA journals;
- increasing use of the Creative Commons licences (see Laakso *et al.*, 2011; Suber, 2012); and
- the establishment of the Open Access Scholarly Publishers Association (OASPA), which aims to improve the quality standards of OA journals (Ball, 2016: 178; Laakso *et al.*, 2011).

Laakso *et al.* (2011) estimate that, in 2009, between 5.9% and 7.7% of all articles were published in OA journals, based on the publications indexed in Scopus (6.8%), WoS (5.9%), and in Ulrich's Periodicals (7.7%). In 2006, it was estimated that OA journals constituted only 5% of the total global academic journals available (Fullard, 2007: 40). In 2015, the DOAJ listed over 10 000 OA journals, which were estimated to have published approximately 11–12% of all articles (Ware & Mabe, 2015: 156). A study methodologically similar to the current study[7] (Dorta-González, González-Betancor & Dorta-González, 2017: 879–880) found that, in 2014, of all journals indexed in WoS, 8.6% were OA journals and, of all the articles, 11.5% were published in OA journals. These percentages differ considerably across subject areas, with some completely lacking OA journal publishing, while in others, such as Tropical Medicine, more than half (52.8%) of articles are published in OA journals. On average, 10.2% of the articles in subject areas in the Science Citation Index Expanded (SCIE) are published in

[6] The characteristics of the journals indexed in Scopus and WoS are elaborated on in sub-section 4.2.1.1.

[7] The methodology is discussed in Chapter 4, and the study by Dorta-González *et al.* (2017) is discussed in detail in Chapter 5 and Addendum G.

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OA journals, while this percentage is much lower (4.46% and 4.1%, respectively) for those in the Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (AHCI).

There is a substantial difference between the estimated percentages of articles that are OA journal articles and that are rendered OA through a hybrid OA policy. The Scholarly Publishing division of the Association of American Publishers found that, in 2009, 74% of the journals surveyed offered hybrid OA. In the same year, the SHERPA[8] project listed 90 publishers that offered hybrid OA. However, this form of OA is rarely used by authors, with an average of only 2% of eligible articles (in the aforementioned study) being rendered OA this way (Dallmeier-Tiessen *et al.*, 2010: 2; Suber, 2012: 141). Even a cursory comparison with Laakso *et al.*'s (2011) estimates show that OA journal articles represents a higher percentage of articles than hybrid OA articles do. Another study reports similar results, with the uptake of the hybrid OA option higher only in the case of a few journals that provide additional incentives (McKerlich, Ives & McGreal, 2012). These results pertain only to a select few journals and subject areas; further information regarding their presence in other subject areas is lacking. Without the assistance of publishers, the use of the hybrid OA option is arduous to investigate for a larger number of articles than those in a single journal, as indexes do not contain data on whether an article has been rendered OA in this manner. Even with the new OA tags available since 2018 (Napolitano, 2018), it is unclear whether articles made OA through hybrid OA can be distinguished from delay-OA articles.

In general, identifying the presence of OA journal articles is problematic due to the lack of data available on OA publications, the varying coverage of subject areas by different indexes, and potential changes in journal policies over time (Lewis, 2012: 496). For example, some (established) publishers, which previously only published subscription-based journals, have launched new OA journals (e.g. *Chemistry Open*, from Wiley), bought out smaller OA publishers (e.g. Nature Publishing Group [NPG] acquired *Frontiers*), or changed the access model of some journals to OA only (e.g. *Stem Cell Research*, published by Elsevier) (Björk & Solomon, 2014: 20; 2015: 374).

In addition to changes in journal policy, a new type of journal has also emerged, namely the OA megajournal. These journals cover a broad scope of subjects and publish a large volume of articles (Eve, 2015: 147). Although articles are accepted by such journals if they demonstrate scientific rigour through a process of peer review, they do not need to demonstrate novel findings. Examples of such

[8] The SHERPA project was launched by SHERPA (Guédon, 2008b), which stands for "securing a hybrid environment for research preservation and access", and which aims to support OA repositories and publishing through a variety of projects that include RoMEO, OpenDOAR and Juliet (see SHERPA/RoMEO, 2011).

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journals are *PLoS One*, *Nature Scientific Reports*, *Springer Plus*, and *Sage Open* (Binfield, 2014: 158; Björk, 2013: 9; Eve, 2015: 147). This development in the OA movement is likely to have a significant effect on the presence of OA journal articles in multidisciplinary subject areas, due to the connection between the novelty of an article and the number of citations articles receive, as megajournals do not focus on novelty and publish a substantial number of OA journal articles in these subject areas (Tahamtan, Safipour & Ahamdzadeh, 2016: 1199).

Finally, investigations of the geographic location of OA journals have found that developing countries tend to publish a larger overall share of OA journals than developed countries do, with many local journals from the former being OA journals (Sotudeh & Horri, 2009: 22). Developing and developed countries have previously been shown to differ in terms of preferred avenues to OA. In the past, developed countries tended to make more use of repositories than of OA journals, while developing countries preferred OA journals as a means of rendering articles OA (McVeigh, 2004: 4; Sotudeh & Horri, 2008: 71). This difference could be due to, inter alia, the policies of funders in developed countries, or the fact that developed countries were the first adopters of OA, which initially took the form of repositories, while developing countries joined the OA movement only when OA journals began emerging. Thus, OA journal publications could originate disproportionally from developing countries, which could affect the number of citations OA journal articles receive as there are various factors negatively affecting these local journals' visibility (Sotudeh & Horri, 2008: 71).

2.7. Summary

This chapter considered, as its starting point, a conceptual examination of different OA-related terms, in order to clarify concerns with the subscription model of publishing academic articles, as raised in the literature. This provided the background for a description of some of the potential benefits of OA journals, as an alternative to the subscription model. The chapter further suggested that OA is not a panacea for the problems plaguing academic publishing. Rather, the possibility of providing free online access to research articles simply made stakeholders aware of these issues, and so a possible alternative was formulated by means of OA.

The review touched on a number of topics discussed in the literature regarding the development, benefit and presence of OA, while focusing on those most relevant to this study. The public good argument in favour of OA was considered in this chapter, on the basis of which one may conclude that OA is beneficial, regardless of evidence of an OA citation advantage. Other benefits, such as reducing the knowledge gap between developed and developing countries, and providing the public access to research, are all worth pursuing. However, without supporting empirical evidence, it would be

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misleading to espouse that publishing in OA journals would necessarily increase the visibility of research. It would be equally premature to warn authors of potential pitfalls of OA. It is therefore paramount that OA journal publishing, and in particular citations to the articles in such journals, be understood in more detail.

The discussion in this chapter illustrated that, even though OA publishing is a relatively recent development, it is already occurring in a number of subject areas, and more information is therefore needed to guide future initiatives successfully. While the chapter discussed a range of proposed benefits of OA, this study focused on exploring one specific potential benefit of OA – a citation advantage for OA journal articles compared to non-OA journal articles – which is discussed in more detail in the next chapter.

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CHAPTER 3:
A review of the literature on open access citation advantage

3.1. Introduction

This chapter focuses on one of the suggested benefits of OA, namely that articles that are available free online would receive more citations than those that are only available via subscription to a journal. This is referred to as the OA citation advantage postulate (Sotudeh *et al.*, 2015; Swan, 2010). To explore this postulate, the current chapter first elaborates upon the importance of visibility and the accruing of citations for researchers and institutions, and then briefly explains why citation analysis, rather than altmetrics (see Wehrmeijer, 2014:61), was applied in this study. Some mechanisms through which OA may affect the number of citations an article receives are discussed, by referring to the Matthew effect (Merton, 1973a), as well as the various reasons why an OA citation advantage might occur. This is followed by a related discussion on factors that influence the number of citations articles receive, with the focus on those that are relevant to OA journals. Lastly, three measures of citation advantage are explained, two of which have rarely been considered in relation to the OA citation advantage. This chapter concludes with a summation of the gaps in the literature, as identified through the review, and the research questions for this study that were derived from these.

3.2. Citation analysis and the measurement of visibility

From a theoretical perceptive, citation analysis is based on a normative view of science, specifically the norm of communalism (Merton, 1973b: 273; Stodden, 2014: 226). Citations are generally viewed as acknowledgements of the influence previous research has had on the ideas presented in a research article. A reference links two or more articles, indicating a shared subject matter or methodology (MacRoberts & MacRoberts, 1989: 342; Zhoa & Strotman, 2015: 8). By investigating citation patterns, it is possible, for example, to evaluate scholarly impact, map subject areas, track knowledge flows, determine the visibility of an individual or other unit of analysis, and study the users of scholarly literature (Cronin, 1984: 25). Citation analysis has become a popular method in the sociology of science and bibliometrics, as it is considered unobtrusive and transparent, thereby allowing for a more objective investigation of science and scientists than, for example peer review (Anania & Caruso, 2013: 618; Bornmann & Daniel, 2008: 45–46; Gilbert, 1977: 113; Porter, 1977: 257). Some of the techniques

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of citation analysis include citation counting, co-citation counting, and bibliographic coupling (De Bellis, 2009: 302; Zhoa & Strotman, 2015). Citation counting was the technique chosen for this study. Specifically, the presence of citations, percentile indicators, and the average number of citations articles received were investigated as proxies to measure visibility of research articles among publishing researchers. The following sub-sections explain why a wide readership of academic literature is desired, how citation analysis can be applied to measure visibility of research articles among peers, and which other methods exist for the measurement of visibility among different audiences of academic research.

3.2.1. Research evaluation and citations

Various forms of citation metrics have become part of research evaluation, partially due to the relative ease (in comparison to peer review) whereby citation analysis can be conducted, and because citation counts have been positively correlated with other performance measures and indicators of quality (Bornmann & Daniel, 2008: 45–46; Harnad, 2009: 149–150; Seglen, 1989). Using citation metrics for research evaluation is based on the assumption that research of high quality and novelty is more likely to receive many citations (Tahamtan, Safipour & Ahamdzadeh, 2016). This assumption has led some institutions to base grants, promotion and the awarding of permanent academic positions on the number of citations an author's articles receive, or the journal impact factor[9] (JIF) of the journals in which such articles are published. This, in turn, increases authors' concern with the number of citations their research receives, and thus with the potential factors that influence this (Butler & McAllister, 2009; Lansingh & Carter, 2009).

3.2.2. Visibility as a factor affecting citation counts

Many factors may affect the number of citations an article receives, some of which are unrelated to the quality of the cited article (Stremersch, Verniers & Verhoef, 2007; Tahamtan et al, 2016). A clear example of this is negative citations (MacRoberts & MacRoberts, 1989: 344; Okubo, 1997). Other factors, such as the language in which an article is written, document type, and the citation practices of a discipline, have been shown to have a marked effect on the number of citations an article receives (Glänzel & Moed, 2002: 178; Leimu & Koricheva, 2005; Pendlebury, 2009: 8; Tahamtan *et al.*, 2016: 1213). Furthermore, factors related to the journal and authors of an article have also been

[9] "A journal's impact factor is based on 2 elements: the numerator, which is the number of citations in the current year to items published in the previous 2 years, and the denominator, which is the number of substantive articles and reviews published in the same 2 years" (Garfield, 2006: 90).

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investigated and found to influence the number of citations it receives, for example, the prestige of the journal, the frequency with which the journal is published, the affiliation of the author, and the order in which the article appears in an issue of the journal (e.g. first as opposed to last). However, some of these do affect the perception of the quality (of the content) of the article and, in so doing, affect the number of citations an article receives (Bornmann & Daniel, 2008), while others reflect the size of the audience to which the article is exposed.

While citation counting could measure the quality of the research indirectly, citation counting is more accurately described as a measurement of the extent to which the ideas in an article are acknowledged and officially incorporated into the wider collection of scientific knowledge (Zhoa & Strotman, 2015: 1). The quality and novelty of the research are two factors that attract attention, and thus citations, to an article. Another factor is the size of the audience that has access to an article, as a larger audience increases the likelihood of an article being incorporated into another researcher's work. In other words, the article needs to be visible to other researchers. This is why the language in which an article is written influences the number of citations it receives, as language determines which audiences are able to read the content.

It is thus important to examine OA articles by means of citation analysis, considering that researchers can only cite work to which they have access. Subscription journals, by definition, limit access to their content to their subscribers; thus, *caeteris paribus*, such articles should receive fewer citations than those that are available to a wider audience (Asemi, 2010: 487; Czerniewicz & Goodier, 2014: 2; Moed, Glänzel & Schmoch, 2004: 104; Sotudeh & Horri, 2009: 7; Yuan & Hua, 2011: 682). However, it should be noted that this argument is based on the assumption that citations are a way of acknowledging the influence previous work has had on the citing publication – an assumption that is only partially true, as it is not always clear, even to the citing authors themselves, why they cited a particular publication (Bornmann & Daniel, 2008: 64).

3.2.3. Visibility among different audiences of academic research

The results of citation analysis reflect only one specific activity of a specific audience of scientific literature. These are mostly academic researchers, and exclude most lay people and non-publishing researchers as audiences and authors. In other words, the audience only includes individuals who not only read published research, but who also make use of and reference published research in their own academic journal publications. Citation analysis excludes researchers' other research activities and outputs, such as blogs and public engagement activities. Investigating the number of citations articles receive is thus almost exclusively a measurement of the scholarly impact of published research, rather

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than a measurement of general knowledge transfer, and is highly unlikely to gauge the impact the research has on society (Swan *et al.*, 2014: 10).

OA to research is often advocated exactly because it has a greater potential to reach audiences beyond academia than the distribution of academic research through subscription-based journals has. However, citation analysis is not the ideal instrument to measure visibility and usage amongst these audiences. Citation analysis is also limited to the citing of articles in journals indexed by the major citation indexes, and by those researchers who have access to the journals thus indexed. WoS and Elsevier's Scopus citation indexes[10] attempt to index the most impactful journals in the world (Kähler, 2010; Testa, 2018). However, this aim tends to result in the inclusion of journals with an international focus and the exclusion of journals from developing countries and those not published in English (Koler-Povh, Južnič & Turk, 2014: 1034; Sotudeh & Horri, 2009: 22; Van Leeuwen, Tatum & Wouters, 2015: 1139–1140). In essence, citation analysis is suited to measure the academic impact of the content of the most prominent journals, which could also equate to the measurement of the citation behaviour of those researchers whose institutions can afford the high subscription costs publishers of these journals tend to charge.

To overcome some of these limitations, many alternative metrics have been suggested. These alternative methods of measuring impact make use of online tools both for data collection and as data sources, and are often collectively referred to as "altmetrics" (Graziotin *et al.*, 2014: 1636; Mingers & Leydesdorff, 2015: 2). Examples are: examining bookmarks as recorded on bookmarking websites; investigating documents uploaded to referencing software (e.g. Mendeley); page views and downloads of research articles; and presence on social media (e.g. Twitter and Facebook) (Mingers & Leydesdorff, 2015: 2; Neylon, Willmers & King, 2014). There appears to be a positive correlation between the number of times an article is downloaded and the number of citations it receives. However, most altmetrics are still in the process of being standardised and measurement tools are being refined to enable systematic assessment (Mingers & Leydesdorff, 2015: 34; Page-Shipp & Hammes, 2006: 96; Wouters & Costas, 2012: 42–43).

For this study, citation analysis of data sourced from a multidisciplinary citation index was selected to investigate the veracity of the oft-repeated claim that OA leads to a citation advantage (see for instance Sotudeh & Estakhr, 2018; Piwowar et al, 2018). The following section presents various postulates on how OA and the number of citations an article receives could be linked.

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[10] The Scopus and WoS citation indexes are discussed in more detail in sub-section 4.2.1.1.

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3.3. The link between open access and citations

This section elaborates upon the main theoretical constructs that are useful to understand the number of citations that OA articles receive. The first that is addressed is the Matthew effect, which suggests that social and psychological biases could counteract the citation advantage OA potentially offers. Then three different postulates for why OA articles might receive more citations than non-OA articles are presented, namely the early-view postulate, the self-selection postulate, and the OA postulate. These three postulates are often examined in the literature, primarily in connection to self-archived articles, but the last two are relevant to our discussion on OA journals as well, as will be explained in this chapter.

3.3.1. The Matthew effect on recognition of articles in open access journals

The Matthew effect, as described by Merton (1973a: 446), is "the accruing of greater increments of recognition for particular scientific contributions to scientists of considerable repute and the withholding of such recognition from scientists who have not yet made their mark". This same construct may be applied to journals, with OA journals tending to be of the latter type, which counteracts the increase in visibility OA potentially offers. OA journals also tend to be academic-society journals, or with a local focus and published in local languages, while few established, reputable commercial publishers make wide use of the OA journal publication model (Torres-Salinas *et al.*, 2016: 23). This means that, compared to subscription journals, most OA journals have not been in existence long enough to have established a trusted reputation.

Combined with the detrimental effect that predatory journals have on the trust authors and readers place in OA journals, it comes as no surprise that authors are reluctant to publish what they perceive to be their most impactful works in OA journals (Björk & Solomon, 2014: 22; Sotudeh & Horri, 2008: 89). This lack of high-impact articles further influences the image of OA journals negatively, as journal quality is often judged according to the JIF, either as an indicator of the quality of the articles in a journal or of the desirability of publishing in a journal[11] (Garfield, 2006: 92). In other words, because authors perceive OA journals as being of a lower quality, they will tend to submit their lower-quality articles to these journals, which perpetuates the view that OA journals publish research of low quality. The perception that the quality of OA journals tends to be lower than that of subscription journals, has been found to be pervasive (Dulle & Minishi-Majanja, 2009: 9; Fullard, 2007: 44; Xia,

[11] This practice, however is contentious (Archambault & Larivière, 2009; Lozano, Larivière & Gingras, 2012; Mingers & Leydesdorff, 2015: 21), as briefly discussed later in this chapter.

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2010: 622). Many factors contribute to this view, as discussed earlier, such as the occurrence of predatory journals and concerns about the effect APCs have on the peer-review system (Fullard, 2007: 44). The perception that OA journals are of lower quality has the additional effect that readers who could potentially cite the work are dubious about its quality and less likely to make use of it as a source. As the discussion on the Matthew effect highlights, the social biases in favour of more established journals, could potentially partially explain the number of citations non-OA and OA journal articles receive.

Many potentially confounding factors therefore may affect the number of citations an article receives. These confounding factors are only indirectly related to the fact that an article is available gratis. Previous studies have controlled for these factors, for example by –

- only investigating articles from journals with a high JIF (Antelman, 2004; Norris, Oppenheim & Rowland, 2008b: 1965; Atchison & Bull, 2015; Xia & Nakanishi, 2012);
- comparing journals with similar JIFs (Gargouri *et al.*, 2010; Lansingh & Carter, 2009);
- excluding newer journals from an investigation (Sotudeh & Horri, 2008); or
- investigating the citations received by articles rendered OA in hybrid OA journals compared to those that were not (Eysenbach, 2006; Sotudeh *et al.*, 2015).

3.3.2. The early-view postulate

One of the first researchers to investigate and find an OA citation advantage, was Lawrence (2001), who studied self-archived conference articles in computer sciences and related subject areas. In response to this study, Kurtz *et al.* (2005) suggest three potential, non-exclusive explanations for the existence of such a citation advantage: the early-view postulate, the self-selection postulate, and the OA postulate. The first explanation postulates that articles which are self-archived before they are officially published by a journal, have more time to be cited than other articles published (only in a journal) within the same year. This is also referred to as the early-access effect (Norris *et al.*, 2008b: 1964). The time frames for citation acquisition by the two types of articles (i.e. those with earlier self-archived versions and those without) are not the same, and thus constitute an unfair comparison, especially if lifetime citations are considered (Craig *et al.*, 2007: 243). An OA citation advantage for OA journal articles cannot be explained by the early-view postulate, as the articles are made OA immediately on publication; earlier versions are therefore not applicable.

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3.3.3. The self-selection postulate

The effect of self-selection was already touched upon during the discussion of the Matthew effect, when it was suggested that researchers may withhold their high-quality articles from lesser-known journals (which mostly tend to be OA journals), and rather publish them in subscription journals with higher JIFs. However, when the self-selection postulate was initially formulated (see Kurtz *et al.* 2005), it suggested the opposite, namely that authors are more likely to self-archive their 'best' works, or that more prominent authors are more likely to self-archive as a result of a self-selection bias (Dorta-González *et al.*, 2017: 878; Kurtz *et al.*, 2005: 2). Thus, the articles are self-archived because they received or were expected to receive many citations, and not the other way around.

Several scholars argue that a self-selection bias is either not relevant in the particular subject area, or not relevant in general to the discussion of an OA citation advantage (Atchison & Bull, 2015; Donovan & Watson, 2011; Hajjem, Harnad & Gingras, 2006; Xia & Nakanishi, 2012). The question is still open: arguments against the existence of a self-selection bias are based primarily on a study of OA mandates, which are applicable only to self-archived articles (Gargouri *et al.*, 2010), the practice that authors either archive none or all of their articles (Antelman, 2004); or the claim that, without access, articles cannot be cited at all (Atchison & Bull, 2015; Hajjem *et al.*, 2006). This third claim (i.e. articles without access cannot be cited at all) holds some merit, as it has been shown in a study by Norris *et al.* (2008b: 1967) that of the articles which received no citations, a smaller percentage were OA (36.8%) than subscription-access (63.2%) articles. Another study arrived at a similar conclusion (Eysenbach, 2006). This suggests that OA articles are more likely to be cited, but do not necessarily receive more citations than subscription-access articles (Norris *et al.*, 2008b: 1967).

The reasoning that authors self-archive either none or all their articles holds less sway. There are many reasons why authors would selectively self-archive. Authors could simply be self-archiving articles to serve as exemplars of their best work (Kurtz *et al.*, 2005), or novel research may be requested more often by readers, which motivates authors to self-archive such frequently requested articles (Wren, 2005). In addition, more established researchers could simply be more likely to self-archive than less-established researchers are. The effect of the self-selection bias for self-archived articles is also potentially very different from the effect on those rendered OA through a journal's hybrid OA policy or through OA journals. Unlike self-archiving, which is cost-free and can be repeated in multiple archives and websites if so desired, the process of rendering an article OA by publishing it in an OA journal, or rendering it such in a hybrid OA journal, has limitations. For these articles, there may be financial costs involved in rendering it OA (i.e. APCs) and the selection of journal is exclusionary and permanent, as an article can only be published in one journal. To do otherwise, and publish an article

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in multiple journals would be regarded as self-plagiarism, although it can still be self-archived. For OA journals, the self-selection bias is difficult to investigate through citation analysis alone, as authors have a choice where to publish, and the reasons behind their choice could be considered a factor that influences the number of citations an article receives.

3.3.4. The open access postulate

The open access postulate is based on the idea that researchers can only cite articles which they can read; therefore, an OA article (which is easily accessible to anyone who has an Internet connection) would potentially be cited more often than one which is behind a "paywall" (Harnad *et al.*, 2008: 37). Stated differently, an article is more likely to be cited at all if it is freely available, as this increases the potential audience that would be able to cite the work (Eysenbach, 2006; Swan, 2010). However, it has been well established that the distribution of citations across articles in a subject area is skewed, with most articles receiving no citations and only a few being cited extensively (Garfield, 2006: 91; Porter, 1977: 263). In addition, providing OA to an article does not change its content; the article therefore still needs to report on original, quality research to attract many citations. Admittedly, providing OA could have an influence on the perception of quality, as previously discussed (Björk & Solomon, 2012a: 10; Fullard, 2007: 44; Sotudeh & Horri, 2009: 23). The OA citation advantage postulate proposes that quality OA articles will receive more citations than quality articles with limited access, due to a wider audience, that is able to cite the OA articles (Cullen & Chawner, 2011: 463). This could be measured by investigating the share of OA journal articles among the most-cited articles (Torres-Salinas *et al.*, 2016). However, as discussed earlier in this chapter, there could also be a selection bias, with only the highest-quality articles being made OA, whether through self-archiving or by publishing in an OA journal, or by rendering the articles OA in a journal that follows a hybrid OA policy.

3.4. Main factors affecting the number of citations for open access articles

The primary aim of the current study was to investigate the OA citation advantage for OA journal articles. The methodology of this study involved comparing articles published in OA journals with those that are not, while recognising that the latter also comprise hybrid OA articles, delay OA articles and articles for which self-archived versions are potentially available online. It is also acknowledged that many other factors affect the number of citations an article receives. The current section elaborates upon those factors that have been investigated in studies that included the examination of

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the effect that the access status of articles has on the number of citations an article receives. The literature review on the topic is divided into two sections: one that addresses the type of factors which potentially affect the number of citations an article receives, and another that discusses a review of the empirical studies that specifically consider the OA citation advantage. It should be noted that studies, that investigate the OA citation advantage are difficult to compare, because the studies differ in –

- the types of OA they investigated;
- the subject areas they investigated;
- sampling methods used; and lastly
- the citation indexes they used to extract citation data from (e.g. WoS and Scopus)

Nevertheless, some comparison across the studies was attempted for this review.

Three main types of factors were identified in the literature that could influence the number of citations an article receives, i.e. those related to the author(s), the content of the article, and the journal (Calver & Bradley, 2010; Lansingh & Carter, 2009; Tahamtan *et al.*, 2016). These are summarised in Table 3.1, together with an indication of which were investigated empirically in the current study. Only those factors that could be linked logically to OA and OA journals were examined in detail.

Table 3.1: Factors influencing the number of citations an article receives, and those investigated in this study

	Factor	OA-linked	Included in this study
Article	Quality of the publication	Yes	Partially controlled
	Novelty, popularity and interest of subject	No	No
	Characteristics of a discipline	Yes	Subject areas separately studied
	Methodology	No	No
	Document type	No	Articles and reviews investigated
	Study design	No	No
	Characteristics of results discussion	No	No
	Use of figures and appendices in publications	No	No
	Characteristics of title, abstract and keywords	No	No
	Characteristics of references	No	No
	Length of publication	No	No
	Age of cited publication (age effect)	Yes	Citation window applied
	Accessibility and visibility	Yes	Comparing OA and non-OA journal articles

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	Factor	OA-linked	Included in this study
Author	Number of authors and co-authorship	Yes	No
	Author's reputation and previous citations	No	No
	Author's academic rank	No	No
	Self-citation	No	Self-citations excluded
	International and national collaboration	Yes	No
	Author's country affiliation	Yes	No
	Author's gender, age and race	No	No
	Author's productivity	No	No
	Author's organisational features	Yes	No
	Funding and grants received by author	Yes	No
Journal	Publisher	Yes	No
	Age	Yes	No
	Journal impact factor and prestige	Yes	No
	Language of journal (language of article)	Yes	Sensitivity analysis conducted
	Scope and coverage of journal	Yes	No
	Accessibility and visibility	Yes	OA and non-OA journal articles compared

3.4.1. Characteristics of articles

Various characteristics of articles have been investigated by studies that tested whether the access status of an article has an effect on the number of citations an article receives (Bornmann & Daniel, 2008: 47; Calver & Bradley, 2010; Laband, 1990: 349), for example, type of document, length of document and subject area. The current study did not investigate the content of articles (e.g. methodology, study design, use of figures, number of references and length of abstract) separately, as there was no reason to believe that OA journal articles and non-OA journal articles would differ in terms of these characteristics, even if there were reason to believe they might differ in terms of quality or novelty. As mentioned before, quality and novelty are two of the major factors affecting the number of citations received. In this section it is explained how (perception of) quality and OA could be linked through a process of self-selection and social biases and how these, in turn, affect the citations OA articles receive.

Megajournals do not attempt to publish only novel research, and OA megajournals potentially constitute a large percentage of the OA publications within certain broad subject areas (Binfield, 2014: 158; Björk, 2013: 9; Eve, 2015: 147). This relative lack of novelty and broad scope could negatively influence the number of citations that articles in these journals receive. This, in turn, could affect the number of citations OA journal articles in these broad subject areas receive, due to the large

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proportion of OA articles published in megajournals. However, not all OA journals follow a policy of including non-novel publications.

The age effect, namely that older articles have had more time to receive citations than articles published at a later date (Tahamtan *et al.*, 2016) has been observed in studies investigating OA citation advantage. This is however mainly a function of researchers neglecting to use citation windows when comparing articles published in different years. A variation of the age effect is the early-view effect, which is a particularly difficult effect to control for, as it needs to be known whether a self-archived version of an article is available online, and when it was self-archived. Strictly speaking, the early-view effect is not limited to non-OA journal articles, as OA journal articles may also be self-archived. Various studies have shown that self-archived articles have a citation advantage over both OA journal articles and those only available through subscription journals (Archambault, Amyot, Deschamps *et al.*, 2014: 20; Gargouri *et al.*, 2010; Henneken *et al.*, 2006; Swan, 2010). Archambault, Amyot, Deschamps *et al.* (2014: 20) identified an OA journal citation disadvantage for most subject areas while investigating articles published from 1996 to 2013. However, this does not confirm the existence of a citation disadvantage for journal-based OA in comparison to subscription-based access, as other factors are applicable to journal-based OA than OA gained through self-archived versions. It is also not clear whether OA journal articles are more likely to be self-archived than subscription journal articles are. The age effect was thus not further investigated, as this study did not investigate OA derived from self-archiving, and this review focuses on those factors that affect journal-based OA.

Document types differ in terms of the number of citations they tend to accumulate, and subject areas differ in terms of document types preferred (Pendlebury, 2009: 3). In the social sciences and humanities, for example, books and book chapters are cited more often than in the natural sciences. Review articles also tend to accumulate a larger number of citations in comparison to other document types. Differences such as these highlight the need to investigate subject areas separately. Document type has occasionally been investigated in studies examining OA citation advantage, either by comparing, in a single subject area, the OA citation advantage of book chapters to that of journal articles (Calver & Bradley, 2010), focusing on the OA citation advantage of working papers (Ingwersen & Elleby, 2011), or investigating whether the document type of a publication that is rendered OA has a significant effect on the number of citations a publication receives (Lansingh & Carter, 2009). While any link between document type and OA is unlikely, publishers' practice of varying APCs for different document types could influence authors' choice to render a document OA in a journal that follows a hybrid OA policy, or whether to publish a document in an OA journal (Björk & Solomon, 2012b).

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Another factor that has been shown to influence the number of citations of an article significantly is the subject area of the research on which the article reports, as publication and citation practices differ between subject areas (Waltman & Van Eck, 2013: 699–700). Many studies have investigated the difference in number of citations received between OA articles and non-OA articles across different subject areas. For example, in their investigation of the "average of relative citations" (ARC), Archambault, Amyot, Deschamps *et al.* (2014: 17) found that all subject areas experienced a general OA citation advantage. Their study considered various types of OA, including self-archived articles, and found the largest citation advantage for self-archived articles, while in some subject areas ('General Arts, Humanities and Social Sciences[12]', 'Built Environment and Design', 'Economics and Business', and 'Visual and Performing Arts') OA journal articles (i.e. 'gold OA') experienced a citation disadvantage. Archambault, Amyot, Deschamps *et al.* (2014:17) warn that the ARC is not a scale-independent measure and it is highly susceptible to certain characteristics of OA journals. In other words, the measured disadvantage could be an artefact of the tendency of many OA journals to be smaller and younger than subscription journals. It was found (Archambault, Amyot, Deschamps *et al.*, 2014: 19), that the uptake of OA journals has been low in 'General Arts, Humanities and Social Sciences' (2.8%) compared to 'Science and Technology' (58%). Interestingly, in subject areas in which the uptake of OA was found to be low, the OA citation advantage was greater than for those subject areas in which the uptake was high.

3.4.2. Author characteristics

Author characteristics that have been investigated in relation to the OA citation advantage are author citation and publication profile, funding received for a study, number of co-authors, and country affiliation (Calver & Bradley, 2010; Lansingh & Carter, 2009; Sotudeh & Horri, 2008: 88–89). Self-citations are elaborated upon in this section as part of author characteristics, as such citations reflect the behaviour of the author, and not the behaviour of the reader of research articles. Other author characteristics suggested by the literature as affecting the number of citations an article receives, but which have not been examined with reference to OA, are the author's academic position at a university and his or her gender.

While self-citations are not linked specifically to OA, in previous studies on the OA citation advantage their effect on citation analysis have been recognised and these self-citations have mostly been

[12] When a subject area is written in single quotation marks it refers to the subject area categories as applied within WoS (see sub-section 4.2.1.5) and Scopus (see Elsevier, 2017a).

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excluded (Antelman, 2004; Norris *et al.*, 2008a: 1967). Self-citations are generally excluded from citation analyses, as was done in the current study, as such analyses do not measure visibility beyond the authors themselves. In a study by Ingwersen and Elleby (2011), self-citations were specifically investigated and found not to be endemic to OA articles available through Google Scholar.

Whether a study was funded, the language in which an article is written, and country of origin were identified by Lansingh and Carter (2009: 1430) as significant variables when investigating citations received by publications hosted on PubMed, whereas access status was not. Funding data are rarely available, and therefore a difficult factor to control for, and consequently outside the scope of this study. As a proxy of authors' citation history, prestige and experience, some studies made use of the Hirsch index (Hirsch, 2005) of an author when investigating the OA citation advantage (Calver & Bradley, 2010; Vanclay, 201). The Hirsch (H) index indicates "the number of papers with citation number ≥h" (Hirsch, 2005: 16569). Previous studies that investigated both the authors' H index and the access status of their articles found that either the H index and access status are not major factors that determine the number of citations an article receives (Vanclay, 201), or that only the H index (and not also the access status of an article) is a major factor that determines the number of citations (Calver & Bradley, 2010). However, a more significant factor is the journal's impact factor, which is elaborated upon in sub-section about journal characteristics.

Various studies have shown that there is a correlation between the number of co-authors and the number of citations an article receives, in that articles with multiple authors tend to be cited more often than those with only one author (Leimu & Koricheva, 2005: 31; Tahamtan *et al.*, 2016: 1214). It is argued (see Tahamtan *et al.*, 2016: 1208) that this is due to the larger audience to which the article is exposed through academic activities (for example conferences, seminars and workshops) by multiple authors as opposed to a single author. Various studies have examined how this relationship between the number of authors and the number of citations interacts with the access type of an article, although mainly in relation to self-archived articles (Calver & Bradley, 2010; Eysenbach, 2006; Gargouri *et al.*, 2010; Lansingh & Carter, 2009; Vanclay, 2013). The argument is that multi-authored articles are also more likely to be self-archived, as there are more authors to do so (Craig *et al.*, 2007: 242; Tahamtan *et al.*, 2016: 1208). This relationship has not been investigated extensively for journal-based OA and when it has, conflicting results have been found. Eysenbach (2006) found that the access status of articles in the Proceedings of the National Academy of Sciences of the United States of America (PNAS) is a reliable predictor of the number of citations an article receives, even when various factors are controlled for, with the number of authors being one of these. Other studies have found that access status of an article does not remain significant once the number of authors is controlled

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for (Calver & Bradley, 2010; Lansingh & Carter, 2009; Vanclay, 2013). However, potential for comparison of these studies to the current one is limited, because:

- Eysenbach (2006) investigated hybrid OA;
- Lansingh and Carter (2009) investigated articles on the PubMed database;
- Vanclay's study was based on publications by only 57 authors; and
- Calver and Bradley (2010) investigated only two journals.

The reason why journal-based OA articles might have more authors than subscription journal articles do, might be linked to the high cost of APCs (usually too high for an individual to pay), or pressure exerted by funders of large-scale studies (which tend to involve multiple researchers) to provide OA to publications, but this has not been investigated yet. Investigating whether OA journal articles tend to have more authors than non-OA journal articles, and whether this in turn has an effect on the number of citations received, fell outside the scope of the study for various reasons. First, to be able to investigate the possible relationship between APCs and number of authors, one will need to distinguish those OA journal articles that required an APC for publication, from those that do not. This would require substantial additional data collection. A similar argument can be made regarding the possible pressures exerted by funders of large-scale studies, as one would need data to distinguish between those studies that have such funder requirements, and those that do not. Secondly, while data on the number of authors of an article are available from the WoS microdata, determining the relationship between number of authors and number of citations involves additional considerations related to the type of collaboration. While collaboration has been linked to an increase in number of citations, the number of authors is not necessarily an indication of whether collaboration took place (Katz & Martin, 1997: 2). In addition, not all types of collaboration are linked to a significant increase in citations. Articles that involved international collaboration are more likely to be highly cited than those that involved intranational collaboration (Lancho Barrantes, Guerrero Bote, Rodríguez & De Moya Anegón, 2011: 481). Simply measuring the number of authors would not capture the nuances of the relationship between the types of collaboration and number of citations. Including 'collaboration type' as a variable would require substantially more complicated data extraction and analysis than what are within the scope of this study.

The OA citation advantage for particular countries has also been investigated by comparing the OA journal articles (in terms of citations received) with the non-OA journal article output of such countries (Shin, 2012; Sotudeh & Horri, 2008), or by comparing the articles in OA journals by authors affiliated with a specific country (e.g. Spain) with the OA journal articles of other authors in WoS (Torres-Salinas *et al.*, 2016). Sotudeh and Horri (2008: 88–89) found that not all countries experience an OA journal

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citation advantage, and the subject areas in which a citation advantage is experienced differ between countries. There are also some disciplines in which no country derives an OA citation advantage from publications in OA journals (e.g. the natural sciences). Sotudeh and Horri (2008) investigated a range of countries and classified them as either developing or developed countries. They found that developing countries are less likely than developed ones to experience an OA citation advantage. However, in the life sciences, some developing countries (e.g. Greece, Kenya, Mexico, and Indonesia) derive an OA citation advantage from their contributions in OA journals. Sotudeh and Horri (2008) also investigated 13 subject areas. Developing countries were also less likely to experience a citation advantage for their OA journal articles than developed countries in the various subject areas. The subject areas in which developing countries' OA journal articles do experience a citation advantage are:

- 'Immunology': Singapore, China, Kenya, Mexico, Colombia and Brazil;
- 'Infectious Diseases': Kenya, China, Colombia, Brazil, Argentina, Mexico, Spain and Thailand;
- 'Medicine, Research & Experimental': China, Spain, India, Turkey and Argentina; and
- 'Pharmacology & Pharmacy': Mexico and Spain.

Sotudeh and Horri (2008) report that this difference is partially an artefact created by certain subject areas being smaller (resulting in fewer articles and journals in those subject areas) than others, certain subject areas having established OA journals, as well as a country's specialisations in certain subject areas (Sotudeh & Horri, 2008: 82, 74). Sotudeh and Horri (2008) propose that this lack of an OA citation advantage in OA journals among developing countries could also be due to underdeveloped science systems in the countries in question, but this explanation does not address the fact that articles by authors from Brazil, Chile and India that are published in non-OA journals receive significantly more citations than the world average in certain subject areas.

3.4.3. Journal characteristics

Journal characteristics are particularly important to the current study, as this study focused on OA journal articles and whether they experience a citation advantage. The JIF, whether a journal is a long-established journal, the language of the journal, and the international and local scope have all been associated with the access status of journals and with the number of citations an article receives, as elaborated upon in this section.

Initially, the JIF was consulted by librarians to identify which journals to subscribe to (Archambault & Larivière, 2009: 637). However, the JIF has become associated with journals' quality and thus prestige, even though the association between the JIF and the number of citations individual articles receive

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have decreased over the years (Lozano *et al.*, 2012: 2140). The use of the JIF as an indicator of the quality of the publications in a journal has been criticised by numerous scholars, not only because it can be manipulated by publishers (Archambault & Larivière, 2009: 635; Wehrmeijer, 2014), but also because it disregards the skewness of the distribution of citations across articles in a journal (Mingers & Leydesdorff, 2015) and thereby making the error of an ecological fallacy (Bryman, 2012: 323). Consulting the JIF is therefore inappropriate for evaluating individual publications or researchers (Taylor *et al.*, 2008: 21). The JIF has often been investigated in studies on the OA citation advantage (Dorta-González *et al.*, 2017; Frandsen, 2009; Gargouri *et al.*, 2010; Vanclay, 2013; Wren, 2005; Xia & Nakanishi, 2012); however, it was not investigated in this study due to the aforementioned criticisms.

Another journal characteristic that was discussed earlier in this chapter is the age of journals, as a proxy of how established they are. Age here refers to the number of years since the initial launch of the journal. The newer OA journals that appear in citation indexes exhibit a similar scientific impact to their subscription counterparts, specifically OA journals charging an APC in the subject area of biomedicine (Björk & Solomon, 2012a: 9), which suggests that the number of years a journal has been in operation is a significant factor when investigating the number of citations articles in OA journals receive. Whether a journal is long established has been suggested to have an effect on the citations to the articles therein, with articles in younger journals receiving fewer citations (Archambault, Amyot, Deschamps *et al.*, 2014: 17). In this case 'age' might be closely related to prestige, which has been shown to influence the number of citations articles receive (Tainer *et al.*, 1991: 1408; Van Dalen & Henkens, 2004). Older journals have more visibility due to an established readership and associated prestige. This increases the likelihood of articles in such journals being read and thus cited.

The language in which an article is written also affects the number of citations it receives. Articles written in English tend to receive more citations than those written in other languages, partially because, as has been shown, they are more likely to be included in citation indexes (Archambault, Vignola-Gagne, Côté, Larivière & Gingras, 2006: 329; Bornmann & Daniel, 2008: 47&70; Pendlebury, 2009: 4). A number of academic society journals, journals that promote publishing in a local language, and journals with a local focus have adopted an OA distribution model in an attempt to gain increased visibility with governments and other initiatives assisting with this goal (Björk, 2011: 7). For example, the SciELO project aims to transform local journals into OA journals, to enhance the visibility of such journals that are under strain due to having a local focus and being published in a local language. This conversion of local journals from subscription journals to OA journals in effect reduces the proportion of subscription journals in this category. As a result, an increasing proportion of local journals are OA journals, which potentially plays a confounding role when investigating whether OA journals

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experience a citation advantage. Whether this has a significant effect on the number of citations that OA journal articles receive, in comparison to non-OA journal articles, was undetermined at the time of writing.

3.5. Empirical studies on the open access citation advantage

The occurrence of an OA citation advantage has been investigated by many studies with various foci, such as specific subject areas, specific document types and different methods of rendering an article OA, as well as focussing on specific countries (Antelman, 2004; Eysenbach, 2006; Harnad *et al.*, 2004; Moed, 2007). However, there is a lack of consensus on whether a general OA citation advantage exists or for which subject areas an OA citation advantage can be observed. Archambault, Amyot, Deschamps *et al.* (2014: 17) found that, in general, articles which are rendered OA experience a citation advantage, although this does not apply to OA journal articles. Without a specific subject area focus, Van Leeuwen *et al.* (2018) found that, in 2001, OA journal articles from Switzerland and Denmark experienced a citation advantage, although this advantage did not continue thereafter. Dorta-González *et al.* (2017: 899–900) state that only selected subject areas experience an OA citation advantage for their OA journal articles. Researchers disagree on what accounts for the observed citation advantage for OA articles (Craig *et al.*, 2007: 247; Kurtz *et al.*, 2005: 11). These apparently disparate results are in part due to the different methods for providing OA to content (self-archiving, hybrid OA, OA journals, delayed OA), the various research designs applied to investigate citation behaviour (for example, experimental designs and case studies), differences in citation and publication practises between subject areas, and the various confounding factors present when investigating OA articles and citations to these.

In addition, self-selection bias is practically impossible to investigate for OA journals, as authors have a choice of where to publish and thus the reasons behind their choices could be considered factors which indirectly influence the number of citations the articles receive. Thus, previous studies on the number of citations articles in OA journals receive often focused on journal prestige bias (such as Sotudeh & Horri, 2007a; Björk & Solomon, 2012a) and author characteristics (such as Calver & Bradley, 2010; Vanclay, 2013), and how these might explain the number of citations observed for OA journal articles. This focus on the prestige bias led to the comparison of the JIFs of OA journals and non-OA journals, as the JIF is considered a measurement of prestige and a normalised measure, as discussed earlier in this chapter. Various other methods, which are based on the individual articles and not on journal-level measurements, also exist for normalising citation scores to enable comparison between

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the average number of citations articles receive. In the case of studies investigating OA articles, a variety of these methods have been applied, such as –

- investigating the proportion of the mean number of citations that OA articles receive in comparison to non-OA articles (Dorta-González *et al.*, 2017);
- a comparison of "adjusted relative citation impact" (ARCI) (Sotudeh & Horri, 2009); and
- the MNCS, as applied by the Centre for Science and Technology Studies (CWTS) at Leiden University (Van Leeuwen *et al.*, 2015).

The need for normalisation and the way it was conducted in the current study, are further examined in the following chapter.

The majority of studies on the OA citation advantage defined OA articles either as self-archived articles or any article that can be found gratis online (Torres-Salinas *et al.*, 2016: 18). However, as illustrated by the review so far, different factors influence the number of citations an OA article receives, depending on the type of OA. The current study only investigated journal-based OA, in other words, OA journal articles were compared with non-OA journal articles. Ideally, further disaggregation of the non-OA journal articles would have assisted with the analysis, because non-OA journal articles and self-archived articles are not mutually exclusive. The same applies to hybrid OA articles. Few previous studies (such as Eysenbach, 2006; Sotudeh & Estakhr, 2018) have been able to identify hybrid OA articles and disaggregate them from non-OA and OA journal publications, and only recently, after data collection and analysis for this study had been completed, WoS started including microdata on self-archived articles and other journal-based OA (Napolitano, 2018).

Because of the lack of a standard methodology to investigate the OA citation advantage, and the relatively new method used by the current study to identify OA journal articles, the number of comparative studies is limited. This literature review thus discusses some studies with methodologies that differ vastly from the methodology of the current study, but which still had an influence on the conceptualisation and design of this study. The following, more detailed discussion of the literature on OA citation advantage is divided into two sections. The first addresses those studies that investigated a general OA citation advantage; the second reports on the studies that investigated single or multiple subject areas.

3.5.1. Studies investigating a general open access citation advantage

Investigating a general OA citation advantage for OA journal articles, i.e. irrespective of subject area, has previously been particularly challenging. Before WoS and Scopus (in 2014 and 2015, respectively)

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added additional microdata to their citation indexes that included data on whether an article is published in an OA journal, studies that investigated the OA citation advantage were not necessarily limited to OA journals. They either investigated OA as defined by those articles discoverable through manual online searches (Antelman, 2004; Jingfeng, Myers & Wilhoite, 2011), created software to extract information on articles which could be found online (Gargouri, Larivière, Gingras & Harnad, 2012; Hajjem *et al.*, 2006), or depended on external resources beyond a citation index itself to identify OA journal articles manually e.g. DOAJ (Archambault, Amyot, Deschamps *et al.*, 2014; Van Leeuwen *et al.*, 2018). In many cases, random sampling of publications in a specific subject area, often from a limited number of journals, was the norm for investigating the OA citation advantage for OA journal articles. Only a few studies (such as those by Cheng and Ren [2008] and Van Leeuwen *et al.* [2018]) attempted to investigate a general OA citation advantage and even then, this was often done only for publications by authors affiliated with specific countries.

Cheng and Ren (2008) conducted a census of all journals published in China, which was facilitated by a country-specific citation index. This included an investigation of whether the OA journal publications experienced a citation advantage, which they did. Van Leeuwen *et al.* (2018: 8–9) investigated the articles, reviews and letters published in academic journals from the Netherlands, Denmark and Switzerland, indexed in WoS, for the publication years 2003 to 2012, and made use of the DOAJ to identify OA journals and match them to journals listed in WoS. They found that, while the OA journal publications from Denmark and Switzerland initially experienced a citation advantage, this changed over the years and suggests that the OA citation advantage needs to be investigated over time.

In 2014, Science-Metrix (see Archambault, Amyot, Deschamps *et al.*, 2014) published a report for which they analysed a publication sample comprising 1.25 million articles published from 1996 to 2013 by authors affiliated with the 28 members of the European Union (EU28) and the European Research Area (ERA) countries as well as Brazil, Canada, Japan and the United States, to determine the percentage of articles that were OA as well as their comparative citation advantage. They investigated 'gold OA', 'green OA', and 'other OA', and found that the three categories of OA articles combined experience a citation advantage in comparison to subscription journal articles. However, while green OA (self-archived articles) and 'other OA' experienced a citation advantage, OA journal articles experienced a citation disadvantage in comparison to subscription-journal articles. This disadvantage observed for articles in OA journals was partially attributed to those journals being smaller and younger than subscription journals (Archambault, Amyot, Deschamps *et al.*, 2014: 17). The study also investigated individual subject areas, as discussed earlier in this chapter.

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While the majority of reviewed studies made use of WoS, it was only in 2014 that WoS added the OA tags to articles published in OA journals, and few studies have had the opportunity to exploit this for identification of OA journal articles (Thomson Reuters, 2014). Torres-Salinas *et al.* (2016) applied two measures of citation impact to investigate all publications from Spain for the publication years 2005 to 2014; a measure reflecting normalised citation impact and another reflecting the share of OA publications among the 10% most frequently cited articles. They found that OA publications from Spain did not experience a citation advantage, and attributed this to the subject areas in which the OA journal publications appeared and publisher type favoured by researchers from Spain. The following section discusses those studies which investigated the OA citation advantage in selected subject areas.

3.5.2. Studies investigating open access citation advantage in selected subject areas

Several studies (such as Solomon & Björk, 2013; Norris *et al.*, 2008b; Sabharwal, Patel & Johal, 2014; Vanclay, 2013) have been conducted for selected subject areas in OA journals and whether OA articles experience a significant citation advantage compared to articles published in subscription journals. While the publications of different years were analysed and some studies made use of WoS and others of Scopus for citation data, an attempt was nevertheless made to compare the results of six studies, as summarised in Table 3.2. Together these studies investigated over 240 subject areas, 86 of these were investigated in more than one of the studies, with results differing for some subject areas.

Table 3.2: Studies on the open access citation advantage of articles published in selected subject areas

Study	Citation index	Subject area focus	Publication years	OA citation advantage
Sotudeh and Horri (2007a)	WoS	Life sciences; natural sciences; engineering and material sciences; and multidisciplinary sciences	2001–2003	Yes, for selected subject areas
Davis *et al.* (2008)	WoS	Physiology	2007	No
Calver and Bradley (2010)	Scopus	Conservation Biology	2000	No
Archambault, Amyot, Deschamps *et al.* (2014)	Scopus	22 subject areas	1996–2013	No
Archambault, Côté, Struck and Voorons (2016)	WoS	22 subject areas	2007–2009	Only for 'Biology' and 'Biomedical Research'
Dorta-González *et al.* (2017)	WoS	Each of the WoS subject areas and the different citation indexes (SCIE, SSCI, AHCI)	2009	Yes, for selected subject areas

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Two of the studies investigated the same 22 subject areas, one using WoS for citation data, the other Scopus, for the years 1996–2013 and 2007–2009 respectively. The subject areas were defined according to the Scopus classification system. Results were similar for 20 of the subject areas, namely that there was no OA journal citation advantage (Archambault, Amyot, Deschamps *et al.*, 2014; Archambault *et al.*, 2016). The two subject areas for which results differed were 'Biology' and 'Biomedical Research', as shown in Table 3.3. The authors made use of the same methodology, comparing OA journal, self-archived, other OA, and non-OA articles to examine the OA citation advantage through the measurement of ARC.

Table 3.3: Comparison of Archambault, Amyot, Deschamps *et al.* 2014 *et al.* (2014) and Archambault *et al.* (2016) in terms of whether articles experience an OA citation advantage in selected subject areas

Subject area	Archambault, Amyot, Deschamps *et al.* (2014)	Archambault *et al.* (2016)
Agriculture, Fisheries and Forestry	No	No
Biology	No	Yes
Biomedical Research	No	Yes
Built Environments and Design	No	No
Chemistry	No	No
Clinical Medicine	No	No
Communication and Textual Studies	No	No
Earth and Environmental Sciences	No	No
Economics and Business	No	No
Enabling and Strategic Technologies	No	No
Engineering	No	No
General Arts, Humanities and Social Sciences	No	No
General Science and Technology	No	No
Historical Studies	No	No
Information and Communication Technologies	No	No
Mathematics and Statistics	No	No
Philosophy and Theology	No	No
Physics and Astronomy	No	No
Psychology and Cognitive Sciences	No	No
Public Health and Health Services	No	No
Social Sciences	No	No
Visual and Performing Arts	No	No

The other four studies made use of WoS and its subject area categories. Two studies (Calver & Bradley, 2010; Davis *et al.*, 2008) investigated only a single subject area each. The first investigated publications in six journals in the field of biodiversity conservation to determine whether type of document, length

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of a publication, author's citation profile, number of authors, and access status (non-OA, self-archived OA, and hybrid OA) had a significant influence on the mean number of citations to articles published in 2005 and 2006 (Calver & Bradley, 2010). All three studies that investigated the OA citation advantage in the field of biodiversity conservation found that OA journal articles did not experience a citation advantage, as shown in Table 3.4. The second single-subject-area study investigated the field of physiology. It is one of the few studies which eliminated self-selection bias by rendering a random selection of articles and reviews OA in otherwise non-OA journals. This was done with the cooperation of the publisher of the journals, i.e. the American Physiological Society (Davis *et al.*, 2008). Together, this study and the study by Dorta-González *et al.* (2017) found no citation advantage for OA journal articles in Physiology, although the study by Sotudeh and Horri (2007a) found that Physiology OA journal articles did experience a citation advantage.

Table 3.4: Comparison of previous results regarding an open access citation advantage in selected Web of Science subject areas

Subject area	Sotudeh and Horri (2007a)	Davis *et al.* (2008)	Calver and Bradley (2010)	Dorta-González *et al.* (2017)
Agriculture, Multidisciplinary	No			No
Agronomy	Yes			No
Biochemistry & Molecular Biology	Yes			Yes
Biodiversity Conservation	No		No	No
Biology	No			Yes
Chemistry, Analytical	No			No
Chemistry, Inorganic & Nuclear	Yes			Yes
Chemistry, Multidisciplinary	No			No
Computer Sciences, Artificial Intelligence	Yes			No
Computer Sciences, Information Systems	Yes			No
Computer Sciences, Software Engineering	Yes			No
Computer Sciences, Theory & Methods	Yes			No
Dermatology	No			No
Ecology	Yes			No
Engineering, Chemical	No			No
Engineering, Electrical & Electronic	No			No
Engineering, Manufacturing	No			No
Engineering, Mechanical	No			No
Engineering, Multidisciplinary	No			No
Entomology	No			No
Environmental Sciences	Yes			No
Fisheries	No			No

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Subject area	Sotudeh and Horri (2007a)	Davis *et al.* (2008)	Calver and Bradley (2010)	Dorta-González *et al.* (2017)
Forestry	No			No
Gastroenterology & Hepatology	No			No
Genetics & Heredity	No			Yes
Geology	No			No
Geosciences, Multidisciplinary	No			Yes
Immunology	Yes			No
Infectious Diseases	Yes			No
Materials Sciences, Ceramics	Yes			No
Materials Sciences, Multidisciplinary	No			No
Mathematics	Yes			No
Medicine, General & Internal	No			No
Medicine, Research & Experimental	Yes			No
Metallurgy & Metallurgical Engineering	Yes			No
Meteorology & Atmospheric Sciences	Yes			Yes
Microbiology	No			No
Multidisciplinary Sciences	No			No
Neurosciences	Yes			No
Nutrition & Dietetics	No			No
Oncology	Yes			No
Ophthalmology	Yes			No
Optics	Yes			Yes
Parasitology	No			Yes
Pathology	No			No
Pharmacology & Pharmacy	No			No
Physics, Mathematical	No			No
Physics, Multidisciplinary	No			No
Physics, Nuclear	Yes			Yes
Physics, Particles & Fields	Yes			No
Physiology	Yes	No		No
Plant Sciences	Yes			No
Psychiatry	No			No
Public, Environmental & Occupational Health	Yes			No
Radiology, Nuclear Medicine & Medical Imaging	Yes			No
Rehabilitation	No			No
Rheumatology	No			No
Sport Sciences	No			No
Surgery	No			No

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Subject area	Sotudeh and Horri (2007a)	Davis *et al.* (2008)	Calver and Bradley (2010)	Dorta-González *et al.* (2017)
Telecommunications	No			No
Thermodynamics	No			No
Toxicology	No			Yes
Tropical Medicine	No			Yes
Urology & Nephrology	Yes			No
Veterinary Sciences	No			No

In total, there were 28 subject areas (of the 65 that both studies investigated) for which the results differed between the studies, as shown in Table 3.4. There were some fundamental methodological differences between the two studies, which could explain the discrepancies. Firstly, the studies examined different publication years, as shown in Table 3.2. Secondly, Sotudeh and Horri (2007a) excluded all articles from journals that had been launched after 2001. Furthermore, the authors applied different measures of citation advantage. Sotudeh and Horri (2007a) calculated the ARCI, whereas Dorta-González *et al.* (2017) investigated the proportion of the mean number of citations OA articles received in relation to non-OA articles. Lastly, Dorta-González *et al.* (2017) identified OA journal articles using the 'gold OA' tag in the WoS microdata, while Sotudeh and Horri (2007a) identified 114 OA journals that were included in the Journal Citation Reports (JCR). Sotudeh and Horri (2007a) found that 27 of the subject areas experienced an OA citation advantage, while Dorta-González *et al.* (2017) found that, of the 65 subject areas, 11 experienced a citation advantage.

3.6. Alternate measures of citation advantage

Most studies investigating the OA citation advantage equate citation advantage with articles receiving on average a higher number of citations than non-OA articles. One of the challenges of comparing the mean number of citations that articles receive is that the distribution of citations across articles is severely skewed (Mingers & Leydesdorff, 2015; Porter, 1977: 263). As a result, other citation performance measures have been formulated. The current study aimed to investigate two additional measures, which have rarely been applied before to investigate OA citation advantage, namely whether articles are cited at all (or remain uncited) and the presence of articles among the 1%, 5% and 10% most frequently cited articles. The next two sections present these two measures and the few studies that have applied these, or similar measures, when investigating OA articles.

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3.6.1. Number of uncited articles

In 1990 and 1991, the topic of the percentage of academic articles that did not receive any citations drew considerable attention after it had been claimed that 55% of all scientific publications receive no citations within five years of publication, with even higher percentages for the social sciences (75%) and humanities (92%) (Schwartz, 1997). This caused concern, as these uncited articles are often deemed to be irrelevant publications, with no impact on scientific knowledge, and referred to as articles relegated to the "dustbin of the uncited" (Cronin, 1984: 32; De Bellis, 2009: 198).

However, not only is the reported percentage of uncited articles inflated by the inclusion of document types not generally considered academic articles, for example, meeting abstracts, but the citations counted only include citations from other articles in WoS. Thus, documents not included in the index could potentially have cited these supposedly uncited publications. Despite these two considerations, uncited articles are still a concern, as many performance evaluations depend on the citations an author's publications receive. These evaluations are based on analysis using citation indexes, which render references by publications outside of these citation indexes essentially equal to being uncited, at least for evaluative purposes. Although this is a crude measure of impact, and the percentage of uncited articles is not as high as initially estimated, receiving any citations at all, as opposed to none, is still desirable for researchers, even if an article does not receive exceptionally many citations (Cronin, 1984; De Bellis, 2009).

While rarely investigated, it could be argued that OA articles potentially have a reduced chance of remaining uncited, due to their potential to reach a wider audience. A wider audience might not lead to exceptionally high citations, but it could increase the chance of an article getting cited at all, due to more readers being able to cite the article. This assumes that a wider audience includes researchers and not just the general public. Three studies that investigated the OA citation advantage examined whether a lower percentage of OA articles than non-OA articles remain uncited. However, these three studies investigated different types of OA, as shown in

Table 3.5.

Of the three studies, the one by Sotudeh and Horri (2007a) is the only one that investigated OA journal articles and distinguished between subject areas. The authors investigated the percentage of articles (published in 2001, 2002, and 2003) that remained uncited by 2006. A smaller percentage of OA journal articles remained uncited in three of the four subject areas, namely Engineering and Material Sciences (16.4%), Multidisciplinary Sciences (8.6%), and Natural Sciences (24.8%). The study also found

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that the percentage of uncited articles differed considerably between the subject areas, but no test was conducted to determine whether these differences are statistically significant.

Table 3.5: Studies that investigated the percentage of open access articles

Study	Publication year	OA focus	Sample	OA citation advantage
Eysenbach (2006)	2004	Hybrid OA	1 journal: PNAS	Yes
Hajjem *et al.* (2006)	2006	Self-archived	Across 10 disciplines: Biology, Psychology, Sociology, Health, Political Science, Economics, Education, Law, Business, Management	No
Sotudeh and Horri (2007a)	2001–2003	OA journal articles	Engineering and Material Sciences; Life Sciences; Multidisciplinary Sciences; Natural Sciences	3 of the 4

Eysenbach (2006) found that hybrid OA articles published in 2004 in PNAS were less likely than their non-OA counterparts to remain uncited 194 days after being published in the journal. With the former at 82.5% and the latter at 80.2%, the percentage of uncited articles remained high at such a short time after publication. The OA citation advantage was also investigated for self-archived articles 10 to 16 months after publication and Eysenbach (2006) found that hybrid OA articles that were self-archived (2.8%) had the lowest uncited percentage, followed by hybrid OA not self-archived (5.7%), then non-OA and self-archived (9.9%), and lastly non-OA and not self-archived (13.8%) articles. The differences were found to be statistically significant (see Eysenbach, 2006: 693). Eysenbach's (2006) study also illustrates the difference the size of the citation window makes for this particular measure of citation advantage. While Hajjem *et al.* (2006) investigated the OA citation advantage, they only did so for self-archived articles and their study is therefore not applicable to the current study.

3.6.2. Presence among the most frequently cited articles

The presence of frequently cited articles renders the use of the average number of citations, as the only measure of impact, questionable. An alternative (and complementary) citation-based impact measure designed to address this issue is the investigation of the position of a publication in the citation distribution of publications, investigated by subject area. An often-applied version is the inclusion of an article among a certain percentage of frequently cited articles (Waltman & Schreiber, 2013). This has previously been applied to investigate the OA citation advantage, but in studies limited to a selection of journals in a singular subject area, and rarely for OA journal articles (e.g. Gargouri *et al.*, 2010). Only one study applied this measure for OA journal articles, and did so across multiple subject areas (Torres-Salinas *et al.*, 2016).

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This section included four studies that investigated similar or related measures and not only for OA journal articles, as summarised in Table 3.6. The study by Torres-Salinas *et al.* (2016) examined frequently cited publications for publications by authors with a Spanish affiliation. This was done by comparing the percentage of OA publications among the 10% most frequently cited publications to the percentage of publications in general among the 10% most frequently cited. This analysis was conducted using citation data from WoS for the years 2005 to 2014, for selected disciplines. The study found no OA citation advantage on this measure, not when comparing Spanish OA journal publications with Spanish non-OA journal publications for each of the publication years examined, for any of the subject areas, or for OA journal and non-OA journal articles in WoS in general.

Table 3.6: Studies that investigated the presence of open access articles among the most frequently cited articles

Study	Publication year	OA focus	Method	Findings
Torres-Salinas *et al.* (2016)	2005–2014	OA journal articles	Share of OA journal output among 10% most frequently cited publications	No
McVeigh (2004)	2003	OA journal articles	JIF percentile	Undetermined
Gargouri *et al.* (2010)	2002–2006	Self-archived	Citation categories (1–4, 5–9, 10–19, and 20+ citations)	Yes
Fukuzawa (2017)	2010–2012	OA journal articles	Publications among the 10% most cited percentile	No

Torres-Salinas *et al.*’s (2016) results potentially may be an artefact of a difference between local and internationally orientated journals instead of a difference between OA journals and non-OA journals. The study by Fukuzawa (2017) potentially addressed this issue by comparing the citations received by articles published from 2010 to 2012 in local OA journals, international OA journals, local non-OA journals, and international non-OA journals. The study found that non-OA journal articles in international journals received a citation advantage while those in local journals, there was no relationship between their access status and whether they were among the 10% most frequently cited articles.

McVeigh (2004) investigated the JIF and determined that 14 OA journals were among the 10% journals with the highest JIF in their respective subject areas. However, this provides little comparison with non-OA journals and whether this constitutes a citation advantage is therefore unclear. Based on logistic regression, Gargouri *et al.* (2010) determined that the OA citation advantage for self-archived articles was the greatest for frequently cited articles. This concludes the review of some of the few articles that investigated the presence of OA articles among the most frequently cited articles, which illustrates that this aspect of OA citation advantage has received little attention in the empirical literature.

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3.7. Research questions derived from the literature review

A variety of sources in the literature suggest that OA to research could lead to an increase in the number of citations an article would receive, due to an increase in the potential audience that would be able to access the document. This review showed that altmetrics could potentially measure the assumption that OA leads to an increased audience. However, those methods have not been standardised yet. While citation analysis is not the ideal method to measure visibility among all audiences, it is a reliable method to investigate the citing and publication behaviour of researchers.

The review identified various mechanisms that could explain the number of citations OA articles tend to receive. These range from a selection bias in favour of or against OA articles, an early-view bias, the influence of how established a journal is, and the influence of the language in which an article is published. Some of these, for example the early-view effect, are mainly applicable to self-archived articles, highlighting the need to distinguish between different types of OA, as articles of the different types do not necessarily receive the same number of citations.

The review of the literature also revealed that, as with other citation and publication behaviours, there are differences between subject areas. More importantly, the review showed that different studies have arrived at different conclusions regarding whether an OA citation advantage exists in a particular subject area. Even in a single study, it has been shown that the presence of an OA citation advantage changes over time, necessitating a longitudinal approach.

Lastly, while the OA citation advantage has been explored in numerous studies, most applied some measure of average number of citations received. However, other definitions of citation advantage may also be applied, although these have received little attention in the literature in the context of the OA citation advantage as shown in this chapter. The current study aimed to apply the most common measure of citation advantage (namely the average number of citations received), as well as two other measures that take into account the skewed nature of the citation distribution across articles. These measures are the percentage of articles that has received any citations, and the percentage of articles among the most frequently cited articles.

Thus, the review assisted with defining the research focus of this study, namely that it would make use of citation analysis to investigate the difference between OA journal and non-OA journal articles in different subject areas. This was investigated across time, while using three measures of citation advantage. Chapter 4 details how this objective was formulated into research questions and hypotheses, as well as the methodology this study followed to investigate the OA citation advantage.

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CHAPTER 4: Methodology for examining the open access citation advantage

4.1. Introduction

This chapter describes the research problem, the research questions, and the hypotheses that were derived from it. This is followed by a clarification of the research design, after which the demarcation of the study is described in detail, including the selection of the citation index, the time frame investigated, the language considerations, as well as the document types included in the two datasets. Thereafter data collection is discussed by describing the two datasets that were constructed, as well as elaborating upon the key variables in this study and their definitions, i.e. access status, citation windows, NCS, uncited articles, and percentile-based citation indicators. The chapter then discusses the data analysis methods and techniques, by explaining the rationale for selecting these methods to investigate OA journal articles and the OA citation advantage, as well as the choices made during data analysis. The chapter concludes with the way in which the obstacles presented by the nature of the data collection methods were dealt with, the characteristics of the citation index, and challenges presented by using the subject categories of WoS when conducting citation analysis.

4.1.1. Research problem

The research problem was derived from the review of the literature regarding the relationship between access status and citation behaviour, as discussed in Chapter 3. In addition, recent developments in the data recorded in the major multidisciplinary citation indexes provided new opportunities for citation analysis involving OA journal publications. At the core of studies that have investigated the relationship between access status and citation behaviour is the idea that OA articles should, theoretically, receive a higher number of citations than non-OA articles – referred to as the OA citation advantage hypothesis.

While the basic argument for an OA citation advantage seems intuitively correct, the veracity of the OA citation advantage claim has been difficult to examine empirically. The main reason is that, until the year 2014, the main multidisciplinary citation indexes (namely WoS and Scopus) that allowed large-scale citation analysis, had not provided any data on the access status of articles. Previously, studies aimed at determining whether an OA citation advantage for OA journal articles exists had to

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rely on the DOAJ to identify OA journal articles, and would often be limited to a single subject area at a time. Additionally, previous studies and reviews tended to conflate types of OA, i.e. those which were derived from self-archiving, selective OA in otherwise subscription journals, and OA in entirely OA journals (Antelman, 2004; Donovan & Watson, 2011). This is problematic, as there are valid reasons to suspect that the OA types differ in terms of number of citations they receive and the factors that influence the number of citations they receive (Archambault, Amyot, Deschamps *et al.*, 2014; Kurtz *et al.*, 2005).

These issues, in addition to incomparable methodologies, explain why it has been difficult to formulate a definitive hypothesis as to whether a substantial OA citation advantage exists, especially as it pertains to OA journal articles. With the inclusion of data embedded in selected citation indexes to identify OA journal articles, it is now possible to investigate OA citation advantage at a larger scale, including more journals than ever before, and across multiple subject areas. This allows for the application of various citation analysis techniques, as well as the opportunity to determine, without having to rely on estimates, the degree to which OA journal articles are present in the various subject areas and how their percentages have changed over the years.

This study used the new capability of one of the main multidisciplinary citation indexes to identify OA journal articles in order to overcome the aforementioned limitations of previous studies. In particular, this study is explicit about the access types that were compared. This study involved analysis on a large scale, sourcing citation data from a prominent multidisciplinary citation index and focussed on a single type of OA, namely OA through OA journals. Three measures of citation advantage were applied in this analysis to better understand the various ways in which OA could provide a citation advantage to articles.

4.1.2. Research questions

The central question this study aimed to address could be expressed as a general hypothesis that OA journal articles experience a citation advantage in comparison to non-OA journal articles. The null hypothesis was simply that articles in OA journals accrue no citation advantage in comparison to those published in non-OA journals. This hypothesis was initially tested regardless of subject area, although field-normalised citation scores were applied. It was then tested further by subject area, as citation behaviour differs significantly among subject areas (see Waltman *et al.*, 2011). In this manner, the veracity of the general assumption – that because citation behaviour differs across subject areas, an examination of an OA citation advantage across subject areas would yield ungeneralisable results – was investigated empirically.

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To provide context for the investigation of the OA citation advantage hypothesis, this study also described the percentage of publications that appeared in OA journals and how this changed from 2005 to 2014. The percentage of publications that appeared in OA journals is reported for all OA journal publications (irrespective of subject area) for the years investigated (i.e. 2005–2014), as well as for each individual subject area. These percentages were compared to results of previous studies (such as Archambault, Amyot, Deschamps *et al.*, 2014 and Dorta-González *et al.*, 2017; Torres-Salinas *et al.*, 2016) estimating the presence of OA journal publications.

Three different aspects of citation advantage were examined:

1. Do OA journal articles attain a higher MNCS than non-OA journal articles?
2. Do a higher percentage of OA journal articles than non-OA journal articles receive at least one citation within two years after publication?
3. Is there a higher percentage of OA journal articles than non-OA journal articles among the most frequently cited 1%, 5%, and 10% of articles?

4.2. Research strategy and design

This investigation into the link between access and the act of citation followed a quantitative strategy. Such a strategy was considered appropriate, because it aimed to test an existing hypothesis about the relationship between access status and citation behaviour on a large scale, across multiple subject areas, by using new quantitative data, namely the gold OA tag in WoS. This study is situated in the fields of bibliometrics (because statistical methods were applied to forms of communication) and scientometrics (since quantitative methods were applied to investigate an aspect of science) (Pritchard, 1969: 348; Zhoa & Strotman, 2015: 18). The study involved the secondary analysis of existing data derived from a multidisciplinary citation index. No primary data were collected as data were extracted from the WoS microdata for processing and analysis.

This study can be best described as a comparative citation analysis study (Porter, 1977: 265; Sotudeh & Estakhr, 2018: 563), as publications of different access types (i.e. articles published in OA journals vs non-OA journals) were compared in terms of various measures of citation advantage. The main research questions implied a causal relationship, i.e. the presence of an article in an OA journal leads to it experiencing a citation (dis)advantage. Description (of both a cross-sectional and longitudinal nature) was involved when determining the percentage of OA journal publications and how this changed from 2005 to 2014.

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4.2.1. Defining the population

This study took the form of a census, i.e. data for all units comprising the population were collected (Harding, 2006: 26–27). This section defines the characteristics of that population by specifying and justifying the source of data, as well as decisions regarding the time frame, document types, language considerations and subject areas. Since this study compared (OA journal and non-OA journal) articles with each other, the unit of analysis was the articles as social artefacts (Babbie & Mouton, 2008a: 85).

4.2.1.1. Citation index

Citation indexes are searchable, bibliographical indexes, which provide an index of citation links from and to publications – a notion first proposed by Eugene Garfield (1955: 108) – in addition to the standard bibliographical data on research publications (such as keywords, author affiliations and journal title). While initially intended to assist with information retrieval, citation indexes also allow researchers to identify potentially related publications. This is done by examining other publications referenced in a publication that the researcher cites, as the references indicate a level of relatedness to the cited publication in either topic or method (Sugimoto & Larivière, 2018: 22–23Z; Zhoa & Strotman, 2015: 4). Due to citations indicating relatedness, citation indexes have been used to map research fields, follow the development of ideas across publications, assist with literature reviews and analyse citation networks. These indexes have also been applied for large-scale citation analysis (Zhoa & Strotman, 2015: 8–9). Multidisciplinary citation indexes allow for such analysis to extend across disciplines. The three most prominent multidisciplinary citation indexes are WoS, Elsevier's Scopus, and Google Scholar (Waltman, 2016). By comparing WoS to the other two indexes, the decision to select WoS as the source of data for this study is explicated below.

WoS comprises various indexes, seven of which form part of the Web of Science Core Collection. Two are book citation indexes, another two index conference proceedings. The remaining three, index journal publications, namely the Science Citation Index (8 859 titles[13]), the Social Sciences Citation Index (3 242 titles) and the Arts and Humanities Citation Index (1 778 titles) (Thomson Reuters, 2017). This core collection indexes over 1 200 OA journals. Journals are included mainly on the basis of their citation impact in the preceding years (Testa, 2018). The number of journals is kept sufficiently low to enable the tracking of article citations. The above two considerations are based on Garfield's Law of Concentration (see Garfield, 1971) derived from Bradford's Law of Scattering, according to which a

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[13] The number of titles included in the indexes changes frequently, the numbers reported here are what was reported on Thomson Reuter's website on the 17th of April 2017.

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relatively small number of journals account for a large majority of the influential research in a field. This set of core journals is identified for inclusion by examining citation patterns (De Bellis, 2009: 51; Garfield, 1971; Guédon, 2008a: 43). Over the years, many studies have made use of WoS to conduct citation analysis, thereby enhancing the understanding of the various characteristics of the index and enabling more robust studies (Waltman, 2016). In 2014, WoS introduced an additional label, which allows filtering on whether an article is published in an OA journal or not, thereby enabling more extensive studies on OA journal publications[14] (Torres-Salinas *et al.*, 2016).

The Scopus abstract and citation index was established by Elsevier in 2004, and indexes a larger number of journals than WoS – more than 21 500 titles (in 2016), and 4 200 OA journals (Elsevier, 2017b). Titles under consideration for inclusion in Scopus undergo an evaluation process conducted by the subject chairs at Elsevier and a team of reviewers. A scoreboard system is consulted, which comprises the following considerations:

- number of citations in Scopus;
- citation profile (in Scopus) of the editors of a journal;
- availability of English-language abstracts;
- quality of homepage;
- regularity of publications;
- type of peer review; and
- diversity in terms of geographical location of authors and editors (Kähler, 2010: 337–340).

Since 2015, the online version of Scopus enables searches specifically for OA journal publications (Beatty, 2015).

Google Scholar indexes a larger range of academic output than either Scopus or WoS, as it includes document types, such as theses and technical reports, in addition to journal publications, books and conference proceedings. Peer review of content is not a requirement for a document to be indexed (Wouters & Costas, 2012). Unlike WoS and Scopus, which indexes the documents that are published in selected journals, the documents indexed by Google Scholar originate from various unspecified online sources. These include academic publishers, professional societies, universities and online repositories. The use of Google Scholar is free, while only paying subscribers have access to Scopus and WoS. However, Google Scholar is mainly aimed at generating individual author metrics and only

[14] Furthermore, in 2018, additional green OA tags were also introduced (Napolitano, 2018), creating opportunities to investigate these as well.

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of those authors who have created a profile on Google Scholar. Journal-level citation analysis is possible, but collecting the data is a laborious process (Björk & Solomon, 2012a: 4; Wouters & Costas, 2012: 20). It is also significantly more complicated to distinguish OA journal publications from others, as a filter for this distinction is not inherent to the index. It is therefore ill-suited for investigating OA journal article-related topics. Although Google Scholar indexes a larger number of documents, it is not as standardised as WoS or Scopus, as its content is subjected to little, if any, quality control, which introduces errors and duplication (Aguillo, 2012: 344; Pendlebury, 2009: 2; Zhoa & Strotman, 2015: 9).

WoS was selected for the current study partly because the characteristics of the index have been well documented during a long history of research using data from the index. Thus, it is possible to acknowledge certain limitations of the index, and even to compensate for them, as well as to build upon the strengths of WoS, as elaborated upon throughout this chapter. One of these strengths that was particularly relevant for this study, is the benchmark of quality of the journals included in WoS. For a journal to be included in WoS, or to have published in such a journal, has become a sign of prestige, as well as a measure of quality by some evaluators (Guédon, 2008a: 44). Thus, making use of WoS as a prominent citation index also allows for a measure of control for prestige as confounding factor when investigating the number of citations articles receive.

While Scopus and WoS differ in the extent to which they index journals from different research fields, studies have shown that the results of the two indexes correlate and using either should therefore be sufficient (Waltman, 2016). Even though there is overlap between the journals indexed by Scopus and WoS (Koler-Povh *et al.*, 2014), WoS was also selected because the author had access to the microdata files of the WoS indexes through a licence agreement between CREST and Clarivate Analytics (Waltman 2016; Zhoa & Strotman, 2015: 20). Such access allows for more extensive citation analysis than is possible with the online version of WoS.

4.2.1.2. Time frame

This study examined the hypothesis of OA citation advantage by investigating articles published in selected years, i.e. 2005–2014. The publication years investigated for this study were determined by the chosen citation window and the relatively short history of OA journal publishing. A two-year citation window, i.e. citation data comprising citations received in the year of publication and the following two years, was applied in this study. As the data were collected in 2017, citation data up until the end of 2016 were available at the time. Using a two-year citation window implied that only publications with a publication date up until 2014 could be investigated.

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While journals with publishing policies conforming to the definition of OA have been in existence since as far back as 1995 (Laakso *et al.*, 2011), the term 'open access' was only coined in the 2001 BOAI declaration (Chan *et al.*, 2002; Cullen & Chawner, 2011). This means 2002 was the first complete year that the term existed, and 2002 is therefore a reasonable starting point for a study on OA citation advantage. However, 2005 was selected as the first year for this study, thereby representing ten years of OA journal publishing. In addition, this corresponds to the years covered by one of the comparator studies, thereby allowing for comparison of results (Torres-Salinas *et al.*, 2016).

4.2.1.3. Document types

Documents indexed in WoS are classified into 38 different document types (Harzing, 2013; Thomson Reuters, 2015). Only some of these e.g. articles, letters and reviews, are published in academic journals. As discussed in the previous chapter, document types tend to differ in terms of the numbers of citations they receive, i.e. reviews are cited more often than articles, and articles tend to be cited more often than letters. However, the distinction between reviews and articles is not clear in the WoS classification of document types, partly because the WoS definitions of document types are not mutually exclusive. WoS defines (Thomson Reuters, 2015: n.p.) articles as "reports of research on original works", which "include research papers, features, brief communications, case reports, technical notes, chronology, and full papers that were published in a journal and/or presented at a symposium or conference". A review is "a renewed study of material previously studied". The category includes "review articles and surveys of previously published literature", which "[u]sually will not present any new information on a subject" (Thomson Reuters, 2015: n.p.). The WoS definition of a review potentially overlaps with that of an article due to the flexible terminology (i.e. 'usually') and the subjective interpretation of the term 'new information'. Systematic reviews and meta-analyses do not, for example, fit well in the review category, and share qualities with the article category, as they present new information on a subject through the examination of previously published work (Bryman, 2012a: 102–103).

In addition to the ambiguous definition of these document types, studies report that WoS systematically misclassifies research documents, especially in the social sciences (Donner, 2017; Harzing, 2013). Two examples of document types that have been misclassified are the categories 'conference proceedings' and 'review documents'. While the WoS definition of articles allows for the inclusion of research articles derived from work presented at conferences and workshops, articles that acknowledge this activity are often classified as conference proceedings, even when published in an academic journal (Harzing, 2013). This is partially rectified by WoS simultaneously categorising such articles as proceedings and articles. Another example of misclassification in WoS is that articles with

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more than 100 references, and/or with the words 'review' or 'overview' in the title, are included only in the review category (Garfield, 1994; Harzing, 2013). The distinction in the WoS index between reviews and articles is thus to some degree arbitrary, and was therefore not implemented in this study, which examined both reviews and articles as research publications, collectively referred to in this dissertation as 'articles'.

Various studies have similarly grouped multiple document types together for the purpose of conducting citation analysis, e.g. articles, letters, notes and reviews (Glänzel & Moed, 2002; Van Leeuwen, Moed, Tijssen, Visser & Van Raan, 2001), articles, letters and reviews (Van Leeuwen *et al.*, 2015), and research articles together with reviews (Davis *et al.*, 2008).

4.2.1.4. Language

The language in which an article is written has been shown to have an effect on the number of citations it receives. Specifically, articles published in English tend to receive more citations than non-English-language articles (Tahamtan *et al.*, 2016; Van Leeuwen *et al.*, 2001). Consequently, non-English articles are often removed from citation studies, in order to control for this language effect (Kousha & Thelwall, 2007; Moed *et al.*, 2004; Waltman & Van Eck, 2013).

OA journals are thought to include a high percentage of non-English titles, as many journals that serve local scholarly societies have turned to an OA distribution model due to libraries unsubscribing to their content (Björk, 2011; Solomon *et al.*, 2013). Thus, citation analysis of OA journal research articles would potentially be disproportionally affected by the inclusion (or exclusion) of non-English-language articles if they were to be compared to non-OA journal articles, as the results could be, at least partially, an artefact of language. While non-English articles were included by many previous studies that investigated OA journals and the number of citations that articles in these receive in comparison to non-OA journal articles, (Archambault, Amyot, Deschamps *et al.*, 2014; Lansingh & Carter, 2009; Sabharwal, Patel & Johal, 2014; Van Leeuwen *et al.*, 2015; Yuan & Hua, 2011), some of these do not acknowledge that language is an important factor to consider (Torres-Salinas *et al.*, 2016). A selected few studies limited their sample to English-language documents only (Asemi, 2010; Koler-Povh *et al.*, 2014; Sotudeh & Horri, 2009). The argument for including English-language articles only is precisely due to the relationship between the number of citations and language, and the assumption that OA journal articles would be over-represented in the non-English articles group.

However, in the current study, limiting the documents examined to English-language articles only proved problematic. Only a few articles published during the time of the investigation were classified

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in terms of language in the WoS microdata. A preliminary investigation conducted by the author in 2017 showed that, in the majority of subject areas (253 out of 274), language data were available for less than half of the articles published in the years 2005 to 2014. In the case of those articles for which language data were available, more than 97% of the articles in most subject areas are written in English. For more recent articles, e.g. from 2015 (beyond the scope of this study), the availability of language data improved considerably. Excluding from this study all articles which did not have English listed as the language of publication would have meant the exclusion of a significant number of articles that had no language data available, but may have been written in English.

While it is acknowledged that the language in which an article is written has an effect on the number of citations it receives and that OA journal articles are potentially more often published in languages other than English, this is unlikely to be the case for WoS OA journal articles. This is because WoS mainly indexes English-language, internationally focused journals (Van Leeuwen *et al.*, 2015), which drastically reduces the likelihood of inclusion of articles published in languages other than English. It was therefore decided that, for this study, all articles published from 2005 to 2014 would form part of the articles examined, regardless of the language in which they were written.

A sensitivity analysis was conducted to determine whether language may have a confounding effect on the relationship between access status and citation advantage. This was done by investigating the relationship between access status and the MNCS for a dataset similar to the one used for the rest of the study, with the exception that it only included those articles for which the language data is known, and which are published in English. Due to the lack of data for articles in the majority of subject areas, the sensitivity analysis was only conducted for WoS as a whole and not for the subject areas individually.

4.2.1.5. Subject areas

WoS uses a subject categorisation system consisting of more than 250 subject areas, and each indexed journal is categorised into one or more of these subject areas (Thomson Reuters, 2010). All articles ‘inherit’ the classification of the journal in which they are published, although some articles that are published in journals with the categories ‘Multidisciplinary Sciences’ and ‘Medicine, General and Internal’ are classified individually (Thomson Reuters, 2018: 7). Articles are thus often assigned multiple subject area labels. The dataset includes all articles and reviews indexed in WoS for the years 2005 to 2014, and thus all subject areas associated with those articles. The extent to which OA journal articles were present in the various subject areas could be determined in this manner.

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While the extracted dataset included 275 subject areas, these included nine pairs of apparent duplicates, which contain exactly the same number of articles and have similar labels. One of these duplications was due to a misspelling by WoS of the subject area ‘History of Social Sciences’, which was corrected. The other eight pairs, with the number of articles published in OA journals and non-OA journals, are shown in Table 4.1.

Table 4.1: Duplicated subject areas in the Web of Science dataset (2005–2014)

Subject area pairs		Number of articles	
		Non-OA journal	OA journal
Biodiversity & Conservation	Biodiversity Conservation	35 367	3 040
Biology	Life Sciences & Biomedicine – Other Topics	69 904	17 232
Biomedical Social Sciences	Social Sciences, Biomedical	24 014	818
Film, Radio & Television	Film, Radio, Television	25 195	540
Geography, Physical	Physical Geography	39 242	1 438
Legal Medicine	Medicine, Legal	15 237	0
Mathematical Methods In Social Sciences	Social Sciences, Mathematical Methods	19 576	73
Research & Experimental Medicine	Medicine, Research & Experimental	130 108	26 884

When reporting on these potentially duplicated subject areas in the following chapters, both will be reported, with a footnote reminder of the potential duplication. Another potential, but not exact, duplication was ‘General & Internal Medicine’ as opposed to ‘Medicine, General & Internal’. Both are reported in the results in each case as they contain a different number of articles; 241 155 in the former, and 196 114 in the latter. While all subject areas were analysed and appeared in the addenda, including multidisciplinary subject areas and ‘Multidisciplinary Science’, only selected subject areas are discussed in detail, namely those

- that are also discussed in the literature and comparative studies;
- for which statistically significant results were found;
- for which results with large enough effect sizes were found; and/or
- selected as examples, as motivated in the results chapters.

4.2.2. Data extraction

This section provides details on the data that were extracted from the WoS microdata, as well as concepts fundamental to both datasets, the analysis and the variables. These include operationalising the access status of articles (i.e. how the distinction was drawn between OA journal articles and non-OA journal articles), the importance of using citation windows when conducting any form of citation

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counting, an explanation of how NCSs are calculated, and how the percentile indicator was applied in this study. The data were first extracted in a comma-separated values (CSV) file format, which was then imported into the statistical software SPSS[15] (Version 25), to allow for transformation of some of the variables and for data analysis.

4.2.2.1. Characteristics of the datasets

Two datasets, each consisting of bibliographic records and their citation data, were extracted in September 2017 from the WoS microdata housed at CREST. The first of these contained single entries for each article. Each entry contained the following details on the article:

- WoS accession number (the unique identifier);
- year of publication;
- access status (i.e. OA journal article or non-OA journal article);
- the NCS as calculated by CREST; and
- whether the document was included in the 1%, 5% and 10% most frequently cited articles, on the basis of the NCS.

In SPSS, the variables were renamed, measurement types assigned (i.e. nominal, scale or ordinal), and string variables recoded into numeric ones. One new variable was created from the data extracted in SPSS, namely whether an article was cited or not. This was based on the NCS, as described later in this section.

This dataset allowed for the identification of the total number of OA journal and non-OA journal articles, as well as any changes over time in the frequency and percentage of articles in these categories, and for testing the OA citation advantage hypothesis (according to three definitions thereof). As articles were assigned to multiple subject areas, another dataset was extracted to investigate the aforementioned measures of citation advantage for each subject area.

The data extracted for both datasets were therefore similar, except for the inclusion of the variable 'subject area' in the second dataset. An article (i.e. its WoS accession number) appears as many times in the second dataset as the number of subject areas to which it has been assigned. With the second dataset, the subject areas were each analysed in terms of total number and percentage of OA journal and non-OA journal articles, as well as any changes over time in the frequency and percentage of

[15] SPSS stands for the International Business Machines (IBM) Corporation's Statistical Package for the Social Sciences (see Landau & Everitt, 2004).

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articles in these categories, and to test, for each subject area, the hypothesis of OA citation advantage (according to three definitions thereof) for OA journal articles. The data extracted are summarised in Table 4.2.

Table 4.2: Web of Science microdata extracted for each article

Variable	Level of measurement
WoS accession number	Nominal
Publication year	Ordinal
Access status of the journal (OA/non-OA)	Nominal
Normalised citation score	Scale
Subject area[16]	Nominal
Whether an article was cited	Nominal
Whether article is among the 1% most frequently cited	Nominal
Whether article is among the 5% most frequently cited	Nominal
Whether article is among the 10% most frequently cited	Nominal

4.2.2.2. Access status

An article may be rendered OA in various ways. It is important to be clear on the types of access that are compared when conducting citation analysis with the aim of testing the hypothesis of OA citation advantage (in this case, specifically a gold OA citation advantage). Various factors could affect the number of citations an article receives, which is only applicable for articles rendered OA through specific methods, as discussed in Chapter 3. For example, a self-archived version of an article is uploaded before its final version is published; therefore, it has more time to be viewed and cited, compared to an article for which the final version published by a journal is the only version available. In other words, self-archived versions potentially benefit from an “early view” effect (Davis & Fromerth, 2007: 204). This is also why citation windows are important.

The access status of an article is determined by the access policy of the journal. In this study, an OA journal article was defined as one published in a journal that provides OA to all articles it includes (i.e. gold OA). Non-OA journal articles are those published in journals that are not OA journals. These are journals that have a delay OA policy[17], journals in which articles are only accessible with a subscription, as well as those journals that include individual articles that are accessible without a subscription. The latter articles are often referred to as ‘hybrid OA articles’, and while it is a controversial policy

[16] Variable only present in second dataset, as explained in sub-section 4.2.2.1.

[17] Delay open access is defined in sub-section 2.2.3.

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implemented by journal publishers, previous studies have found that only a few articles in the journals that follow a hybrid OA policy have been rendered OA through this option (Sotudeh & Estakhr, 2018: 569). At the time of data extraction there was no method to identify the OA articles systematically in otherwise subscription journals in a large-scale study such as this one. Consequently, there was no option but to group them together with non-OA journal articles.

Hybrid OA articles were deemed to have little effect on the reliability of the classification system of this study, as hybrid OA articles constitute a small percentage of the total number of articles published (Dallmeier-Tiessen *et al.*, 2010: 2; Suber, 2012: 141). Estimates in 2009 were that they constitute only 2% of all the articles published in journals that had a hybrid OA policy (McKerlich *et al.*, 2012: 1498). Sotudeh and Estakhr (2018) estimated, by examining a limited number of Elsevier journals, that the hybrid OA articles published from 2012 to 2015, constituted 2.2% of articles in the natural sciences, 6.2% in the life sciences, 7.1% in the health sciences, and 11.9% in the social sciences and humanities. A preliminary investigation for this study, conducted in 2017, of the access status of all the articles in the WoS subject area category 'Virology' for the years 2005 to 2011, found that only 1.1% of all the articles were hybrid OA articles, while for the OA journal articles, it was 11.2%. This preliminary study also confirmed the difficulty of identifying hybrid OA articles, as many journals that follow such a policy (at least in 'Virology') also follow a delay OA policy. This rendered 15.3% of all the articles in 'Virology' OA through a delay policy, some of which could have been OA before the embargo period due to hybrid OA options also available in those journals.

In 2014, WoS introduced a functionality that allowed users of their web interface to filter searches according to inclusion or exclusion of OA journal documents (Thomson Reuters, 2014; Torres-Salinas *et al.*, 2016). However, the WoS microdata, which were used this study, indicate only whether an article is published in an OA journal; no indication is given if an article is not published in an OA journal. This study was therefore based on the assumption that any article not classified as an OA journal article, was published in a non-OA journal. As this is one of the first studies using the label, no indication of its reliability was yet available. This is discussed in more detail later in this chapter.

4.2.2.3. Citation counting

The citation data extracted from the WoS microdata were derived from the number of documents indexed in the WoS Core Collection that reference a cited document (Sugimoto & Larivière, 2018: 81). While only reviews and articles were examined as cited documents in this study, citing documents of any type were counted. However, author self-citations and citations that fell outside of the citation window selected for this study, were excluded.

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Self-citations are often removed in citation analysis, as these citations are not deemed part of a valid measure of scientific impact of the research on the wider scientific community, and are believed to increase the number of citations to a publication artificially (Aksnes, 2003; Wang, 2013: 854). On the other hand, studies have shown that removing self-citations has little effect on the results of citation analyses on highly aggregated levels (e.g. countries), in terms of both the degree to which self-citations occur and the relationship that exists between the number of self-citations and other citations (Aksnes, 2003; Glänzel & Thijs, 2004). Nevertheless, the datasets extracted from the WoS microdata excluded self-citations, because the issue of visibility to individuals beyond the authors of the document lies at the core of the OA citation advantage hypothesis. Simply stated, authors can read and cite their own articles irrespective of whether they were published in an OA journal or a non-OA journal; hence the removal of their self-citations.

'Author self-citation' refers to citations from citing documents that share any authors with those of the cited document, but only if the author names have been recorded in precisely the same manner, e.g. H. Prozesky and H.E. Prozesky would be treated as two different authors. On the other hand, WoS does not distinguish between different authors with identically spelled names (Glänzel & Thijs, 2004; MacRoberts & MacRoberts, 1989). Author disambiguation is a significant challenge for citation indexes. However, services like ORCID are attempting to reduce its occurrence by allowing researchers to register and use their ORCID ID to identify themselves uniquely in published articles (Fenner & Haak, 2014: 293–296). Conducting additional author disambiguation was neither viable nor deemed necessary for the purposes of this study, due to high level of aggregation in this study.

4.2.2.4. Citation windows

It is standard practice in citation analysis to use fixed citation windows in order for a fair comparison to be drawn between documents published in different years (Craig *et al.*, 2007). If the lifetime number of citations (i.e. variable citation windows) is investigated, articles published earlier (e.g. in 2000) have had more time during which they could have been cited than those published more recently (e.g. in 2011). At the time of data extraction, the 'older' articles would be more likely than the 'younger' articles to have received citations, thereby placing the latter at a disadvantage. If a fixed citation window is applied, similar lengths of time are compared, e.g. the first two years after publication, which is the same for articles published in 2000 and 2011. A fixed citation window of two years was selected for this study.

Such a short citation window could fail to capture the citations of articles in certain subject areas due to slower citation ageing (Wang, 2013) in those subject areas. Citation ageing refers to the time it

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takes an article to achieve citation maturity (i.e. receiving the highest number of citations per year) and citation decline (i.e. how long this peak is maintained). The risk posed by using a short citation window to the validity of the results of this study was deemed minimal, as one may reasonably assume that citation ageing would be similar for OA journal articles and non-OA journal articles in a subject area. To empirically determine whether the effect of citation ageing differs between OA journal articles and non-OA articles in subject areas was outside the scope of this study. Examining this requires much longer citation windows, i.e. of a minimum of five years (Costas, Van Leeuwen & Van Raan, 2010), which at the time of this study was not possible, due to the short history of OA publishing.

Selection of a citation window depends on several factors, and no single citation window is appropriate for all types of studies. It requires striking a balance between timeliness of the results and the validity of the measurement. Selecting a too short citation window would complicate the citation analysis of subject areas in which it takes long for publications to be cited. Examples of such subject areas are the Social Sciences and Mathematics, especially in comparison to the biomedical fields (Wang, 2013). One consequence is that many articles in these subject areas would be classified as uncited, or a large percentage would form part of the 1% most frequently cited articles due to many articles having the same NCS. A citation window that corresponds with the year of publication, also referred to as the immediacy index (McVeigh, 2004; Pendlebury, 2009: 2), is particularly problematic, as articles published at the start of a year are compared to those published at the end of the same year (Waltman, 2016). An additional consideration is that short citation windows favour articles that receive citations soon after publication, which is not necessarily an accurate indicator of the number of citations they receive in following years (Costas *et al.*, 2010). When a short citation window is applied in the measurement of most frequently cited articles, the results discriminate against those articles that experience a delay in accumulating citations (Wang, 2013: 852). On the other hand, selecting a too long citation window generates results that are obsolete (Moed *et al.*, 2004). A careful balance needs to be struck, keeping in mind the goal of the study and the data available.

While the appropriate citation window for a single subject area can be calculated (Wang, 2013), this study investigated a large range of subject areas. Citation windows typically range from one year to five years (Aksnes, 2003; Biscaro & Giupponi, 2014; Ruiz-Castillo & Waltman, 2015; Van Leeuwen *et al.*, 2001). A two-year citation window has an advantage over longer citation windows in that it reduces the effect that delayed OA or self-archiving embargoes may have on the results of the citation analysis, as these tend to apply only after two years. Furthermore, considering the relatively short history and recency of developments in OA publishing, a two-year citation window allows for an investigation of the most current articles, as well as an investigation of articles over a sufficient

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number of years. While a two-year period is considered a too short citation window for the Social Sciences and Humanities, as well as for Mathematics, for which a seven-year citation window is more appropriate (Wang, 2013), it is considered sufficient for the Natural Sciences and Engineering (Archambault & Gagné, 2004). This limitation will be important when the results are presented and interpreted as findings.

4.2.2.5. Normalised citation scores

Investigating the mean number of citations an article receives has formed the basis of most previous studies on OA citation advantage. However, using simply the arithmetic mean number of citations that articles in a subject area receive, renders the results incompatible between subject areas, as subject areas themselves differ significantly in terms of the mean number of citations articles in them tend to receive (Pendlebury, 2009: 2–3). The mean also differs from one year to the next. To allow some comparison between subject areas and years, normalisation is required (Leydesdorff & Opthof, 2011; Moed, De Bruin & Van Leeuwen, 1995; Schubert & Braun, 1996). Methods detailing how previous studies have overcome this issue include:

- comparing OA articles with non-OA articles in terms of "the proportion of the average citation of OA articles in relation to non-OA articles" (Dorta-González *et al.*, 2017: 880);
- "adjusted relative citation impact" (ARCI) (Sotudeh & Horri, 2008: 76); and
- the MNCS, as applied by CWTS (Van Leeuwen *et al.*, 2015).

For this study, the MNCS was selected as the preferred method of citation normalisation, as it controls for both the differences between years and between subject areas, and it is a well-established method of normalisation in citation analysis (Mingers & Leydesdorff, 2015: 18).

4.2.2.6. Measures of citation advantage

As described in the research questions, three measures of citation advantage were investigated in this study. The sub-sections below describe how these were defined and calculated.

4.2.2.6.1. Mean normalised citation score

The first measure of citation advantage used the MNCS (Waltman *et al.*, 2011). To calculate the MNCS, the NCS of each article is required and for this, one first needs to calculate the expected number of citations (e) for articles per subject area (i) published in a specific year, i.e. (e_i). This is done as follows:

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$$e_i = \frac{\sum_{j=1}^{Ni} \frac{c_j}{f_j}}{\sum_{j=1}^{Ni} \frac{1}{f_j}}$$

Here one sums over all the articles in the subject area (j runs from 1 to the number of articles in subject area [N_i]) and c_j is the number of citations article j received during the citation window. Lastly, f_j is the number of subject areas assigned to article j, thus the total number of citations to an article is distributed evenly to all subject areas associated with that article. Once e_i is calculated, the NCS of article k, i.e. (ncs_k) can be calculated, as follows:

$$NCS_k = \frac{c_k}{f_k} \sum_{i=1}^{f_k} \frac{1}{e_i}$$

Once one is able to calculate the NCS of all the articles in the dataset, their mean can be calculated, as follows:

$$MNCS = \frac{1}{n} \sum_{j=1}^{n} ncs_k$$

In the above formula n refers to the number of publications. This allows for the comparison of OA journal articles with non-OA journal articles based on their MNCS. For this study, the MNCS was calculated for the OA journal articles and non-OA journal articles respectively across all the subject areas, and for each subject area separately. The MNCS of OA journal articles and non-OA journal articles for individual years as well as across all the years, was calculated. The way in which the NCS and MNCS were calculated meant that they were comparable across subject areas and years, while taking into account that articles can be assigned to multiple subject areas.

4.2.2.6.2. Cited and uncited articles

The second measure of citation advantage refers to whether articles were cited within the first two years after publication. In this study, an 'uncited article' refers to an article that received no citations (excluding self-citations) during the first two years after publication. This variable was not directly extracted from the WoS microdata; instead, it was recoded into a new variable once the data had been imported into SPSS. In the reporting of the results, the focus is on the positive interpretation, e.g. the percentage of articles cited, and not on the percentage of articles that remained uncited, as the status of having been cited is considered an indicator of citation advantage.

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4.2.2.6.3. Percentile-based indicators: percentage of frequently cited articles

The third indicator of citation advantage that was investigated in this study is the percentage of articles among non-OA journal articles and OA journal articles that, on the basis of the NCS, belong to the 1%, 5% and 10% most frequently cited articles in their subject area. Investigating the most frequently cited articles is a commonly applied percentile-based indicator (Waltman & Schreiber, 2013: 372). Due to the complications caused by multiple articles potentially having the same number of citations, various methods have been proposed in the literature for calculating these percentiles. The method chosen for this study was the one applied in the SCImago Institutions Rankings (Waltman & Schreiber, 2013: 374). According to their method, all articles that have the appropriate number of citations to qualify for the 1% most frequently cited articles are included under the label '1% most cited'. Likewise, for 5% and 10%. This generally results in the inclusion of a higher percentage of articles in the x% most frequently cited articles (e.g. more than 1% of articles are included within the 1% most frequently cited articles), but avoids reintroducing the problems associated with a skewed distribution from which other calculations suffer. The NCS forms part of the calculation of the percentiles per subject area and for the dataset as a whole.

4.2.3. Analysis methods and techniques

To answer the research questions, both descriptive statistics and inferential statistics were required: the former to provide a comparative description of the population of OA journal articles and non-OA journal articles, and the latter to test the relationship between access status and the various measures of citation advantage. The descriptive statistics allowed for a comparison to be drawn between the percentage of OA journal articles and non-OA journal articles indexed in WoS. This comparison was conducted for the dataset as a whole as well as for the individual subject areas. The descriptive statistics also describe changes over time in the percentage of OA journal articles indexed, again for the population as a whole, and for the subject areas separately.

To assess whether OA journal articles experienced a citation advantage, the relationships between access status and each of the three measures of citation advantage was tested by comparing OA journal articles and non-OA journal articles in terms of the following: MNCS, percentage of cited articles, and percentage of articles among the 1%, 5%, and 10% most frequently cited articles. A combination of two broad categories of statistical tests was consulted, i.e. tests of statistical significance and tests to determine effect size. The following sub-sections provide the rationale for performing the tests, as well as details on the specific techniques that were applied. The analysis involved various combinations of dichotomous and continuous variables, and the sub-sections 4.2.3.3

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and 4.2.3.4 were organised according to the combination of variables analysed, because the same tests of statistical significance and effect sizes were applied for similar combinations of variables types. All these tests were conducted using SPSS.

4.2.3.1. *Descriptive statistics*

The results of the descriptive analysis of the percentage of OA journal articles are presented in the form of frequency tables and scatterplots, both for the population as a whole, cross-sectionally and longitudinally, and for the subject areas separately. The analysis by subject area allowed for the identification of those subject areas without any OA journal articles indexed in WoS, and for which the OA citation advantage hypothesis could therefore not be investigated. It also allowed for the identification of those subject areas which did not have OA journal articles for each of the years investigated, indicating subject areas which did not have established OA journals, a characteristic which in itself could affect the number of citations OA journal articles receive in those subject areas. Lastly, this analysis also allowed for the identification of those subject areas for which OA journal articles were prevalent in WoS, and whether this corresponded with those that experienced an OA citation advantage. These results were compared to those of previous studies that investigated the presence of OA journal articles.

Scatterplot graphs, with linear trendlines, were drawn to illustrate change over the years in the percentage of OA journal articles. The slope of the linear trendline provides an indication of change across years, i.e. a linear trendline of $y = 1.13x + 1.87$ shows an approximate year-on-year rate of increase of 1.13 (i.e. $m = 1.13$). The R^2 value of the linear trendline provided an indication of how well the linear fit described the line, with a value of 1 indicating a perfect fit. A value higher than 0.8 was considered a particularly good fit. When the standard deviation is calculated it is calculated with the formula that assumes the data represents the entire population, as follows:

$$\sqrt{\frac{\sum(x-\bar{x})^2}{n}}$$

4.2.3.2. Statistical significance and effect size

The aim of conducting tests of statistical significance is to establish whether it can be stated, with some measure of certainty, that the differences observed in a sample are also present in the population, rather than due to sampling error, i.e. that the findings can be generalised to the population based on the sample (Bryman, 2012b: 347). The question that arises is whether such tests are relevant or applicable to data on a whole population. Arguments both for and against the use of

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statistical significance tests on such census data are found in the literature. On the one hand, it is argued that, in the case of census data, sampling error is impossible, and that any difference observed in the sample is also true for the population, as they are one and the same, i.e. the sample statistics are the population parameters (Babbie & Mouton, 2008b: 173). The counter-argument is that a population can at any given time vary from one moment to the next, as its composition at a particular moment is the result of a complex process of generating a population (Figueiredo Filho *et al.*, 2013). This is especially the case when referring to a population of people, the membership of which may constantly change. This reasoning was also applied to this study, because journals can be excluded or included at any given time. These changes in the composition of the index change the parameters of the population, i.e. all articles indexed in WoS that were published in the years 2005 to 2014. In this case, tests of statistical significance are applied to determine whether the observed results could be considered the population parameters or whether they potentially occurred by chance. Due to the frequent changes in the journals indexed in WoS, the *p*-value was therefore calculated in this study, with a statistically significant result referring to a *p*-value smaller than 0.05. In other words, if a statistical significance test resulted in a value less than 0.05, the null hypothesis was rejected, and it could be concluded that there was a difference between the values for OA journal articles and non-OA journal articles. In this study, due to the large sample size, the test for statistical significance was mainly applied to determine whether there were too few data points for any association to be validly observed.

While tests of statistical significance provide an indication of whether two groups differ, such tests seldom provide any indication of the size of this difference and cannot inform us as to the degree of the variability of the results may be attributed to the access status of an article. For this purpose, various measures of effect size may be applied. Another reason why they were applied is that tests of statistical significance are highly sensitive to sample size: the larger the sample, the more likely one is to find a statistically significant result (Durlak, 2009; Figueiredo Filho *et al.*, 2013). Thus, it is possible to generate results that are statistically significant, but with an insignificant effect size, which means there is a difference, but a negligibly small one. This issue is relevant to the current study, as the population comprised a significantly large number of units.

Guidelines exist for determining whether an effect size is large or small; however, these are not necessarily applicable beyond the discipline (behavioural sciences) in which they were originally formulated (Cohen, 1988; Durlak, 2009: 925; Ialongo, 2016). The recommended practice is to determine which magnitude of effect size is considered meaningful by comparing results of prior research in the field. Without much previous research on the topic of the OA citation advantage that

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reported effect size, this study reported any effect size that could at least be considered small (according to Cohen's guidelines [see Cohen, 1988]), as it is known that many factors influence citation behaviour. The following two sub-sections describe the specific tests of statistical significance and the measure of effect size that were applied in this study.

4.2.3.3. Techniques for testing dichotomous-by-dichotomous relationships

As described earlier, the following variables are all dichotomous: access status, whether an article was cited, as well as the three percentile indicators (i.e. whether an article is among the most frequently cited 1%, 5% and 10% of articles). Thus, the same tests of statistical significance and calculations of effect size were applied for testing whether there was a relationship between access status of an article and these three variables.

When testing the relationship between two dichotomous variables, one of two tests of association may be applied, i.e. the chi-square test of independence (see Bryman, 2012b) and the Fischer's exact test (Howell, 2008: 473), both of which are non-parametric tests. The simpler chi-square test of independence is generally preferred, except when dealing with a small sample size, for which the Fischer's exact test is more appropriate (Laerd Statistics, 2016a). In this study, the chi-square test of independence was applied except for some subject areas that had too few cases for the chi-square test of independence (i.e. if any cell in the cross-tabulation had an expected count of less than five[18], as highlighted by SPSS when the chi-square test of independence is performed). In these cases, the results of the Fischer's exact test were consulted. To determine whether the results were statistically significant, the *p*-value of the chi-square of independence and the Fischer's exact tests were examined, as reported by SPSS as part of the results when calculating these.

SPSS provides two measures of effect size for nominal-by-nominal associations, i.e. the phi-coefficient (ϕ) and Cramer's V. However, for a dichotomous-by-dichotomous association (a specific case of a nominal-by-nominal association) these values are identical, with only the sign potentially differing, in which case ϕ is usually reported; thus, ϕ was selected for the current analysis. The calculation of the ϕ is essentially a Pearson's product moment correlation calculated on two dichotomous variables (Laerd Statistics, 2016a). According to Cohen's (1988) criteria, the effect size is considered small at 0.10, medium at 0.30, and large at 0.50. Within the current study any effect size larger than 0.1 as considered sufficient to justify interpretation. Neither of these two tests reliably indicated the

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[18] 'Expected count' here refers to the expected value if the null hypothesis is assumed to hold.

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direction of the association; thus, the difference between percentages was also calculated, in order to determine the direction of the potential relationship.

4.2.3.4. Techniques for testing continuous-by-dichotomous relationships

To determine whether there is a statistically significant association between a dichotomous variable and a continuous variable, two tests may be performed: an independent samples t-test (see Laerd Statistics, 2016b) as a parametric test, and a Mann–Whitney U test (see Pallant, 2016a: 230) as a non-parametric test. Parametric tests are preferable to non-parametric test, but their use is subject to certain assumptions being met by the data. When these assumptions are not met, the non-parametric test may be applied as an alternative. However, due to complications with measuring the effect size when using the Mann–Whitney U test (as elaborated upon below), it was not a viable option for this study, and the results of only the independent samples t-test are reported.

As the independent samples t-test is a parametric test, the data must meet certain criteria, due to the assumptions upon which parametric tests are based. The data investigated in this study did not comply with some of these assumptions. However, due to the robustness of the independent samples t-test, some violations of these assumptions were tolerated under certain conditions. This section discusses three of these assumptions, and the choices made regarding the challenges they posed. First, the independent samples t-test is based on the assumption that the data have no significant outliers (see Laerd Statistics, 2016b). An inspection of the data collected for this study showed, as expected, that significant outliers existed in the dataset, in the form of a few articles with much higher numbers of citations than the majority of other articles. When confronted with such a dataset, four strategies are available in order to conduct a test of statistical significance:

- conduct a non-parametric test in the form of the Mann–Whitney U test;
- modify the outliers so that they are rendered less extreme;
- transform the dependent variable; or
- include the outliers as they are.

To determine the number of outliers, a boxplot of the NCS was generated. Due to the size of the dataset, an unmanageable number of cases were identified as outliers by SPSS, and it was therefore not deemed a viable option to modify the outliers for each individual subject area. Transforming the dependent (i.e. continuous) variable into an ordinal variable was also not viable due to time constraints, as this would have to be done for each of the 274 subject areas separately. Fortunately, the same factor that rendered the options impractical, i.e. the large size of the dataset, reduced the

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effect of the outliers and therefore the threat they might have posed to the reliability of the test results. The outliers and the continuous variable were therefore kept in their original format.

The second assumption is that the dependent variable is approximately normally distributed for each group. If the data violate this assumption, it is still appropriate to conduct an independent samples t-test if both groups are similarly skewed. Side-by-side histograms of the NCS distribution of the two groups (OA journal articles and non-OA journal articles) in the whole dataset and in selected subject areas were generated to inspect the distributions visually. As an example, are the histograms[19] for the subject area 'Parasitology', provided in Figure 4.1 (OA journal articles) and Figure 4.2 (non-OA journal articles) for articles published in 2014.

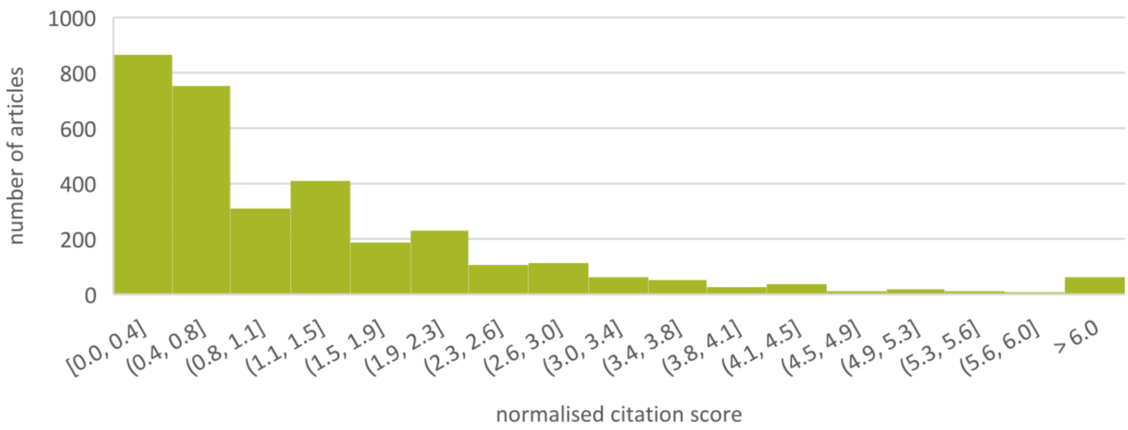

Figure 4.1: Histogram of normalised citation scores for open access journal articles in 'Parasitology', 2014

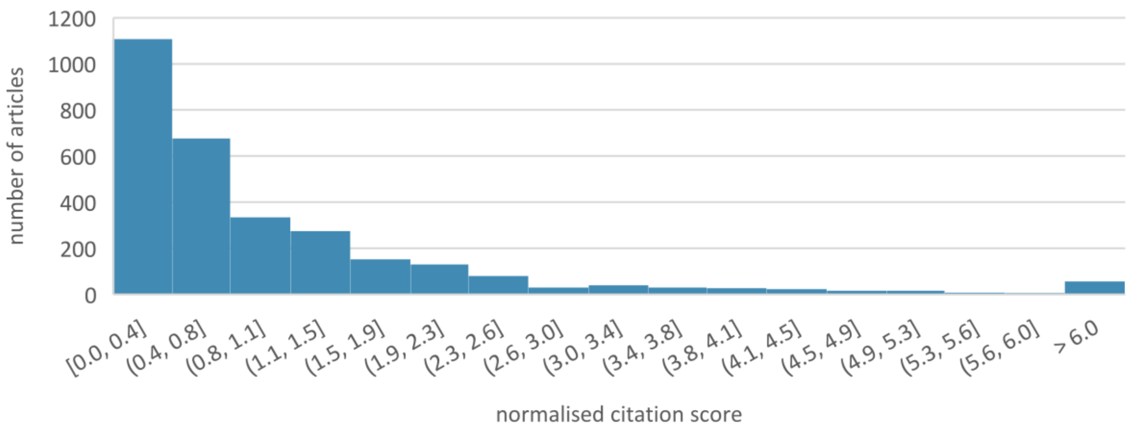

Figure 4.2: Histogram of normalised citation scores for non-open access journal articles in 'Parasitology', 2014

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[19] Categories overlap due to rounding.

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Based on an inspection of the histograms for all the subject areas, it was determined that the distribution of NCS for OA journal articles and non-OA journal articles was similarly skewed. If the groups were not equally skewed, the other recourse would have been to conduct a Mann–Whitney U test. While this test was initially conducted, the results are not reported, for reasons listed later in this section.

The last assumption is that the variance is equal for each of the groupings of the independent variable. This is an important assumption for parametric tests, although the independent samples t-test may be applied even when variance is unequal. When conducting an independent samples t-test in SPSS, a Levene's test for equality of variances (see Pallant, 2016b: 246) is also run, and results are provided for the independent samples t-test, in the case of both equal and unequal variance. For this study, when an analysis was conducted, the Levene's test was consulted to decide which *p*-value, i.e. the one for equal or unequal variance, to report. If the Levene's test for equality of variances itself produced a *p*-value of less than 0.05, the results of unequal variance for the independent samples t-test were consulted and reported. If the *p*-value was 0.05 or higher, the results of equal variance for the independent samples t-test were consulted and reported.

Various methods to measure the effect size for a relationship between a nominal variable and continuous variable are available in SPSS. These include the Pearson's product-moment correlation (see Durlak, 2009), Spearman's rho (if the continuous variable has been transformed) (see Ialongo, 2016) and Kendall's tau-b (as a non-parametric equivalent of the Pearson's product-moment correlation) (see Bolboacă & Jäntschi, 2006). The point-biserial correlation (see Durlak, 2009) was selected as the parametric test, which is mathematically identical to the Pearson's product-moment correlation, with the only difference being that the nominal variable is a dichotomous one. The point-biserial correlation coefficient (r_{pb}) was applied as a measure of effect size, in a similar manner as ϕ, namely any effect size of larger than 0.1 was considered sufficiently large to report. The non-parametric version of this test, a Kendall's tau-b test, could not be performed by SPSS, due to the size of the datasets[20]. As a result, and because it has not often been applied in previous studies of the OA citation advantage, the Mann–Whitney U test was eventually abandoned, as no effect size for it could be calculated in SPSS.

[20] When running the test, it took more than an hour to resolve, without producing any usable results. Bootstrapping (see IBM Corporation, 2013) was not an option in the version of SPSS used in this study.

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4.3. Limitations and sources of error

Some of the sources of error and shortcomings of this study were already addressed in the previous sections, such as the possibility of OA journals and non-OA journals differing in terms of their likelihood to publish reviews, the inability to distinguish between articles and reviews, and how the document type of an article could potentially influence the NCS of OA journal articles and non-OA journal articles. The following sections elaborate upon three further challenges: collecting data retroactively, WoS subject areas as units of analysis, and misclassification in WoS.

4.3.1. Collecting data retroactively

When considering the results of this study, the volatility of the OA journal status of articles, and the challenges this poses for the reliable collection of especially longitudinal data on OA journal articles needs to be taken into account. This volatility arises because the access status of an article seems to be determined by WoS on the basis of the current access policy of the journal in which the article is published, not the access status of the article at the time of publication. OA is a relatively new development in scholarly journal publication, and journals' access policies are in flux. A preliminary, exploratory investigation conducted for this study in 2017 on the gold OA label in WoS, using the 'Virology'[21] subject category as a case, revealed that the OA journal label was assigned retroactively to journals (and to their articles) after they had changed their access status. In other words, an article that was not an OA journal article when it was published in a journal, could be assigned the OA journal label if the journal changes its access status at a later stage. Clarivate Analytics (2018) reports that the access status data for its indexed journals are based on the DOAJ and provided by ImpactStory (see Neylon *et al.*, 2014: 6). However, due to the relatively recent addition of the OA label to WoS data, the accuracy of this classification and the exact way in which it is applied, are yet to be investigated.

This poses a threat to the reliability of results on changes in the percentage of OA journal articles over time, and therefore these need to be interpreted with caution. For example, if an article was published in 2006 in a journal that had until 2010 been a non-OA journal, only those citations it received as a non-OA journal article will be counted. However, if the journal became an OA journal in 2011, WoS would have added the OA journal label retroactively to such an article; thus, it would be classified as an OA journal article, even though the citations counted for the purposes of this study were received

[21] The access status of individual articles and journals associated with 'Virology' indexed in WoS for the years 2005 to 2011 was investigated during the preliminary investigation to gain some understanding of the OA journal tag. 'Virology' was selected due to the relatively few journals (35 in total and 5 OA journals) and articles (±37 863) in the subject area, and an OA citation advantage occurring based on the NCS.

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while it was still a non-OA journal article. The situation is further complicated by the fact that the growth in OA journal articles could be attributed either to newly created OA journals, or to non-OA journals that have changed their funding polices. Thus, an increase in articles published in OA journals does not necessarily reflect a conscious choice by authors to publish in an OA journal. The journals the authors published in regularly could simply have changed their funding policy, e.g. from subscription journal to OA journal. These changes are not reflected in WoS and would require investigating journals and their policies individually, to ascertain whether any such changes occurred. Such investigations, which would be required for each journal for each subject area, were beyond the scope of this study.

4.3.2. Web of Science subject areas as analytical units

Using the WoS subject areas to construct citation normalisation has become an established practice in citation analysis (Leydesdorff & Bornmann, 2016). However, it needs to be recognised that the WoS subject categories were originally created for information retrieval, and that they were not developed on the basis of publication or citation practices. As a result, in some cases, significant within-subject-area publication and citation differences can be observed. Thus, in the current study, articles were not necessarily grouped together in subject areas due to similarities of their citation trends. Compared to broader categorisation systems, e.g. the five broad research areas of WoS[22], the 274 WoS subject areas used in this study potentially reduced the effect of the aforementioned within-subject differences.

Other subject-area categorisation systems or methods that are more sensitive to these within-subject-area differences exist, for example subject areas created on the basis of observed citation clusters, or the more sophisticated subject-classification system of the CWTS (Leydesdorff & Opthof, 2011; Ruiz-Castillo & Waltman, 2015; Waltman & Van Eck, 2015). However, using a subject-area classification system based on citations received would be inappropriate for measuring the percentage of articles in a subject area that remain uncited, as uncited articles would not be classified into a subject area. While CWTS's subject-classification system uses citation clusters to distinguish subject areas, it is not solely based on these. Nevertheless, the CWTS classification system would not have been preferred, as it would have limited the extent to which the findings of this study could be compared to previous studies using the WoS subject area categories.

[22] These five research areas are: Life Sciences and Biomedicine; Physical Sciences; Technology; Arts and Humanities; and Social Sciences (Thomson Reuters, 2012).

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4.3.3. Misclassification and missing data in the Web of Science citation index

Citation indexes are susceptible to technical errors, such as misprints, errors in the formatting of references in the original articles, difficulties in terms of identifying authors uniquely, misattribution of articles to authors, and misspelling of names. This leads to mostly random errors, although some may lead to systematic errors, which could substantially affect the number of citations articles receive, e.g. systematic errors due to the classification system, or data in the index not being of a uniform quality (Bornmann & Daniel, 2008: 47; De Bellis, 2009: 207; Harzing, 2013: 23; MacRoberts & MacRoberts, 1989: 346). The latter was already illustrated in sub-section 4.2.1.4, with reference to the large number of articles that lacked language data. In addition, it was noted during data extraction that several articles had not been assigned to any subject areas, as there were none to 'inherit' from the journal i.e. no subject areas were assigned to the journals. However, these 3 918 articles (3 404 of which were non-OA journal and 514 OA journal) constituted an insubstantial percentage (less than 0.1% in each case) of the two sub-groups in the population. Discovering journals without subject areas was quite unexpected, considering that OA journal status is based on the journals indexed in the DOAJ, which categorises all the journals it indexes into subject areas. However, investigating this further was beyond the scope of this study.

In addition, WoS provides only limited information on the OA status of the journals and articles it indexes. At the time of data retrieval, the web version of WoS only distinguished between gold OA and green OA (Thomson Reuters, 2017). This had implications for the current study, as delayed OA articles as well as hybrid OA articles, could not be separated from non-OA journal articles. Consequently, articles in journals not labelled OA journals by the index could not be deemed articles only accessible by subscription to the journals. This is because, at the time, there were few ways of distinguishing between hybrid OA articles, delay OA articles and subscription only accessible articles beyond checking each individual article. Checking articles individually was not a viable option for this study due to the large number of articles examined. For this reason, the current study compared articles published in OA journals and those published in non-OA journals, but did not compare OA journal articles with subscription journal articles. The benefits associated with analysis a large dataset and the explicit goal of investigating the OA citation advantage through complete OA journals, rendered this an acceptable compromise.

Furthermore, due to the relatively recent introduction of the gold OA label in WoS, there was little information regarding its accuracy, compared to, for example, the extensive literature on faulty document-type attribution. During a preliminary investigation by the researcher in 2017, it became

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clear that, at times, the OA journal label was not assigned to journals known to be OA journals. A prominent case is *PLoS Pathogens*. Although it has been an OA journal since its launch in 2005 (PLoS, 2018), articles that appeared in the journal in 2005 were not labelled OA journal articles in WoS. A more extreme case is the *Southern African Journal of HIV Medicine*, a SciELO SA journal published by AOSIS, a SA-based open access publisher. In 2017, none of the articles published in this OA journal were labelled as OA journal articles. However, when the web version of WoS was revisited in 2018, all the articles in both these journals were labelled as OA journal articles. While the extent of this misclassification is unknown, the 2018 data hint at a process of review of this label by WoS or of the data by DOAJ or ImpactStory.

This concludes the discussion of the study's methodology and limitations. The following two chapters present the results of the analysis of the hypothesis of a general OA citation advantage (Chapter 5) and in WoS subject areas separately (Chapter 6).

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CHAPTER 5: Results on open access citation advantage for articles indexed in the Web of Science

5.1. Introduction

The first part of this chapter provides some context for the analysis of the OA citation advantage by reporting on descriptive statistics regarding the presence of OA and non-OA journal articles indexed in WoS for the years 2005–2014, and changes in their distribution over these years. When applicable, results are compared to those reported by similar studies. The second part presents the results in terms of the association between access status and three measures of citation advantage, to investigate the hypothesis of a general OA citation advantage. To examine this, all articles[23] indexed in WoS for the publication years 2005 to 2014 were analysed. The chapter concludes with a reflection on the complications that arose when examining the OA citation advantage for OA journal articles across all articles; an interpretation of the differences observed between the results and those of comparative studies, as well as a critical discussion of the use of the WoS data to examine OA journal article trends retroactively.

5.2. Distribution of open access journal articles (2005–2014)

WoS indexes 12 396 377 articles in total for the publication years 2005 to 2014, as shown in Table 5.1. The number of articles published increased by 60.0%, from 948 779 articles in 2005, to 1 518 031 in 2014. A linear increase in the number of articles is observed for the total number of articles (R^2 = 0.997), the number of non-OA journal articles (R^2 = 0.993), and the number of OA journal articles (R = 0.988), as shown in Figure 5.1. In 2014, the number of OA journal articles was approximately six times higher than in 2005, while the number of non-OA journal articles increased by a factor of only 1.5 over the period. Thus, the number of OA journal articles has shown a considerably greater increase than the number of non-OA journal articles.

[23] 'Articles' here refers to both the 'research article' and 'review article' document types in WoS, as explained in the methodology chapter (see sub-section 4.2.1.3).

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Table 5.1: Number of articles, by access type (2005–2014)

Publication year	Non-OA journal articles		OA journal articles		Total number of articles
	n	%	n	%	
2005	917 132	96.7	31 647	3.3	948 779
2006	970 127	96.2	38 423	3.8	1 008 550
2007	1 030 779	94.9	54 843	5.1	1 085 622
2008	1 086 462	93.4	76 397	6.6	1 162 859
2009	1 121 947	92.5	90 771	7.5	1 212 718
2010	1 146 088	91.4	107 306	8.6	1 253 394
2011	1 200 892	90.1	131 415	9.9	1 332 307
2012	1 248 495	89.2	150 724	10.8	1 399 219
2013	1 294 486	87.8	180 412	12.2	1 474 898
2014	1 319 796	86.9	198 235	13.1	1 518 031
Total	**11 336 204**	**91.4**	**1 060 173**	**8.6**	**12 396 377**

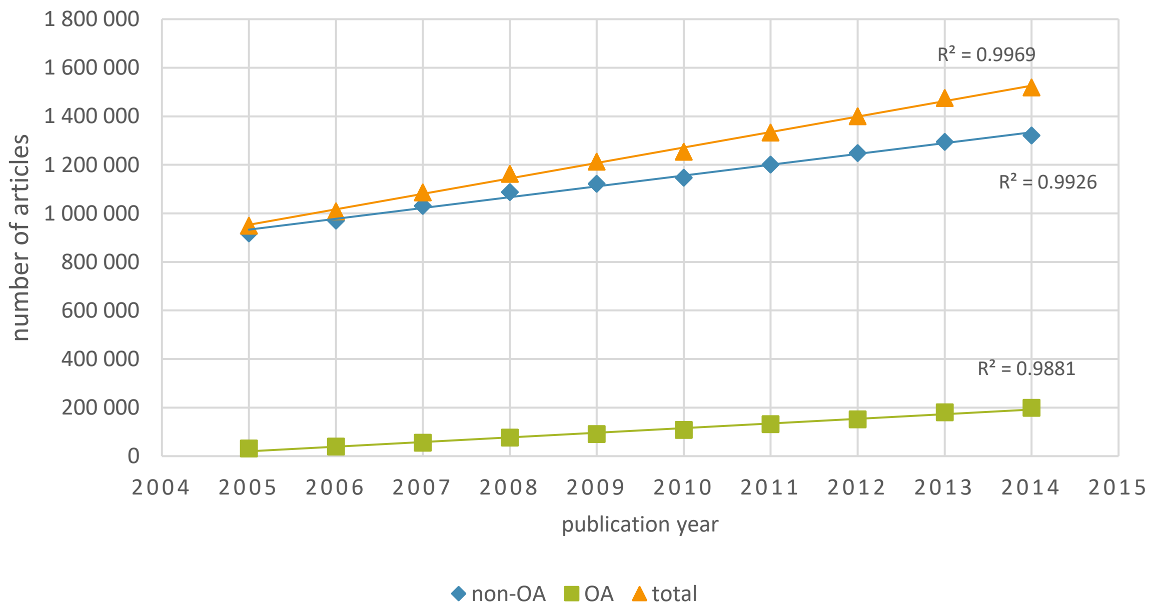

Figure 5.1: Number of open access and non-open access journal articles (2005–2014)

This increase is also reflected in the increase, over the ten years, in the percentage representation of OA journal articles, as shown in Figure 5.2. While OA journal articles are by far in the minority, constituting only 8.6% of the total number of articles across the period as a whole, the percentage of those articles has increased consistently, from 3.3% in 2005, to 13.1% in 2014. This increase follows a linear trend ($R^2 = 0.997$), with an approximate year-on-year rate of increase of 1.13 ($m = 1.13$).

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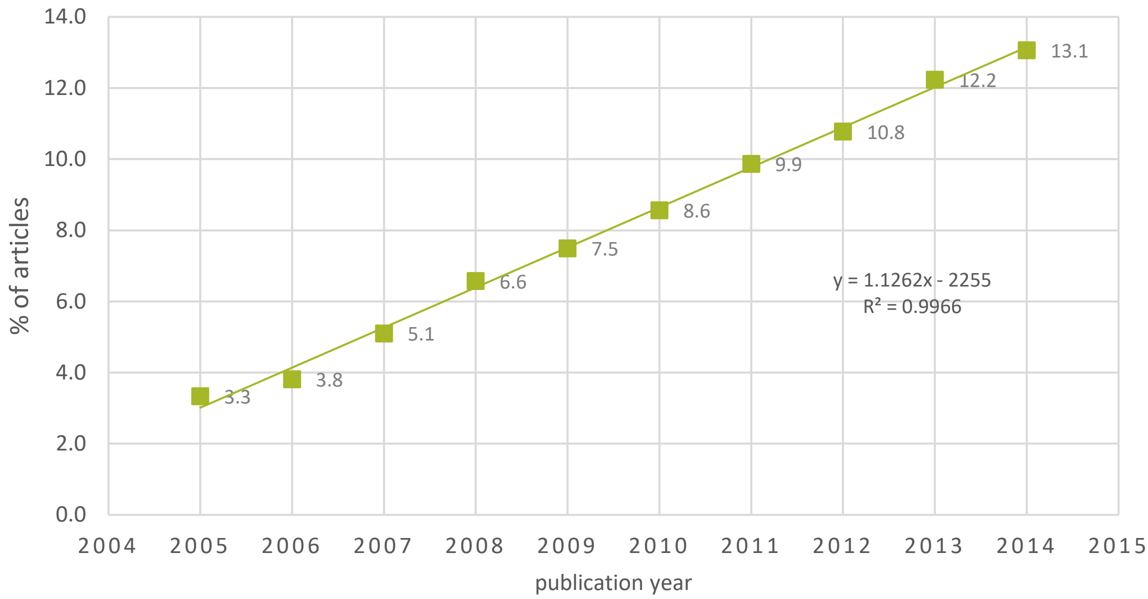

Figure 5.2: Percentage of articles published in open access journals (2005–2014)

Only a few studies have attempted to measure or estimate the percentage OA journal publications[24] globally, or in a single citation index (see for instance Archambault, Amyot, Caruso *et al.*, 2014; Dorta-González *et al.*, 2017; Laakso *et al.*,2011; Torres-Salinas *et al.*, 2016). One such study, which served as a close comparison to the current study, is that of Torres-Salinas *et al.* (2016). They made use of the same citation index (WoS) for the same years (2005 to 2014), and also made use of the gold OA journal label in the index to identify OA journal publications. However, their results differ from those produced by the current study. Torres-Salinas *et al.* (2016: 19) report that OA journal publications represent only 6% of the total publications for the ten years as a whole, as well as a lower rate of increase (m = 0.98) than what was reported for this study, as shown in Figure 5.3. The percentages they report for the years since 2012, however, correspond closer to those produced by the current study. The total number of publications and the total number of OA journal publications they report also differ substantially from the current study, as their dataset consisted of more than 20 million publications. This and the fact that they refer simply to "research output published in gold OA journals" (Torres-Salinas *et al.*, 2016: 19) suggest that they included all document types in their study, whereas the current study only comprised articles and reviews.

[24] These studies did not necessarily include article type documents or even article and review type documents only.

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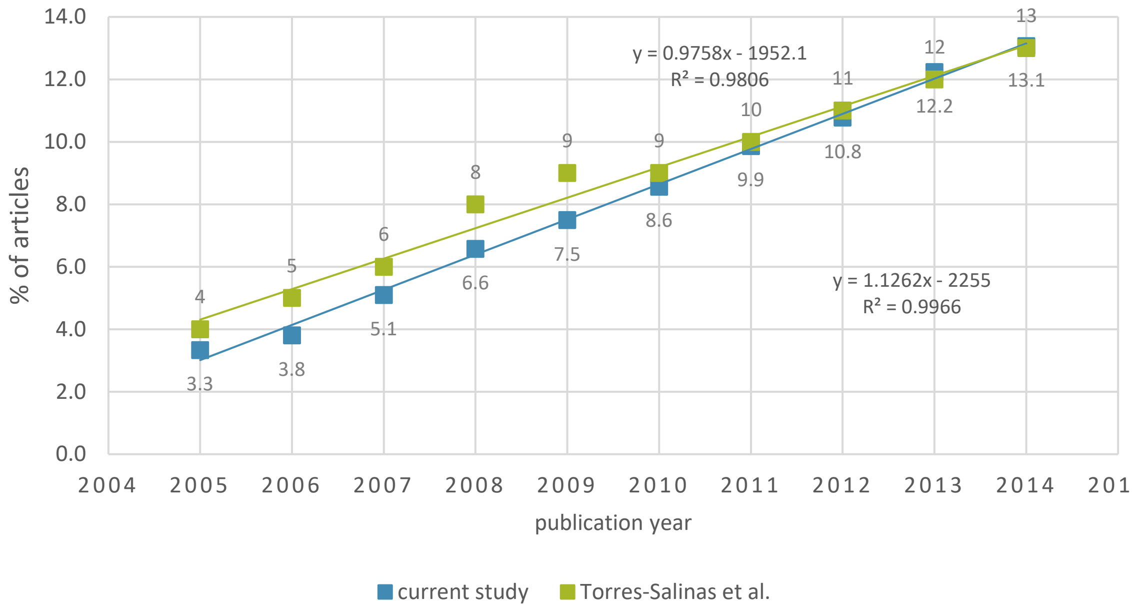

Figure 5.3: Comparison with Torres-Salinas *et al.* (2016) in terms of percentage of open access journal articles reported (2005–2014)

Another potential comparator study, conducted by Dorta-González *et al.* (2017), also made use of WoS as its data source and of the gold OA label in the WoS microdata (Dorta-González *et al.*, 2017: 879). It was expected that the number of documents would be lower for their study than the current one, as the former included only articles, unlike the current study, which included review and article document types. The total number of documents reported by Dorta-González *et al.* (2017) were indeed lower than the current study by 6.1% for 2009 and 5.5% for 2014. The difference in number of OA journal articles was greater than the difference in terms of total documents: 33.3% lower for 2009 and 16.4% lower for 2014. When compared with the results of the current study, the percentages of OA journal articles Dorta-González *et al.* (2017) report are 2.2% and 1.6% lower, for the years 2009 and 2014 respectively, as shown in Table 5.2.

Table 5.2: Comparison with Dorta-González *et al.* (2017) in terms of presence of open access journal articles

Comparison	2009	2014
	OA	
Current study: OA	90 771	198 235
Dorta-González *et al.* (2017): OA	60 566	165 696
% difference	33.3%	16.4%
	Non-OA	
Current study: non-OA	1 121 947	1 319 796
Dorta-González *et al.* (2017): non-OA	1 077 826	1 269 169
% difference	3.9%	3.8%

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Comparison	2009	2014
Total		
Current study: total	1 212 718	1 518 031
Dorta-González *et al.* (2017): total	1 138 392	1 434 865
% difference	6.1%	5.5%
OA %		
Current study: OA %	7.5%	13.1%
Dorta-González *et al.* (2017): OA %	5.3%	11.5%

In a report for the EC, Science-Metrix (Archambault, Amyot, Deschamps *et al.*, 2014) measured the extent of free online availability of academic publications published from 1996 to 2013. This is also a potential comparator study, but unlike Dorta-González *et al.* (2017) and Torres-Salinas *et al.* (2016), the Science-Metrix study made use of custom-designed software to search the Internet for any freely available publications, and drew a sample of publications from Scopus with which to match these. It is unclear from the Science-Metrix report whether document types beyond research articles were included in the sample. While all freely available publications were examined, Science-Metrix reported separately on three different types of OA, namely gold OA, green OA, and other OA. It should be noted that, as discussed in the methodology chapter (sub-section 4.2.1.1), that WoS and Scopus differ in terms of the journals that they index. However, citation analysis results based on the two citation indexes for large entities, such as subject areas or countries, have been shown to correlate. The Science-Metrix study could therefore be compared, albeit tentatively, with the current study, as it included OA journal publications of the gold OA category. However, as the publication years investigated by Science-Metrix and the current study were not the same, only a limited number of publication years could be compared. The Science-Metrix study estimated that 12.1% of all publications from 2011 to 2013, which are indexed in Scopus, were published in OA journals (Archambault, Amyot, Deschamps *et al.*, 2014: 21). The current study found the percentage to be only slightly lower (by 1.1%) for WoS. For the years 2008 to 2013, Science-Metrics estimated that 10.4% of all publications in Scopus were published in OA journals (Archambault, Amyot, Deschamps *et al.*, 2014: 26). The current study found that 9.4% of all articles indexed in WoS was published in OA journals. These results are surprisingly similar, considering the difference in the composition of the two citation indexes.

5.3. Relationship between access status and normalised citation score

The first measure of citation advantage that was investigated involved a comparison between articles in the two different types of journals in terms of their MNCS. The analysis showed that, for the 10-year period as a whole, the MNCS of non-OA journal articles was 1.03, compared to 0.66 for OA journal articles. This suggests a citation advantage for non-OA journal articles.

An independent samples t-test was conducted to determine whether the differences between the two groups were statistically significant. The results are shown in Table 5.3. The results include the Levene's test for equality of variances, which determined that there is significant variance in the dataset ($p = 0.00$). The independent samples t-test found that the difference between the MNCSs of non-OA and OA journal articles is statistically significant, t(1 847 394.8) = 231.7, $p = 0.00$.

Table 5.3: Independent samples t-test results for the relationship between access status and mean normalised citation score (2005–2014)

Tests	Statistics		Equal variances assumed	Equal variances not assumed
Levene's test for equality of variances	F		19476.8	
	Sig.		0	
t-test for equality of means	t		140.9	231.7
	df		12 396 375.0	1 847 394.8
	Sig. (2-tailed)		0.000	0.000
	Mean difference		0.37	0.37
	Std. error difference		0.003	0.001
	95% confidence interval of the difference	Lower	0.37	0.37
		Upper	0.38	0.38

A point-biserial correlation[25] was run to test the strength of the relationship between access status and NCS. The results are shown in Table 5.4. The association was found to be significant ($p = 0.00$). However, the strength of the association between the two variables was weak ($r_{pb} = -0.040$). This indicates that access status alone accounts for less than 1% ($r_{pb}^2 = 0.002$) of the variability in the NCS of articles.

[25] The point-biserial correlation coefficient (r_{pb}) was applied as measure of effect size, as detailed in the methodology chapter (sub-section 4.2.3.4).

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Table 5.4: Point-biserial correlation results for the relationship between access status and normalised citation score (2005–2014)

Statistics	Results
Point-biserial correlation	-0.040
Sig. (2-tailed)	0.000
n	12 396 377

Next, the same analysis was conducted for each year separately, to examine the potential confounding effect of the variable 'year of publication' on the relationship between access status and NCS. The results are tabulated in Table 5.5 and graphically presented in Figure 5.4. The figure shows that, over time, the MNCS of non-OA journal articles remained consistently higher than that of OA journal articles. In fact, the MNCSs of OA and non-OA journal articles experienced little change over the years studied, exhibiting a standard deviation of 0.01 and 0.03, respectively, and a negligibly small rate of change ($m = 0.005$ and $m = 0.004$).

Table 5.5: Summary of the relationship between access status and mean normalised citation score (2005–2014)

Publication year	MNCS for non-OA and OA journal articles			Independent sample's t-test value	r_{pb}
	Non-OA	OA	Difference		
2005	1.01	0.65	0.36	41.608	-0.031
2006	1.01	0.67	0.34	40.861	-0.031
2007	1.02	0.63	0.38	53.961	-0.038
2008	1.03	0.59	0.44	63.259	-0.023
2009	1.03	0.62	0.41	79.657	-0.043
2010	1.03	0.63	0.41	83.122	-0.049
2011	1.04	0.63	0.41	92.296	-0.051
2012	1.04	0.66	0.41	90.360	-0.051
2013	1.04	0.69	0.35	92.488	-0.052
2014	1.04	0.71	0.34	81.793	-0.047

Results for the Levene's test for equality of variances, the independent sample's t-test, and point-biserial correlation were statistically significant ($p < 0.00$) for each year investigated.

The Levene's test for equality of variances indicates a significant variance in the dataset for each of the publication years. The independent samples t-test for each year indicates a statistically significant difference between the scores of non-OA and OA journal articles. The point-biserial correlation, while significant, indicates a weak association for each year ($0.1 \geq r_{pb}$). Thus, while non-OA journal articles have a consistently higher MNCS across the years, and little change in the MNCS for OA journal articles and non-OA journal articles ($m < 0.00$) was observed, investigating this trend in more detail was unwarranted due to the weak association between the variables.

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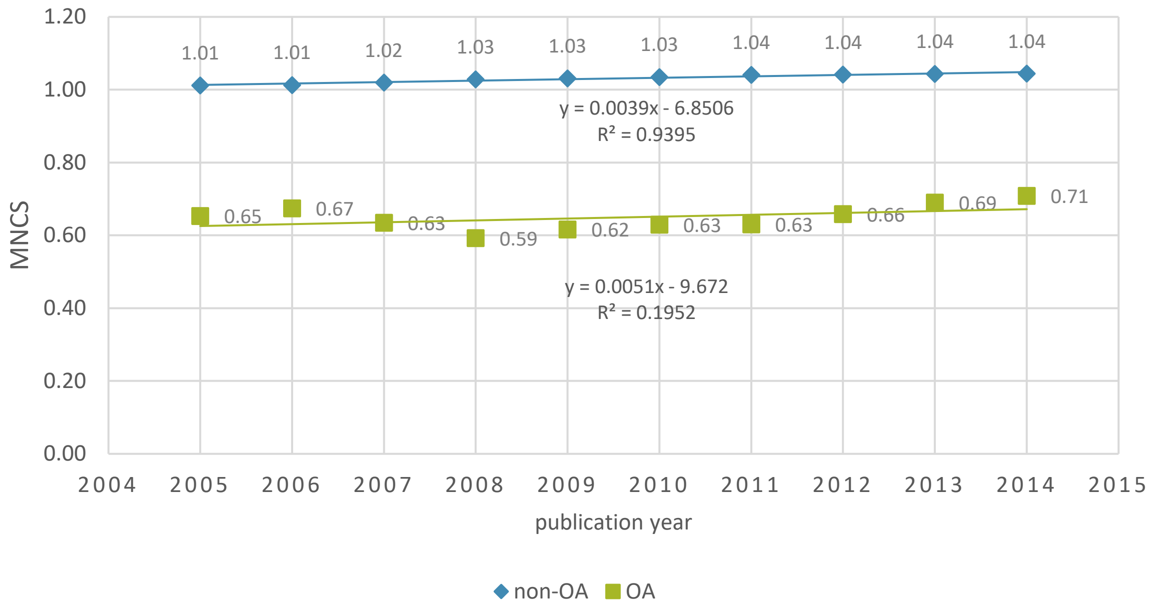

Figure 5.4: Mean normalised citation scores of open access and non-open access journal articles (2005–2014)

Similar results were obtained when conducting the sensitivity analysis for English-only articles. While the MNCS of OA journal articles is slightly higher (0.73 compared to 0.66), the overall results remain the same. The difference between the MNCS for OA and non-OA journal articles when investigating all the articles is statistically significant, t(703 319.5) = 122.3, $p = 0.00$, though the strength of the association is weak ($r_{pb} = -0.031$). This remains the case when investigating the articles published in each of the years separately, with little change across the years (m < 0.00).

5.4. Relationship between access status and being cited within the first two years after publication

The second measure of citation advantage involved determining whether articles had been cited at all during the first two years after publication. Table 5.6 shows that 71.6% of non-OA journal articles had been cited within the first two years after publication, whereas this percentage was lower, at 65.4%, for OA journal articles. The difference of 6.3% suggests a citation advantage for non-OA journal articles, as measured by this indicator, for the period as a whole.

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Table 5.6: Percentage of open access and non-open access journal articles cited within the first two years after publication (2005–2014)

Article cited within two years	Access status				Total	
	Non-OA		OA			
	n	%	n	%	n	%
No	3 212 069	28.3	366 706	34.6	3 578 775	28.9
Yes	8 124 135	71.7	693 467	65.4	8 817 602	71.1

A chi-square test for independence was applied to determine whether these two percentages differed in a statistically significant manner. The results indicate that the difference was indeed statistically significant, $\chi^2(1) = 18469.7$, $p = 0.00$. However, the strength of the association between the two variables, as indicated by the phi-coefficient (ϕ), was weak (ϕ = -0.04, $p = 0.00$). Thus, while non-OA journal articles experienced a citation advantage according to this measure, the variable 'access status' explains little in the variability of the dependent variable, namely whether an article had been cited within the first two years after publication.

Next, the same analysis was conducted for each year separately, to examine the potential confounding effect of the variable 'year of publication' on the relationship between access status and whether an article had been cited within the first two years after publication. The results are tabulated in Table 5.7, and graphically presented in Figure 5.5.

Table 5.7: Summary of relationship between access status and being cited within the first two years after publication (2005–2014)

Publication year	% of journal articles cited			χ2	ϕ
	Non-OA	OA	Difference		
2005	72.3	61.9	10.5	1 660.8	-0.042
2006	70.9	61.8	9.1	1 480.9	-0.038
2007	68.8	58.1	10.7	2 777.8	-0.051
2008	69.4	57.1	12.3	5 013.4	-0.066
2009	70.6	59.4	11.2	4 980.7	-0.064
2010	71.2	62.3	8.9	3 740.7	-0.055
2011	71.8	63.3	8.5	4 139.6	-0.056
2012	72.5	68.1	4.5	1 341.9	-0.031
2013	73.5	70.5	3.0	726.6	-0.022
2014	74.3	71.0	3.3	963.4	-0.025

Results for chi-square tests for independence and ϕ were statistically significant ($p < 0.00$) for each year investigated.

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The first observation is that the change in percentages is not linear for either non-OA journal articles ($R^2 = 0.45$) nor OA journal articles ($R^2 = 0.64$). Even though in each of the years the percentages of non-OA journal articles cited within the first two years after publication are consistently higher than those for OA journal articles, the extent of the difference between the two access types have lessened from 10.5% in 2005 to 3.3% in 2014.

Applying the chi-square test for independence and consulting ϕ yielded similar results to those found for the ten years combined. The chi-square test indicated a statistically significant result for each year, but the association between the two variables was weak ($p < 0.05$, $\phi < 0.1$). Thus, while the results suggest that non-OA journal articles have a citation advantage, and the difference between non-OA and OA journal articles is narrowing, the non-linear change in percentages for both OA and non-OA journal articles and the strength of the association rendered further investigation of this trend unwarranted.

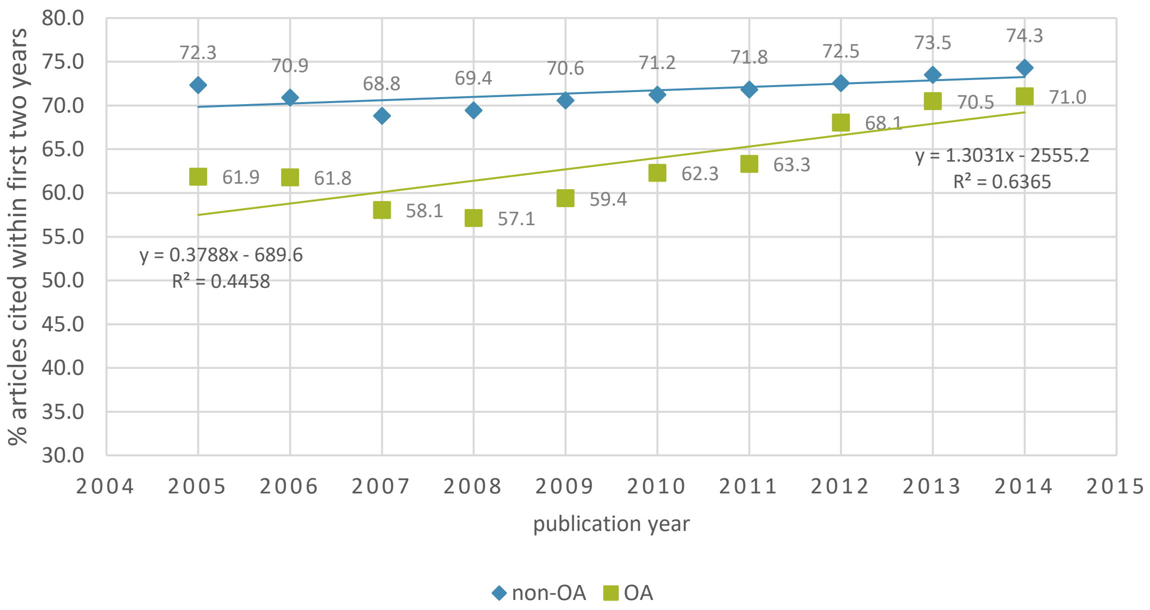

Figure 5.5: Percentage of open access and non-open access journal articles cited within the first two years after publication (2005–2014)

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5.5. Relationship between access status and presence of articles among selected most-cited percentiles

The last of the three indicators of citation advantage that were considered is the percentage of articles among the 1%, 5%, and 10% most frequently cited articles, as based on the NCS.

5.5.1. The 1% most frequently cited articles

As shown in Table 5.8, the percentages of articles that were among the 1% most frequently cited articles was 1.05%[26] for non-OA journal articles – more than double that of 0.41% found for OA journal articles. This suggests a citation advantage for non-OA journal articles based on this measure.

Table 5.8: Percentage of open access and non-open access journal articles among the 1% most frequently cited articles (2005–2014)

Among 1% most frequently cited articles	Access status					
	Non-OA		OA		Total	
	n	%	n	%	n	%
Yes	119 641	1.1	4 368	0.4	124 009	1.0
No	11 216 563	98.9	1 055 805	99.5	12 272 368	99.0

The chi-square test indicated a statistically significant difference between the percentages of non-OA and OA journal articles that were among the 1% most frequently cited articles, $\chi^2(1) = 4052.2$, $p = 0.00$. However, the strength of the association was weak ($\phi = -0.02$, $p = 0.00$). Therefore, while non-OA journal articles experience a citation advantage according to this measure, the variable ‘access status’ explains little of the variability in the dependent variable, namely whether an article is among the 1% most frequently cited articles.

As with the previous measures of citation advantage, the relationship was investigated for each year separately, to examine the potential confounding effect of the variable ‘year of publication’. This was summarised in Table 5.9, and is presented graphically in Figure 5.6. As shown in the figure, the percentages of non-OA journal articles that are among the 1% most frequently cited articles consistently increased (by 0.08%) from 2005 to 2014, a trend which can be described by a linear trendline ($R^2 = 0.98$). The trend for the OA journal articles is not well described by a linear trendline ($R^2 = 0.68$), but does show a total decrease of 0.16%.

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[26] A percentage higher than 1% is possible for this indicator due to multiple articles potentially having the same number of citations. See Chapter 4 (sub-section 4.2.2.6.3) for a detailed explanation.

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Table 5.9: Summary of relationship between access status and percentage of articles among the 1% most frequently cited articles (2005–2014)

	% of journal articles among the 1% most frequently cited				
Publication year	**Non-OA**	**OA**	**Difference**	**χ2**	**ϕ**
2005	1.02	0.56	0.45	63.3	-0.008
2006	1.02	0.60	0.42	65.0	-0.008
2007	1.02	0.55	0.48	120.8	-0.011
2008	1.04	0.42	0.62	277.9	-0.015
2009	1.05	0.42	0.62	328.8	-0.016
2010	1.06	0.38	0.68	456.7	-0.019
2011	1.07	0.36	0.71	602.2	-0.021
2012	1.08	0.37	0.71	684.0	-0.022
2013	1.08	0.40	0.68	740.3	-0.022
2014	1.09	0.40	0.69	830.5	-0.023

Results for chi-square tests for independence and ϕ were statistically significant ($p < 0.00$) for each year investigated.

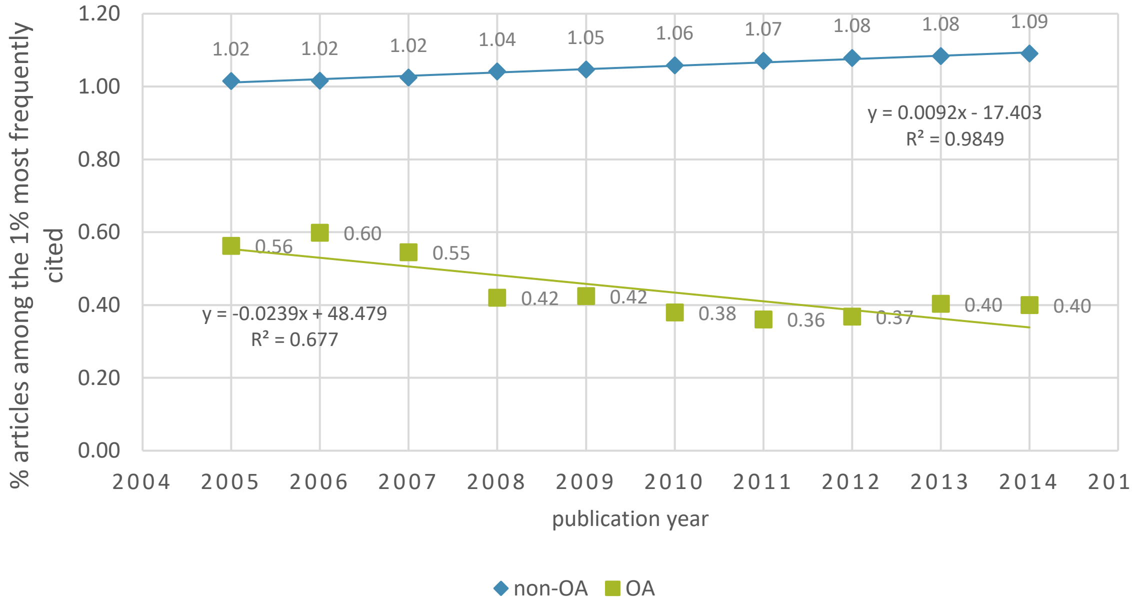

Figure 5.6: Percentage of open access and non-open access journal articles among the 1% most frequently cited articles (2005–2014)

The results of the chi-square test of independence indicated that the differences were statistically significant, but the strength of the association between the two variables was weak, for each of the years ($p < 0.05$, $\phi < 0.1$). Thus, while the difference between non-OA and OA journal articles in the percentages of articles among the 1% most frequently cited articles seems to have increased over the

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years (e.g. comparing a difference of 0.45% in 2005 to one of 0.69% in 2014), further analysis of this difference was rendered irrelevant by the weak association between the variables.

5.5.2. The 5% most frequently cited articles

The same approach as for the previous indicator was followed to analyse the relationship between access type and whether an article is among the 5% most frequently cited articles. As shown in Table 5.10, the percentage of articles that were among the 5% most frequently cited ones was 5.2% for non-OA journal articles – more than double the 2.4% found for OA journal articles. This suggests a citation advantage for non-OA journal articles.

The chi-square test for independence indicated a statistically significant difference between the percentages of non-OA and OA journal articles that were among the 5% most frequently cited, $\chi^2(1) = 16183.3$, $p = 0.00$. However, the strength of the association was weak ($\phi = -0.04$, $p = 0.00$). Hence, while non-OA journal articles experienced a citation advantage according to this measure, the variable 'access status' explained little of the variability in the dependent variable, namely whether an article is among the 5% most frequently cited articles.

Table 5.10: Percentage of open access and non-open access journal articles among the 5% most frequently cited articles (2005–2014)

Among 5% most frequently cited articles	Access status					
	Non-OA		OA		Total	
	n	%	n	%	n	%
Yes	594 368	5.2	25 727	2.4	620 095	5.0
No	10 741 836	94.8	1 034 446	97.6	11 776 282	95.0

The relationship was analysed for each publication year separately, as summarised in Table 5.11, and presented in Figure 5.7. A consistently higher percentage of non-OA journal articles than OA journal articles were among the 5% most frequently cited articles. This trend can be described by a linear trendline ($R^2 = 0.97$). The percentage showed a slight increase of 0.28% from 2005 to 2014, and consistently increased from year to year. The trend for OA journal articles is not well described by a linear trendline ($R^2 = 0.37$) and shows little change over the years, with a slightly lower (by 0.18%) value for 2014 than 2005.

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Table 5.11: Summary of relationship between access status and percentage of articles among the 5% most frequently cited articles (2005–2014)

Publication year	% of journal articles among the 5% most frequently cited				
	Non-OA	OA	Difference	χ^2	ϕ
2005	5.08	2.77	2.31	343.3	-0.019
2006	5.08	2.95	2.13	353.2	-0.019
2007	5.13	2.62	2.51	688.9	-0.025
2008	5.19	2.38	2.81	1183.4	-0.032
2009	5.21	2.39	2.83	1411.8	-0.034
2010	5.25	2.35	2.90	1739.5	-0.037
2011	5.31	2.21	3.10	2396.4	-0.042
2012	5.33	2.26	3.07	2673.0	-0.044
2013	5.37	2.40	2.97	2929.7	-0.045
2014	5.36	2.59	2.77	2787.6	-0.043

Results for chi-square tests for independence and ϕ were statistically significant ($p < 0.00$) for each year investigated.

The results of the chi-square test of independence indicated that the differences for each of the years were statistically significant, but the strength of the association was weak ($p < 0.05$, $\phi < 0.1$). Consequently, further discussion of the observations regarding the change in percentages over time was considered unwarranted.

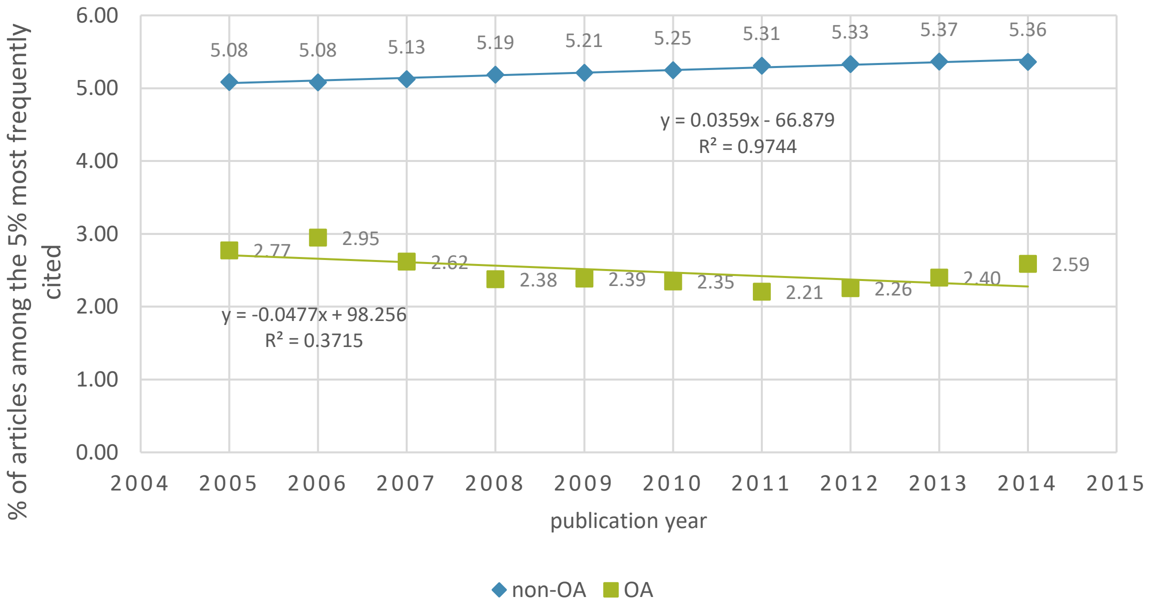

Figure 5.7: Percentage of open access and non-open access journal articles among the 5% most frequently cited articles, 2005–2014

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5.5.3. The 10% most frequently cited articles

The last measure of citation advantage that was applied was the percentages of articles that were among the 10% most frequently cited articles. This study found that 10.44% of the non-OA and 5.29% of the OA journal articles were among the 10% most frequently cited articles. For the previous two percentile indicators, the percentages for non-OA journal articles were double or more than those of the OA journal articles. In this case, the difference was smaller, though the percentage of non-OA journal articles among the 10% most frequently cited articles was still nearly double that of non-OA journal articles and favoured non-OA journal articles, which suggests a citation advantage for non-OA journal articles.

As shown in Table 5.12, the chi-square test for independence indicated a significant difference between the percentages of articles that were among the 10% most frequently cited articles, $\chi^2(1) = 28627$, $p = 0.00$. However, the strength of the association showed that the association between the variables was weak ($\phi = -0.05$, $p = 0.00$). Consequently, while non-OA journal articles were experiencing a citation advantage according to this measure, the variable 'access status' explained little of the variability in the dependent variable, namely whether an article was among the 10% most frequently cited articles.

Table 5.12: Percentage of open access and non-open access journal articles among the 10% most frequently cited articles (2005–2014)

10% most frequently cited articles	Access status					
	Non-OA		OA		Total	
	n	%	n	%	n	%
Yes	1 183 889	10.4	56 059	5.3	1 239 948	10.0
No	10 152 315	89.6	1 004 114	94.7	11 156 429	90.0

This relationship was also investigated for each year separately, as summarised in Table 5.13 and presented graphically in Figure 5.8. A consistently higher percentage of non-OA journal articles were among the 10% most frequently cited articles. The change in percentage of non-OA journal articles was well described by a linear trendline ($R^2 = 0.98$), showing a consistent increase over the years, with a difference of 0.50% from 2004 to 2015. The percentage of OA journal articles that were among the 10% most frequently cited articles showed a decrease of 0.09, and this change was not well described by a linear trendline ($R^2 = 0.05$).

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Table 5.13: Summary of relationship between access status and percentage of articles among the 10% most frequently cited articles (2005–2014)

	% of journal articles among the 10% most frequently cited				
Publication year	**Non-OA**	**OA**	**Difference**	**χ^2**	**ϕ**
2005	10.15	5.74	4.42	663.0	-0.026
2006	10.16	5.86	4.30	759.4	-0.027
2007	10.26	5.25	5.00	1 448.4	-0.037
2008	10.36	4.89	5.47	2 371.2	-0.045
2009	10.40	5.05	5.35	2 672.8	-0.047
2010	10.46	5.27	5.18	2 927.5	-0.048
2011	10.56	4.93	5.63	4 172.6	-0.056
2012	10.59	5.10	5.49	4 505.8	-0.057
2013	10.64	5.42	5.22	4 787.8	-0.057
2014	10.66	5.64	5.01	4 806.7	-0.056

Results for chi-square tests for independence and ϕ were statistically significant ($p < 0.00$) for each year investigated.

For each of the years, the chi-square test for independence showed results similar to those reported earlier in this chapter, i.e. while the difference was statistically significant, the strength of the association was weak ($p < 0.05$, $\phi < 0.1$). Consequently, further discussion of the observations regarding the change in percentages over time was considered unwarranted.

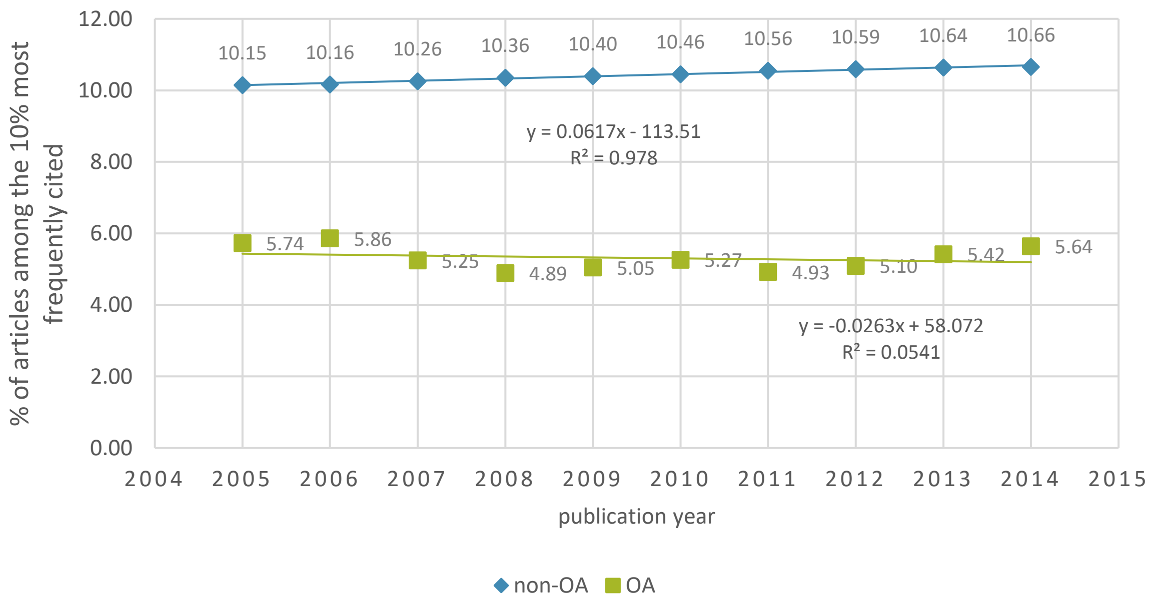

Figure 5.8: Percentage of open access and non-open access journal articles among the 10% most frequently cited articles (2005–2014)

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5.6. Chapter conclusion

This chapter described an increase in the number of articles indexed in WoS, and how OA journal articles increased at a considerably higher rate than non-OA journal articles, which translates into an increase in the percentage of OA journal articles. The results of this study regarding the distribution of OA journal articles in WoS were compared with several similar studies, while remaining cognisant of the differences in document types and data sources analysed. The results of studies are reasonably similar. The differences between the results of the current study and other studies may be attributed partially to the different document types involved. However, it cannot be assumed that a relationship exists between OA and document type (for example that OA journals publish more review type documents). Another explanation could be that subject areas differ both in terms of the number of OA journals they have, and the number of reviews they tend to publish. To clarify this would require a closer examination of the spread of document types across the journal types and subject areas, while attending to the problems with the WoS document categorisation, which is outside the scope of this study.

Any increase of articles in WoS may be attributed primarily to an increase in the number of journals that are included in the index, although it can also be attributed to a gradual increase in the number of articles published by journals over the years (Tenopir & King, 2001: 673). Proposing reasons for this increase in OA journal articles requires careful consideration. A steady increase in OA journals could be the result of the launch, and inclusion in WoS, of multiple new OA journals. On the other hand, the increase is unlikely to be due to established OA journals being included in the index, or non-OA journals changing into OA journals. These events would not give rise to a gradual increase, because back issues of a journal are also included when a new journal is indexed in WoS, and thus articles in these issues would have the OA journal label applied to them as well. Those non-OA journals that changed into OA journals would also not contribute to a gradual increase in OA journal articles, because the gold OA label had been added to previous issues of a journal, even if they were not OA at the time of publication. Thus, while this chapter reports a ‘growth’ of OA journal articles from 2005 to 2014, it is important to note that the current study was limited to what was indexed in WoS at the time of data collection (2017), and not the number of articles that had been indexed during the individual years. This was an unavoidable limitation, as the data could not have been collected longitudinally (in other words collecting each year’s data after the year had passed) for the years investigated, as WoS only began including the OA label in 2014.

The presence of new and converted OA journals has implications for the number of citations OA journal articles receive. Firstly, if the increase in OA journal articles is due to newly launched OA

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journals being included in WoS, this would partially explain why those articles are not experiencing a citation advantage in comparison to the non-OA journal articles. It is a well-established fact that articles in newly formed or less-established journals tend to receive fewer citations (Archambault, Amyot, Deschamps *et al.*, 2014: 17; Tahamtan *et al.*, 2016). Secondly, in the case of the OA journal label having been assigned to previous issues of a journal that had changed its access policy, the citations recorded for the two-year citation window reflect the citation trends of non-OA journal articles in those issues, and not of actual OA journal articles (as discussed in sub-section 4.3.1). However, the extent to which journals change their policy is unknown. Determining whether the growth in OA journal articles is due to newly launched OA journals included in WoS or to journals having changed their access policy, would be useful in clarifying why no OA citation advantage has been observed, and why the strength of the association between access status and various indicators of citation advantage is weak. However, this would require data to be collected at journal level, which was beyond the scope of the current study.

The analysis presented in this chapter found a statistically significant difference between OA journal articles and non-OA journal articles, regardless of the measure of citation advantage. However, when using any test of statistical significance, it needs to be noted that, with a sufficiently large sample (and in this case, the whole population), any such test would produce a result of statistical significance, regardless of the strength of the association between the variables (Durlak, 2009). It can therefore not simply be concluded, based on the significance tests, that non-OA journal articles experience a citation advantage compared to OA journal articles. Any sample with more than 300 cases potentially produces small p-values for small differences (Figueiredo Filho *et al.*, 2013: 45). To determine whether this is the case for a particular analysis, measures of effect size should be investigated. These include investigating absolute differences between the groups, and testing of the strength of the association. The analysis shows that each of the associations was weak, regardless of whether publication date was controlled for. The results in this chapter suggest that the variable ‘access status’ explains only a small amount of the variability in citations to non-OA journal and OA journal articles, even though there is a difference between the two groups of articles, both in terms of percentages and scores.

In conclusion, this chapter provided evidence of a lack of a general OA citation advantage for the OA journal articles and reviews indexed in WoS for the years 2005 to 2014, similar to results of Dorta-González *et al.*, (2017:899) for the years 2009 and 2014. One of the difficulties with investigating the hypothesis of a general OA citation advantage, is that citation behaviour of researchers, and hence the number of citations articles receive, differs between subject areas (Tahamtan *et al.*, 2016; Waltman *et al.*, 2011). This potentially introduces a substantial number of differences in the OA journal

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articles and the non-OA journal articles if subject areas differ in terms of the number of citations their OA journal articles receive. This could explain, at least partially, why the strength of the observed associations was weak, especially since previous studies suggested that certain subject areas experience an OA citation advantage, while others do not, as elaborated upon in Chapter 3. To account for these subject-related differences and thereby gain a better understanding of the OA citation advantage, Chapter 6 presents the results for the different measures of citation advantage for the WoS subject areas separately.

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CHAPTER 6: Results on open access citation advantage for articles indexed in the Web of Science, disaggregated by subject area

6.1. Introduction

The previous chapter investigated whether there is a general OA citation advantage for articles published in OA journals from 2005 to 2014, as indexed in WoS. Three different aspects of citation advantage were investigated, and the results of the analysis showed that the association between each of these aspects and the access status of the journal in which an article is published, is weak, regardless of whether publication year was controlled for. However, other confounding variables could be obscuring the relationship between access status and the different measures of citation advantage. In this chapter, one such a potentially confounding variable, namely subject area, is controlled for.

The following section provides some context for the analysis of the OA citation advantage for the individual subject areas, by reporting on the descriptive statistics regarding the presence of OA journal articles published from 2005 to 2014. This includes a comparison with results of comparator studies. The discussion then proceeds to an analysis of the measures of citation advantage, namely:

1. a description of the differences in scores and percentages between the articles published in OA journals and those published in non-OA journals;
2. the results of tests of statistical significance of the differences; and
3. measures of the strength of the associations.

While controlling for publication year did not improve the strength of the associations investigated for WoS-indexed articles in general, the analysis by subject area investigated whether this was also the case for the individual subject areas. To achieve this, an analysis was conducted for articles published during the total 10-year period and for a single year, for each of the measures and for each of the subject areas. Investigating a single year reduced the effect of between-year variability that might have obscured the strength of the association between access type and the measures. Furthermore, it was not viable to investigate changes across the years for each subject area separately. Analysing the articles for the year 2014 was therefore selected as an alternative method to control for

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the possible confounding effect of the variable 'year of publication' on the associations investigated. The year 2014 also corresponded to the latest publication year investigated and to the latest publication year included in the comparator study with a methodology most similar to that of the current study (Dorta-González *et al.*, 2017). Lastly, articles from the most recent year (i.e. 2014) were also the least likely to suffer from the effects of potential journal policy changes, and the citation counts were less likely to be influenced by self-archived versions of the articles, both of which are limitations of this study discussed at the end of Chapter 4.

6.2. Descriptive statistics for open access journal articles across subject areas (2005–2014)

The following section first describes the occurrence of OA journal articles among the subject areas, to identify those subject areas in which the publication of OA journal articles has been intermittent or relatively rare during the time frame investigated, as the interpretation of inferential statistics for these required careful consideration. Then the representation of OA journal articles, in each of the subject areas, as a percentage of all articles published, is described. Finally, the results on the presence of OA journal articles in specific subject areas are compared with results from previous studies as a form of triangulation.

6.2.1. Distribution of open access journal articles across subject areas

Figure 6.1 summarises the variable presence of OA journal articles in the subject areas, while the remainder of this section provides more details.

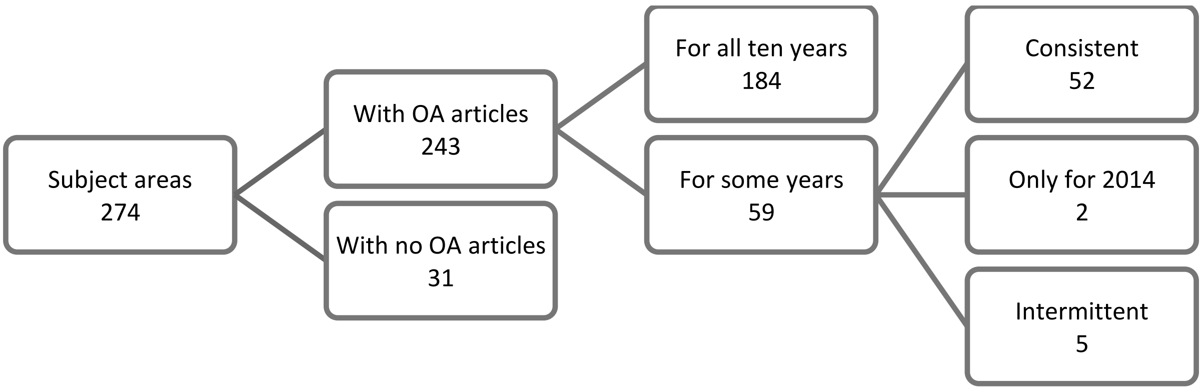

Figure 6.1: Number of subject areas in which any open access journal articles were published (2005–2014)

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The data for the period as a whole comprised articles from 274 subject areas, of which in 243 OA journal articles were published in at least one of the years investigated. The 31 subject areas in which no OA journal articles were published are listed in Addendum A.1 and were excluded from further analysis. In a total of 184 subject areas OA journal articles were published in each of the years (but in some cases only a single OA journal article in some years). In the other 59 subject areas, OA journal articles were published in only some of the years (see Addendum A.2). In 52 of those, OA journal articles were published in each year since they were first recorded for that subject area. In two subject areas, OA journal articles were published only in 2014, namely 'Literature, Slavic' and 'Women's Studies'. OA journal articles were published only intermittently in five subject areas, as shown in Table 6.1.

Table 6.1: Percentage of open access journal articles in subject areas in which open access journal articles were published intermittently (2005–2014)

Publication years	Engineering, Environmental		Horticulture		Literary Theory & Criticism		Psychology, Social		Spectroscopy	
	n	%	n	%	n	%	n	%	n	%
2005	0	0.00	12	0.51	0	0.00	0	0.00	38	0.54
2006	0	0.00	0	0.00	0	0.00	0	0.00	38	0.54
2007	0	0.00	318	11.63	0	0.00	1	0.04	37	0.48
2008	1	0.01	371	11.79	0	0.00	12	0.39	33	0.48
2009	0	0.00	324	10.35	0	0.00	20	0.62	0	0.00
2010	2	0.02	318	9.65	1	0.15	0	0.00	0	0.00
2011	2	0.02	430	12.79	1	0.15	0	0.00	0	0.00
2012	38	0.33	364	10.13	0	0.00	0	0.00	0	0.00
2013	99	0.81	318	9.17	0	0.00	0	0.00	132	1.51
2014	150	1.19	313	8.90	170	18.10	0	0.00	72	0.79

In some of the years, fewer than 20 OA journal articles were published in these five subject areas, followed by a significant increase in number and percentage in later years. An extreme example is 'Literary Theory & Criticism', in which only one OA journal article was published in 2010 and in 2011, but 170 in 2014. In contrast, in 'Spectroscopy', more than 30 OA journal articles per year were published consistently in the years in which OA journal articles were published, although this still constituted a very small percentage (< 1.5%) of the total articles published in 'Spectroscopy' in those years. Of the 59 subject areas in which OA journal articles were published in only some of the years, seven (one was a duplicate) had relatively few (< 100) OA journal articles for the period as a whole. The seven subject areas were:

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- 'Engineering, Aerospace'
- 'Mathematical Methods in Social Sciences'[27]
- 'Operations Research & Management Science'
- 'Psychology, Social'
- 'Social Sciences, Mathematical Methods'
- 'Theater'
- 'Women's Studies'.

In two ('Women's Studies' and 'Family Studies') fewer than ten OA journal articles were published in 2014. The subject areas identified in this section and the implications for the interpretation of the results are discussed further in the concluding section of this chapter.

6.2.2. Percentage of open access journal articles

Among the 243 subject areas in which OA journal articles were published, the percentage of OA journal articles differed considerably. The subject area in which the lowest percentage (0.1%) of OA journal articles was published was 'Women's Studies', while the highest percentage (56.2%) was observed for 'Multidisciplinary Sciences'. However, as already noted in the previous sub-section, in 'Women's Studies', the OA journal articles were all published in 2014, while in 'Multidisciplinary Sciences' OA journal articles were published in each year investigated. When only the 184 subject areas in which OA journal articles were published in each of the years were examined, then the lowest percentage was observed for 'Chemistry, Physical', at 0.4%. In 2014, the subject area in which the lowest percentage (0.2%) of OA journal articles was published was 'Operations Research & Management Sciences', while 'Multidisciplinary Sciences', at 72.7%, remained the subject area in which the largest percentage of OA journal articles were published. The percentages for all subject areas are presented in Addendum A.3.

The aforementioned discussion provided some indication of the range of the percentage of OA journal articles across subject areas, although it gave little indication of the distribution across most subject areas. For over half of the 243 subject areas in which OA journal articles were published in the years 2005 to 2014, fewer than 5% of articles were published in these journals, as illustrated in Figure 6.2. The largest category is for subject areas in which 0–5% of articles were published in OA journals, indicating a severely skewed distribution across the subject areas.

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[27] Considered a duplicate of ''Social Sciences, Mathematical Methods''. See Chapter 4 (sub-section 4.2.1.5).

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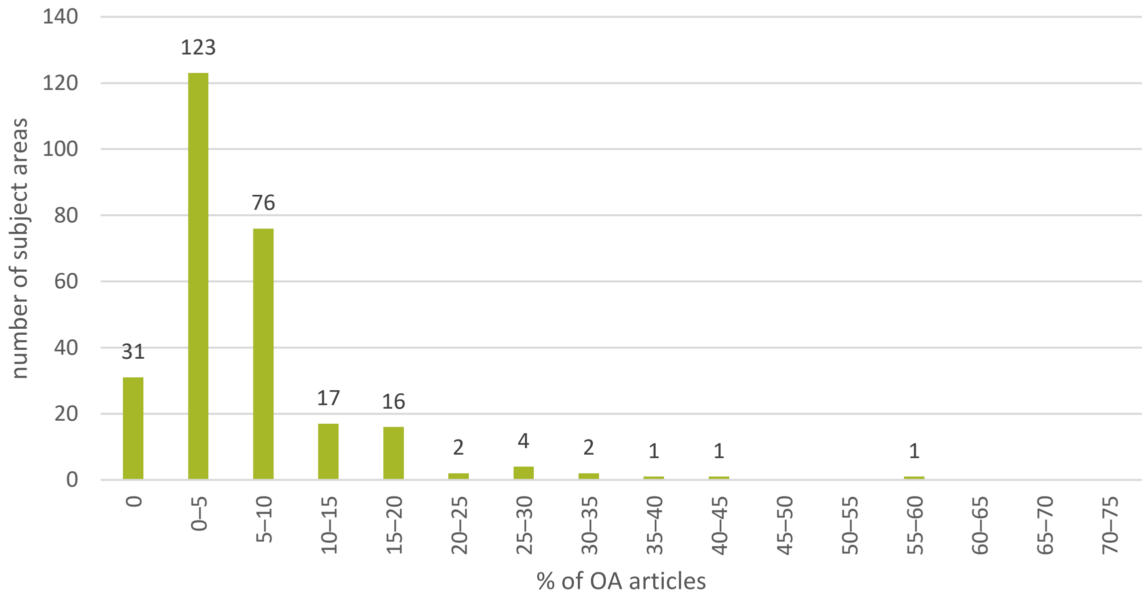

Figure 6.2: Histogram of the number of subject areas categorised by the percentage of articles published in open access journals, in 5% intervals (2005–2014)

'Multidisciplinary Sciences' is the only subject area in which OA journal articles were in the majority, and in only 11 subject areas were more than 20% of articles published in OA journals. These subject areas, and the percentage of the articles published in OA journals, are presented in Table 6.2.

Table 6.2: Subject areas in which more than of 20% of articles were published in open access journals (2005–2014)

Subject area	Total number of articles	% in OA journals
Multidisciplinary Sciences	253 681	56.2
Tropical Medicine	26 564	44.3
Parasitology	45 286	38.6
Primary Health Care	12 266	34.6
Science & Technology – Other Topics	474 597	32.6
Medicine, General & Internal	196 109	28.8
Mathematical & Computational Biology	51 690	27.3
Agriculture, Multidisciplinary	64 206	27.3
Andrology	4 172	25.4
General & Internal Medicine	241 150	24.9
Integrative & Complementary Medicine	24 862	21.7

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Similar to Figure 6.2, Figure 6.3 compares the number of subject areas and the percentage of articles that were published in OA journals for the two years, 2005 and 2014. The first notable observation is that the number of subject areas in which no OA journal articles were published is considerably lower for more recent years: only 32 in 2014, compared to 88 in 2005.

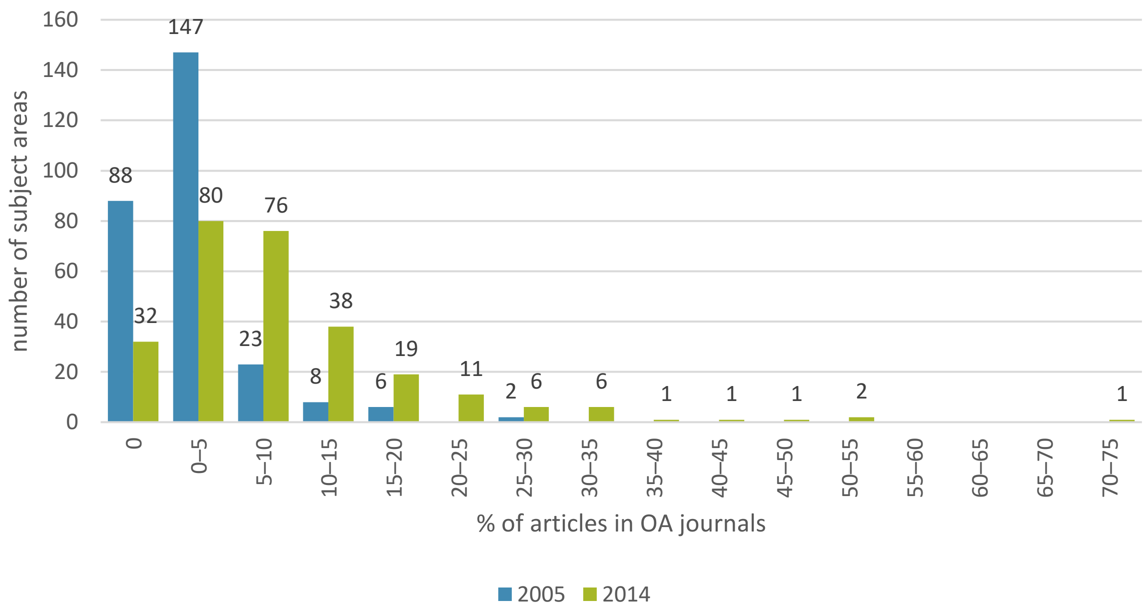

Figure 6.3: Histogram of the number of subject areas categorised by the percentage of articles published in open access journals, in 5% intervals (2005 and 2014)

Secondly, the number of subject areas with more than 5% of articles published in OA journals have also increased over time. For the year 2005, in 147 subject areas, 0–5% of articles were published in OA journals. By 2014, this group remained the largest, but had decreased to 80 subject areas, while the 5–10% group had more than tripled, from 23 subject areas to 76. For 2005, in most of the subject areas 3% or fewer of articles were published in OA journals (excluding those in which no OA journal articles were published). By 2014, this had increased to 8%. In 2005, there was no subject areas in which the majority of articles were published in OA journals, but by 2014, this was the case in three subject areas: 'Multidisciplinary Sciences' at 72.7%, 'Tropical Medicine' at 52.9%, and 'Parasitology' at 52.0%. The presence of articles published in OA journals thus increased for several subject areas across the time frame of this study.

Although the aforementioned measures may provide an overview of the presence of OA journal publishing, using any such measure across the subject areas needs to be done, and should be interpreted, with care, as subject areas overlap. An example of this is the occurrence of seven subject areas with the label 'Chemistry', such as 'Chemistry, Medicinal' and 'Chemistry, Applied'.

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6.2.3. Comparison with results found in the literature

The results of the current study were compared with three studies, which investigated the presence of OA journal articles across selected subject areas, namely Dorta-González *et al.* (2017), Gargouri *et al.* (2012) and Archambault, Amyot, Deschamps *et al.* (2014). The study with a methodology most similar to this study, Dorta-González *et al.* (2017), made use of the WoS OA journal tag, investigated only article type documents published in the years 2009 and 2014, and considered 249 subject areas. The results were similar for the majority of subject areas[28], with particularly large (> 40%) differences found for only 20 subject areas. This difference between the two studies is presented as percentage differences[29], as shown in Table 6.3. Similarities between the results for Dorta-González *et al.* (2017) and the current study were to be expected, due to their methodological similarities.

Table 6.3: Selected subject areas for which the open access journal article percentage showed a notably large difference with Dorta-González *et al.* (2017)

Subject area	Dorta-González *et al.* (2017) %	The current study %	% difference
Mycology	0.7	4.6	557.2
Critical Care Medicine	1.8	9.8	444.7
Engineering, Biomedical	3.6	12.3	240.3
Physics, Nuclear	4.2	13.1	212.9
Astronomy & Astrophysics	2.0	6.0	202.3
Physics, Particles & Fields	6.2	13.7	120.7
Law	2.0	4.0	100.5
History of Social Sciences	7.3	0.0	100.0
Business	1.6	2.6	65.1
Public Administration	3.6	1.3	64.9
Social Sciences, Mathematical Methods	0.7	1.1	60.2
Ethics	7.5	11.6	55.3
Mining & Mineral Processing	6.0	2.7	55.2
Medical Ethics	16.6	25.7	54.6
Engineering, Electrical & Electronic	3.9	6.0	54.3
Art	5.0	2.5	49.6
Physics, Applied	4.4	6.6	49.4

[28] The comparison between the current study and the study by Dorta-González *et al.* (2017) for all 249 subject areas is presented in Addendum G.

[29] The percentage difference is the absolute value of *a* minus *b* divided by *a*, where *a* is the percentage of OA journal articles in the current study and *b* is the percentage of OA journal articles in the study by Dorta-González *et al.* (2017). The equation thereof is: $x = \frac{|a-b|}{a}$

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Subject area	Dorta-González *et al.* (2017) %	The current study %	% difference
Psychology	13.3	7.9	40.9
Evolutionary Biology	12.6	17.7	40.6
Andrology	18.6	26.1	40.3

Dorta-González *et al.* (2017) reported that there were four subject areas in which no OA journal articles were published in 2014, whereas the current study found otherwise. These subject areas are 'History & Philosophy of Science', 'Literary Theory & Criticism', 'Literature, Slavic', and 'Women's Studies'. The difference for 'History & Philosophy of Science' might be due to the spelling error in the WoS microdata (sub-section 4.2.1.5). Another reason why the studies might differ in this manner was the inclusion of review type articles in the current study. Lastly, the differences could be due to changes made to the microdata that occurred after Dorta-González *et al.* (2017) had extracted their data. As shown in sub-section 4.3.3, such changes occurred during the current study as well. This may explain why Dorta-González *et al.* (2017) report OA journal articles for 'History of Social Sciences', whereas none were present in the dataset for the current study.

Another study aimed at estimating the presence of OA journal articles indexed in WoS among 14 disciplines for the years 2005 to 2010 (Gargouri *et al.*, 2012). Gargouri *et al.* (2012) investigated a sample of articles from the ISI citation index for each of the subject areas for each of the years investigated. They applied a "software robot" (Gargouri *et al.*, 2012:286) to search the Internet and gauge which of the sampled articles had OA versions available online. While their study is not comparable with the current study, the results are presented for interest's sake. They investigated both self-archived articles and OA journal articles, reporting the results for each separately. Only five subject areas could reliably be compared, as Gargouri *et al.* (2012) applied different naming conventions from WoS, and combined subject areas. The percentages they report for journal-based OA are similar, although larger than the ones reported by the current study, especially with regard to 'Mathematics' and 'Psychology'. The comparison is presented in Table 6.4.

Table 6.4: Comparison with Gargouri *et al.* (2012) in terms of open access article percentage (2005–2010)

Subject area	Gargouri *et al.* (2012) %	The current study %	% difference
Selected 14 subject areas combined	2.4		
Arts	1.4		
Biology	19.8	14.5	26.8
Biomedical Research	7.9		
Chemistry	3.3	2.1	36.4

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Subject area	Gargouri *et al.* (2012) %	The current study %	% difference
Clinical Medicine	5.1		
Earth and Space Science	2.0		
Engineering and Technology	1.3		
Health	4.6		
Humanities	1.4		
Mathematics	7.6	3.5	53.9
Physics	4.1	2.6	36.6
Professional fields[30]	1.3		
Psychology	3.9	1.6	59.0
Social Science	0.9		

Science-Metrix also estimated the percentage of OA articles for a range of subject areas for the years 2008 to 2013 (Archambault, Amyot, Deschamps *et al.*, 2014). The authors distinguished between three different types of OA of which one was gold OA, and the subject areas were defined according to the Scopus classification system (see Elsevier, 2017a). The methodology of the Science-Metrix study differs from the methodology of this study in terms of sampling method, data collection method, and definition of the population, as explained in section 5.2. While the Scopus and WoS indexed journals overlap, as discussed in the methodology chapter, the citation indexes use different subject-area categorisation methods and names. While this limits comparison with the current study, results for nine subject areas were tentatively compared, as summarised in Table 6.5.

Table 6.5: Comparison of selected WoS and Scopus subject areas

Scopus subject area used by Archambault, Amyot, Deschamps *et al.* (2014)	Comparative WoS subject areas
Agriculture, Fisheries and Forestry	Agriculture
Physics and Astronomy	Astronomy & Astrophysics
Biology	Biology
Chemistry	Chemistry
Economics and Business	Business & Economics
Engineering	Engineering
Historical Studies	History
Psychology and Cognitive Sciences	Psychology
Public Health and Health Services	Public, Environmental & Occupational Health

[30] Gargouri *et al.* (2012) included the following disciplines when referring to professional fields: Communication, Education, Information Science and Library Science, Law, Management, and Social Work.

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Table 6.6 tabulates the comparison of the results presented so far in this chapter, and the estimates of the presence of OA journal articles reported by Science-Metrix. In most cases, the results are similar, with 'Chemistry' showing the largest difference.

Table 6.6: Comparison with Archambault, Amyot, Deschamps *et al.*, (2014) in terms of percentage of open access journal articles (2008–2013)

	Science-Metrix		Current study
Science-Metrix subject area	**%**	**Margin of error**	**%**
Agriculture, Fisheries and Forestry	15.6	±0.4	16.5
Biology	15.3	±0.3	19.8
Biomedical Research	11.4	±0.2	
Built Environment and Design	3.3	±0.4	
Chemistry	8.7	±0.2	3.6
Clinical Medicine	12.4	±0.1	
Communication and Textual Studies	6.5	±0.5	
Earth and Environmental Sciences	7.5	±0.3	
Economics and Business	5.1	±0.3	3.6
Enabling and Strategic Technologies	8.3	±0.2	
General Arts, Humanities and Social Sciences	2.0		
Visual and Performing Arts	3.1		
Engineering	3.2	±0.1	3.6
General Science and Technology	46.5	±0.6	
Historical Studies	6.6	±0.6	5.6
Information and Communication Technologies	10.0	±0.3	
Mathematics and Statistics	9.3	±0.3	
Philosophy and Theology	5.0	±0.6	
Physics and Astronomy	4.6	±0.1	1.9
Psychology and Cognitive Sciences	5.5	±0.3	4.1
Public Health and Health Services	14.3	±0.4	19.0
Social Sciences	8.1	±0.3	
Total	10.4	±0.1	9.4

6.3. Relationship between access status and normalised citation score

In this study, the MNCSs of OA and non-OA journal articles were compared as the first measure of citation advantage to determine whether there is an OA citation advantage. This citation advantage was first measured by comparing the group differences, as a simple measure of effect size (Durlak, 2009: 918) between the MNCSs of OA and non-OA journal articles. This was followed by an

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independent samples t-test to determine whether the differences were statistically significant. For those subject areas that showed a statistically significant difference, the point-biserial coefficient (r_{pb}) was examined as an additional measure of effect size to determine the strength of the association, as discussed in sub-section 4.2.3.4. The aforementioned is reported for all articles published in the period 2005–2014, and separately for the publications of 2014. The reporting of the results focuses on those subject areas in which the difference favoured OA journal articles, to enable the identification of the subject areas that experienced an OA citation advantage.

6.3.1. Articles published during the entire time frame

In 29 subject areas, the MNCS was higher for OA journal articles than for non-OA journal articles, when considering the period as a whole. A summary of the results for these subject areas is presented in Table 6.7. The results for all subject areas are summarised in Addendum B.1.

Table 6.7: Point-biserial correlation coefficient and difference between mean normalised citation scores of open access and non-open access journal articles in subject areas in which the difference favours open access journal articles (2005–2014)

	Number of articles		MNCS			
Subject area	**OA**	**Total**	**Non-OA**	**OA**	**Diff.**	r_{pb}
Primary Health Care	4249	12266	0.51	0.78	0.27	0.149
Virology	8650	61398	1.01	1.59	0.58	0.138
Engineering, Petroleum	1198	17432	0.40	0.78	0.39	0.092
Engineering, Manufacturing	426	47510	0.90	2.34	1.44	0.090
Parasitology	17458	45286	1.06	1.35	0.28	0.085
Family Studies	234	18277	0.98	2.05	1.07	0.078
Optics	36869	237174	0.91	1.39	0.49	0.078
Toxicology	7880	94210	0.98	1.38	0.40	0.072
Mycology	497	18433	0.95	1.37	0.43	0.048
Classics	371	7665	0.97	1.49	0.52	0.035
Meteorology & Atmospheric Sciences	17676	97795	0.97	1.14	0.17	0.033
Biology	17232	87136	0.98	1.08	0.10	0.023
Life Sciences & Biomedicine – Other Topics	17232	87136	0.98	1.08	0.10	0.023
Computer Science, Interdisciplinary Applications	1174	112172	1.23	1.97	0.74	0.020
Tropical Medicine	11776	26564	0.90	0.96	0.05	0.020
Art	869	46264	0.97	1.74	0.77	0.018
Biochemistry & Molecular Biology	46860	643385	1.07	1.28	0.21	0.016
Materials Science, Paper & Wood	2808	15557	0.72	0.78	0.07	0.016
Integrative & Complementary Medicine*	5389	24862	0.94	0.98	0.03	0.012
Industrial Relations & Labor*	791	7890	0.80	0.84	0.04	0.010
Education, Scientific Disciplines*	3607	30268	0.96	1.01	0.05	0.009
Andrology*+	1060	4172	0.76	0.81	0.05	0.022

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Subject area	Number of articles		MNCS			r_{pb}
	OA	Total	Non-OA	OA	Diff.	
Water Resources⁺	5794	97808	0.95	1.01	0.06	0.010
Theater*⁺	56	9058	1.06	1.61	0.56	0.009
Health Policy & Services*⁺	3674	42517	1.02	1.04	0.03	0.005
Psychology, Social*⁺	33	32059	1.00	1.09	0.08	0.002
Area Studies*⁺	155	18349	1.04	1.08	0.04	0.002
Law*⁺	1322	41963	0.95	0.96	0.01	0.001
Physics, Nuclear*⁺	2422	81648	0.89	0.91	0.02	0.001

* Independent samples t-test not significant: $p > 0.01$

⁺ Levene's test for equality variances: $p \geq 0.05$.

To determine whether these differences were statistically significant, independent samples t-tests and Levene's test for equality variances were conducted. For these 29 subject areas, the variance was determined to be equal for eight, namely 'Andrology', 'Area Studies', 'Health Policy & Services', 'Law', 'Physics, Nuclear', 'Psychology, Social', 'Theater', and 'Water Resources'. Of these eight subject areas, the difference was statistically significant only for 'Water Resources' ($p \geq 0.05$). For 19 of the remaining subject areas, the difference was statistically significant ($p < 0.01$). For two subject areas, namely 'Primary Health Care' and 'Virology', the effect size of the relationship was $0.1 \leq r_{pb} < 0.3$. In other words, for these two subject areas, access status explained 14.9% and 13.8%, respectively, of the variability in NCS, and OA journal articles experienced the citation advantage. For the remaining 17 subject areas, the effect size of the relationship was $0.1 > r_{pb}$, indicating a weak association.

A similar analysis found that in 205 subject areas the difference was statistically significant ($p < 0.05$) and favoured non-OA journal articles. For 28 of these, the effect size of the relationship was $0.1 \leq r_{pb} < 0.3$. In other words, in these 28 subject areas, non-OA journal articles experienced a citation advantage.

6.3.2. Articles published in 2014

When investigating only those articles published in 2014, in 43 subject areas, OA journal articles had a higher MNCS than their non-OA journal articles did. Levene's test for equality variances showed that in 23 subject areas the variance was equal for the NCS for OA journal articles and non-OA journal articles ($p \geq 0.05$). For 20 of the 43 subject areas, the difference was determined to be statistically significant ($p < 0.05$). The point-biserial correlation results were statistically significant for these subject areas ($p < 0.05$). For seven of the 20 subject areas, the effect size of the relationship was $0.1 \leq r_{pb} < 0.3$. These subject areas were 'Industrial Relations & Labor', 'Andrology', 'Primary Health Care', 'Virology', 'Tropical Medicine', 'Engineering, Manufacturing' and 'Toxicology'. The results are

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summarised in Table 6.8. The results for all subject areas are summarised in Addendum B.2. OA journal articles in these subject areas, therefore, tend to receive more citations than their non-OA journal counterparts.

Table 6.8: Point-biserial correlation coefficient and difference between mean normalised citation scores of open access and non-open access journal articles in subject areas in which the difference favours open access journal articles (2014)

Subject area	Number of articles		MNCS			r_{pb}
	OA	Total	Non-OA	OA	Diff.	
Andrology	125	479	0.66	1.14	0.48	0.193
Virology	1354	6878	1.00	1.52	0.51	0.129
Primary Health Care	660	1524	0.51	0.73	0.22	0.123
Tropical Medicine	1868	3532	0.75	1.04	0.29	0.112
Engineering, Manufacturing	29	5622	0.95	3.09	2.14	0.111
Toxicology	860	10393	0.94	1.47	0.53	0.106
Industrial Relations & Labor+	81	975	0.80	1.30	0.49	0.102
Biology	2884	10896	0.87	1.20	0.33	0.092
Life Sciences & Biomedicine – Other Topics	2884	10896	0.87	1.20	0.33	0.092
Parasitology	3265	6282	1.04	1.28	0.24	0.071
Family Studies*	8	2357	0.94	2.52	1.58	0.067
Classics*	48	923	0.94	1.83	0.88	0.063
Optics	6058	29817	0.89	1.20	0.32	0.05
Mycology*	91	1978	0.94	1.26	0.32	0.044
Water Resources+	963	13339	0.93	1.12	0.19	0.038
Meteorology & Atmospheric Sciences+	2704	12416	0.97	1.15	0.17	0.035
Law	187	4664	0.87	1.11	0.24	0.029
Physiology	1506	10308	0.89	0.99	0.11	0.029
Education, Scientific Disciplines*+	592	3594	0.99	1.10	0.12	0.025
Geosciences, Multidisciplinary+	2578	21850	1.03	1.17	0.13	0.024
Biochemistry & Molecular Biology	6858	67750	1.03	1.29	0.27	0.023
Crystallography	92	6738	0.75	1.25	0.50	0.023
Microbiology+	2891	19245	1.09	1.19	0.10	0.022
Art*+	121	4805	0.95	1.73	0.78	0.020
Physics, Nuclear*+	1049	7983	0.95	1.35	0.41	0.019
Ethics*+	261	2241	0.88	0.95	0.06	0.016
Geography, Physical*+	362	5695	1.07	1.16	0.09	0.013
Physical Geography*+	362	5695	1.07	1.16	0.09	0.013
Astronomy & Astrophysics	1166	19284	1.06	1.25	0.19	0.013
Geriatrics & Gerontology*+	979	6189	0.98	1.02	0.04	0.011
Literature, Romance*+	132	1857	0.62	0.74	0.12	0.010
Geology*+	2899	24372	1.02	1.08	0.05	0.010
Audiology & Speech-Language Pathology*+	74	2161	1.04	1.12	0.08	0.009

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Subject area	Number of articles		MNCS			r_{pb}
	OA	Total	Non-OA	OA	Diff.	
Automation & Control Systems*	214	8790	1.39	1.54	0.16	0.009
Engineering, Petroleum*+	128	2109	0.45	0.48	0.03	0.008
Health Care Sciences & Services*+	1863	11295	1.04	1.07	0.03	0.007
Psychology, Educational*+	18	2116	1.09	1.25	0.15	0.007
Computer Science, Interdisciplinary Applications*+	198	14350	1.24	1.60	0.36	0.007
Health Policy & Services*	686	5853	0.97	0.98	0.01	0.003
Mining & Mineral Processing*+	74	2753	0.91	0.93	0.02	0.003
Biochemical Research Methods*+	1681	16359	1.04	1.07	0.03	0.002
Music*+	12	4661	0.97	1.07	0.10	0.001
Education & Educational Research*+	1161	14494	1.01	1.01	0.00	0.001

* Independent samples t-test not significant: $p > 0.01$

+ Levene's test for equality variances: $p \geq 0.05$.

A similar analysis found that in 171 subject areas the difference in MNCSs was statistically significant ($p < 0.05$) and favoured non-OA journal articles. In 34 subject areas, the effect size of the relationship was $0.1 \leq r_{pb} < 0.3$. There are two main reasons why, even when the difference between the MNCS of OA journal articles and non-OA journal articles was statistically significant, the effect sizes remained small. Firstly, tests of statistical significance are sensitive to the size of the dataset. Secondly, due to the (equally) skewed distribution of NCS across the articles for both OA journal articles and non-OA journal articles[31], there was large variability among the articles in terms of their NCS.

6.4. Relationship between access status and being cited within two years after publication

The second measure of citation advantage that was investigated for the subject areas separately was whether a higher percentage of OA than non-OA journal articles were cited within two years after publication. As with the previous measure of citation advantage, this measure examined the relationship between whether an article had been cited and the access status of an article, for each subject area separately for the whole period, and then for 2014 only. The strength of the association was measured using the phi-coefficient (ϕ) as a measure of effect size, as described in the methodology chapter (sub-section 4.2.3.3).

[31] This skewed distribution is illustrated in Figure 4.1 and Figure 4.2, with the example of 'Parasitology' articles published in 2014.

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6.4.1. Articles published during the entire time frame

In 39 subject areas, the percentage of cited articles was higher for OA journal articles than for non-OA journal articles, when considering the period as a whole. The results for these are summarised in Table 6.9 (the results for all subject areas are provided in Addendum C.1).

Table 6.9: Phi-coefficient and difference between percentage of open access and non-open access journal articles cited within two years for subject areas in which the difference favours open access journal articles (2005–2014)

	Non-OA		OA		Effect size	
Subject area	**Total**	**% cited**	**Total**	**% cited**	**Diff.**	**ϕ**
Engineering, Petroleum	16 234	27.4	1 198	47.1	19.7	-0.11
Materials Science, Paper & Wood	12 749	45.9	2 808	64.4	18.5	-0.14
Optics	200 305	69.7	36 869	83.2	13.5	-0.11
Primary Health Care	8 017	67.1	4 249	78.1	11.0	-0.12
Family Studies	18 043	68.8	234	89.7	20.9	-0.05
Theater	9 002	8.6	56	21.4	12.8	-0.04
Art⁺	45 395	5.3	869	17.8	12.5	-0.07
Physics, Nuclear	79 226	62.8	2 422	74.8	12.0	-0.04
Psychology, Social*	32 026	73.7	33	84.8	11.1	-0.01
Instruments & Instrumentation	119 529	66.1	7 099	76.9	10.8	-0.05
Education, Scientific Disciplines	26 661	62.2	3 607	72.2	10.0	-0.07
Classics	7 294	13.7	371	22.9	9.2	-0.06
Mathematical & Computational Biology	37 568	75.5	14 122	83.0	7.5	-0.08
Andrology	3 112	79.1	1 060	86.1	7.0	-0.08
Environmental Studies	48 220	75.3	2 483	82.0	6.7	-0.03
Meteorology & Atmospheric Sciences	80 119	78.0	17 676	83.9	5.9	-0.06
Multidisciplinary Sciences	110 994	77.8	142 687	83.7	5.9	-0.07
Critical Care Medicine	42 118	85.8	3 412	90.9	5.2	-0.04
Parasitology	27 828	80.3	17 458	84.5	4.3	-0.05
Neuroimaging	21 358	89.0	362	93.1	4.1	-0.02
Medical Informatics	25 061	80.6	1 831	84.6	4.0	-0.03
Water Resources	92 014	73.9	5 794	77.8	3.9	-0.02
Virology	52 748	89.0	8 650	92.5	3.6	-0.04
Developmental Biology	39 636	88.5	1 150	91.8	3.3	-0.02
Audiology & Speech-Language Pathology*	18 835	73.9	315	77.1	3.2	-0.01
Geosciences, Multidisciplinary	152 048	74.6	15 249	77.6	2.9	-0.02
Education & Educational Research	105 615	58.5	6 988	61.1	2.5	-0.01
Biochemical Research Methods	137 286	85.0	12 254	87.5	2.5	-0.02
Tropical Medicine	14 788	75.0	11 776	77.5	2.4	-0.03

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Subject area	Non-OA		OA		Effect size	
	Total	% cited	Total	% cited	Diff.	ϕ
Psychology, Educational*	17 048	67.0	136	69.1	2.1	0.00
Physics, Applied	456 058	73.2	18 262	75.1	1.9	-0.01
Science & Technology – Other Topics	320 089	81.1	154 508	82.9	1.8	-0.02
Health Care Sciences & Services	76 066	77.6	9 723	79.2	1.5	-0.01
Health Policy & Services*	38 843	76.9	3 674	78.3	1.4	-0.01
Evolutionary Biology	48 353	87.6	5 633	88.9	1.3	-0.01
Peripheral Vascular Disease*	93 047	85.2	1 108	86.4	1.2	0.00
Genetics & Heredity	157 803	85.1	27 072	86.0	0.9	-0.01
Ornithology*	11 477	60.3	136	61.0	0.7	0.00
Geology*	172 182	74.1	17 185	74.8	0.6	0.00

* chi-square test for independence results not statistically significant: $p > 0.01$
[+] expected value: < 5.

After conducting a chi-square test for independence, it was determined that the observed difference for 32 of these subject areas was statistically significant ($p < 0.01$). Only for one subject area, ‘Theater’, was the expected value < 5, which required a Fischer’s exact test (see sub-section 4.2.3.3) to determine whether the difference was statistically significant. For four of the 32 subject areas, the effect size of the relationship was $0.1 \leq \phi < 0.3$, indicating an appreciable effect size. In other words, in these subject areas OA journal articles experienced a citation advantage. These four were ‘Engineering, Petroleum’, ‘Materials Science, Paper & Wood’, ‘Optics’, and ‘Primary Health Care’.

A similar analysis found that in 188 subject areas the difference favoured non-OA journal articles and the difference was statistically significant ($p < 0.05$). In 57 subject areas, the effect size of the relationship was $0.1 \leq \phi < 0.3$.

6.4.2. Articles published in 2014

For articles published in 2014 the difference for non-OA journal articles and OA journal articles in terms of whether articles were cited within two years after publication varied considerably, even more so than when all the articles published in the period as a whole were considered. In 52 of the 242 subject areas in which OA journal articles were published, a higher percentage of OA journal articles than non-OA journal articles were cited. For 26 of these subject areas, the difference was statistically significant, as determined by a chi-square test for independence. In two subject areas, ‘Family Studies’ and ‘Music’, the expected value was < 5, and the differences between OA journal articles and non-OA journal articles were not statistically significant ($p \geq 0.05$). For five subject areas, the effect size of the relationship was $0.1 \leq \phi < 0.3$. These five subject areas were ‘Industrial Relations & Labor’,

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'Andrology', 'Tropical Medicine', 'Physics, Nuclear', and 'Optics'. The results for these 52 subject areas are summarised in Table 6.10 (the results for all subject areas are reflected in Addendum C.2).

Table 6.10: Phi-coefficient and difference between percentage of open access and non-open access journal articles cited within two years for subject areas in which the difference favours open access journal articles (2014)

	Non-OA		OA		Effect size	
Subject area	**Total**	**% cited**	**Total**	**% cited**	**Diff.**	**ϕ**
Industrial Relations & Labor	894	55.0	81	87.7	32.6	-0.182
Physics, Nuclear	6 934	66.2	1 049	83.3	17.2	-0.125
Andrology	354	78.8	125	92.0	13.2	-0.152
Tropical Medicine	1 664	71.7	1 868	84.2	12.5	-0.151
Optics	23 759	70.4	6 058	81.5	11.1	-0.100
Engineering, Petroleum	1 981	37.0	128	55.5	18.5	-0.091
Psychology, Educational*	2 098	71.7	18	88.9	17.2	-0.035
Family Studies*⁺	2 349	71.0	8	87.5	16.5	-0.021
Art	4 684	7.1	121	22.3	15.2	-0.091
Instruments & Instrumentation	14 214	70.3	1 516	81.3	10.9	-0.071
Education, Scientific Disciplines	3 002	66.4	592	76.0	9.6	-0.076
Materials Science, Paper & Wood	1 450	57.9	660	67.3	9.3	-0.089
Primary Health Care	864	68.9	660	77.3	8.4	-0.093
Crystallography*	6 646	70.6	92	78.3	7.6	-0.019
Mathematical & Computational Biology	4 516	71.1	2 093	78.5	7.4	-0.078
Parasitology	3 017	79.6	3 265	87.0	7.4	-0.100
Medical Informatics	3 019	78.8	340	85.9	7.1	-0.053
Neuroimaging	2 666	90.8	187	97.3	6.6	-0.057
Meteorology & Atmospheric Sciences	9 712	80.6	2 704	86.7	6.1	-0.066
Health Policy & Services	5 167	75.9	686	81.8	5.9	-0.045
Classics*	875	11.4	48	16.7	5.2	-0.036
Virology	5 524	87.8	1 354	92.8	5.0	-0.063
Water Resources	12 376	76.6	963	81.5	5.0	-0.030
Multidisciplinary Sciences	14 941	77.9	39 804	82.5	4.6	-0.053
Geosciences, Multidisciplinary	19 272	79.2	2 578	83.8	4.6	-0.037
Engineering, Biomedical	12 019	78.4	1 678	82.7	4.2	-0.034
Obstetrics & Gynecology	11 030	80.2	570	84.4	4.2	-0.023
Substance Abuse*	3 486	81.5	122	85.2	3.7	-0.017
Communication*	2 997	65.3	167	68.9	3.5	-0.017
Audiology & Speech-Language Pathology*	2 087	73.6	74	77.0	3.4	-0.014
Health Care Sciences & Services	9 432	77.5	1 863	80.9	3.4	-0.030

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Subject area	Non-OA Total	Non-OA % cited	OA Total	OA % cited	Effect size Diff.	Effect size ϕ
Genetics & Heredity	17 157	83.3	4 511	86.7	3.4	-0.037
Critical Care Medicine*	4 333	88.0	471	90.7	2.7	-0.025
Geriatrics & Gerontology*	5 210	82.2	979	84.7	2.5	-0.024
Physiology	8 802	83.2	1 506	85.7	2.4	-0.023
Limnology*	1 898	77.4	74	79.7	2.3	-0.010
Literature, Romance*	1 725	5.3	132	7.6	2.2	-0.025
Education & Educational Research*	13 333	63.4	1 161	65.2	1.8	-0.010
Evolutionary Biology*	5 063	87.9	1 090	89.6	1.7	-0.020
Law*	4 477	53.5	187	55.1	1.6	-0.006
Behavioral Sciences*	6 112	87.2	548	88.7	1.5	-0.013
Geology*	21 473	78.8	2 899	80.3	1.5	-0.012
Environmental Studies*	6 632	79.5	788	80.8	1.3	-0.010
Psychology, Clinical*	7 246	79.5	118	80.5	1.0	-0.003
Developmental Biology*	4 010	85.4	117	86.3	0.9	-0.004
Biochemical Research Methods*	14 678	84.4	1 681	85.2	0.9	-0.007
Music*+	4 649	7.5	12	8.3	0.8	-0.002
Medieval & Renaissance Studies*	769	17.3	50	18.0	0.7	-0.004
Biochemistry & Molecular Biology*	60 892	86.2	6 858	86.9	0.7	-0.006
Ethics*	1 980	62.7	261	63.2	0.5	-0.003
Cell & Tissue Engineering*	3 124	92.3	463	92.7	0.4	-0.005
Microbiology*	16 354	87.4	2 891	87.7	0.3	-0.003

* chi-square test for independence results not statistically significant: $p > 0.01$
+ expected value: < 5.

A similar analysis found that in 163 subject areas the difference was statistically significant ($p < 0.05$) and favoured non-OA journal articles. In 62 subject areas, the effect size of the relationship was $\phi \leq 0.1$. In five of these subject areas the effect size of the relationship was $\phi < 0.3$, namely in 'Mathematics, Interdisciplinary Applications', 'Engineering, Multidisciplinary', 'Agricultural Economics & Policy', 'Anthropology', and 'Agricultural Engineering'. This was the first measure that showed a moderate association between access status and citation advantage, although it was in favour of non-OA journal articles.

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6.5. Relationship between access status and presence of articles among selected most-cited percentiles

The last type of citation advantage that was investigated for the individual subject areas was the percentage of articles among the most frequently cited ones, in terms of NCS. This was investigated through three percentiles, namely the percentage of articles among the 1%, 5% and 10% most frequently cited articles. It should be noted this comparison was not aimed at determining whether the 1%, 5% or 10% most cited articles were OA journal articles or non-OA journal articles; instead its aim was to establish which percentage of each of these two types of articles was among the 1%, 5% and 10% most cited articles. In other words, if there were no difference between articles of the two access types, each would have similar or close to 1%, 5% or 10% of the articles in the three groupings respectively, as elaborated upon in the methodology chapter (see sub-section 4.2.2.6.3). The strength of the association was measured using the phi-coefficient (ϕ) as a measure of effect size, as described in Chapter 4 (sub-section 4.2.3.3).

6.5.1. The 1% most frequently cited articles

The first of the percentile-based measure of citation advantage that was investigated for this study was the percentage of articles among the 1% most frequently cited articles.

6.5.1.1. Articles published during the entire time frame

In 35 subject areas, the percentage of articles among the 1% most frequently cited percentile was higher for OA journal articles than for non-OA journal articles, when considering the period as a whole. The analysis for the subject areas in which the difference favours OA journal articles is summarised in Table 6.11. The results for all subject areas are summarised in Addendum D.1.

Table 6.11: Phi-coefficient and difference between percentage of open access and non-open access journal articles among the 1% most frequently cited articles for subject areas in which the difference favours open access journal articles (2005–2014)

	Non-OA		OA		Effect size	
Subject area	**Total**	**% in 1%**	**Total**	**% in 1%**	**Diff.**	**ϕ**
Engineering, Manufacturing+	47 084	0.91	426	10.56	9.65	0.092
Mycology	17 936	0.91	497	6.24	5.32	0.084
Family Studies+	18 043	0.98	234	5.56	4.57	0.051
Computer Science, Interdisciplinary Applications	110 998	1.05	1 174	3.83	2.78	0.027
Toxicology	86 330	0.75	7 880	2.84	2.10	0.061
Psychology, Social+*	32 026	1.01	33	3.03	2.02	0.006

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Subject area	Non-OA		OA		Effect size	
	Total	% in 1%	Total	% in 1%	Diff.	ϕ
Primary Health Care	8 017	0.52	4 249	2.28	1.76	0.079
Virology	52 748	0.85	8 650	2.27	1.41	0.048
Biology	69 904	0.78	17 232	1.98	1.20	0.048
Life Sciences & Biomedicine – Other Topics	69 904	0.78	17 232	1.98	1.20	0.048
Optics	200 305	0.90	36 869	1.97	1.07	0.038
Geography, Physical	39 242	1.09	1 438	2.16	1.07	0.019
Physical Geography	39 242	1.09	1 438	2.16	1.07	0.019
Nuclear Science & Technology	87 333	1.13	628	2.07	0.94	0.007
Biochemistry & Molecular Biology	596 525	0.93	46 860	1.79	0.85	0.022
Social Work*	16 517	0.98	498	1.81	0.83	0.014
Engineering, Petroleum	16 234	0.85	1 198	1.59	0.74	0.020
Industrial Relations & Labor*	7 099	0.94	791	1.64	0.70	0.021
Social Sciences – Other Topics	76 112	1.00	4 231	1.49	0.49	0.011
Social Sciences, Interdisciplinary	37 486	1.03	3 038	1.48	0.45	0.012
Classics*	7 294	2.26	371	2.70	0.43	0.006
Anesthesiology*	36 550	1.02	1 289	1.40	0.38	0.007
Meteorology & Atmospheric Sciences	80 119	1.00	17 676	1.30	0.30	0.011
Engineering, Aerospace+*	25 592	1.20	69	1.45	0.25	0.001
Health Policy & Services*	38 843	0.99	3 674	1.17	0.18	0.005
Parasitology*	27 828	0.92	17 458	1.09	0.17	0.009
Environmental Sciences*	291 221	1.05	15 099	1.21	0.16	0.003
Physics, Nuclear*	79 226	1.34	2 422	1.49	0.15	0.002
Public, Environmental & Occupational Health	177 074	1.00	37 923	1.14	0.14	0.005
Ethics*	17 370	1.03	1 193	1.17	0.14	0.003
Integrative & Complementary Medicine*	19 473	1.02	5 389	1.15	0.13	0.005
Area Studies+*	18 194	1.16	155	1.29	0.13	0.001
Automation & Control Systems*	64 093	1.01	1 850	1.03	0.02	0.000
Microbiology*	159 162	0.95	15 941	0.96	0.01	0.000
Chemistry, Medicinal*	122 776	1.01	3 565	1.01	0.00	0.000

* chi-square test for independence results not statistically significant ($p > 0.01$)
+ expected value: < 5.

For five subject areas, the expected value was < 5, requiring a Fischer's exact test to determine whether the differences between the percentages of non-OA and OA journal articles were statistically significant. These subject areas were 'Family Studies', 'Psychology, Social', 'Area Studies', 'Engineering, Manufacturing', and 'Engineering, Aerospace'. Only the results for 'Family Studies' and 'Engineering, Manufacturing' were statistically significant ($p = 0.00$). For the other subject areas, a chi-square test for independence was conducted to determine whether the difference was statistically significant.

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The difference was statistically significant ($p < 0.05$) in 19 subject areas. In none of the subject areas was the effect size of the relationship ≤ 0.1. However, similar results were observed when investigating whether any subject area experienced a citation advantage for non-OA articles.

While 163 subject areas showed a statistically significant ($p < 0.05$) difference in favour of non-OA journal articles, there was only a single subject area in which $\phi > 0.1$. This subject area was 'Multidisciplinary Sciences' $\chi^2(1) = 2994.6$, $p = 0.00$. Table 6.12 shows that there was a citation advantage for non-OA journal articles with 2.3% of the non-OA journal articles being among the most frequently cited 1% of articles. The strength of the association was weak ($\phi = -0.11$, $p = 0.00$).

Table 6.12: Cross-tabulation of access status and presence among 1% most frequently cited for 'Multidisciplinary Sciences' articles (2005–2014)

	Presence among most frequently cited 1%				
	No		Yes		Total
Access status	n	%	n	%	n
Non-OA	108 452	97.71	2 542	2.29	110 994
OA	142 626	99.96	61	0.04	142 687
Total	251 078	98.97	2 603	1.03	253 681

6.5.1.2. *Articles published in 2014*

In 40 subject areas, the percentage of articles among the 1% most frequently cited articles were higher for OA journal articles than non-OA journal articles. Of these, the difference was statistically significant in 14 subject areas ($p < 0.05$). For 17 subject areas, the expected value was < 5, necessitating a Fisher's exact test to determine whether the difference was statistically significant. The results of the analysis for the subject areas in which the difference favoured OA journal articles are summarised in Table 6.13. The results for all subject areas are summarised in Addendum D.2.

Table 6.13: Phi-coefficient and difference between percentage of open access and non-open access journal articles among the 1% most frequently cited articles for subject areas in which the difference favours open access journal articles (2014)

	Non-OA		OA		Effect size	
Subject area	Total	% in 1%	Total	% in 1%	Diff.	ϕ
Engineering, Manufacturing+	3 611	0.84	100	17.24	16.40	0.123
Family Studies+	1 257	0.98	35	12.50	11.52	0.067
Mycology+	1 625	0.79	14	5.49	4.70	0.098
Crystallography+	8 514	1.04	0	5.43	4.40	0.049
Toxicology	7 079	0.76	548	4.19	3.43	0.093
Computer Science, Interdisciplinary Applications+	7 611	0.90	50	4.04	3.14	0.038

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	Non-OA		OA		Effect size	
Subject area	**Total**	**% in 1%**	**Total**	**% in 1%**	**Diff.**	**ϕ**
Engineering, Aerospace*+	2 183	1.25	0	4.35	3.10	0.023
Classics*+	602	2.06	19	4.17	2.11	0.032
Physics, Nuclear	8 940	0.87	116	2.96	2.09	0.067
Andrology*+	271	0.56	60	2.40	1.84	0.079
Primary Health Care	571	0.35	229	1.97	1.62	0.079
Biology	5 177	0.67	908	2.05	1.37	0.060
Life Sciences & Biomedicine – Other Topics	5 177	0.67	908	2.05	1.37	0.060
Automation & Control Systems*+	3 905	1.01	86	2.34	1.32	0.020
Literature, Romance*	1 337	4.00	76	5.30	1.30	0.017
Astronomy & Astrophysics	14 066	0.96	391	2.06	1.10	0.026
Virology	4 700	0.85	157	1.92	1.07	0.041
Logic*+	501	1.08	0	2.06	0.98	0.028
Geography, Physical*+	2 382	1.09	52	1.93	0.85	0.019
Physical Geography*+	2 382	1.09	52	1.93	0.85	0.019
Optics	15 598	0.88	1 308	1.52	0.64	0.026
Biochemistry & Molecular Biology	55 405	0.93	2 490	1.57	0.64	0.019
Public, Environmental & Occupational Health	12 897	0.97	1 180	1.42	0.45	0.018
Computer Science, Artificial Intelligence*	5 447	1.04	126	1.34	0.30	0.006
Audiology & Speech-Language Pathology*	1 512	1.05	0	1.35	0.30	0.005
Physiology*	9 211	0.98	174	1.26	0.28	0.010
Art*+	4 501	1.39	42	1.65	0.27	0.004
Medical Ethics*+	410	1.01	15	1.25	0.24	0.010
Tropical Medicine*	1 114	0.90	414	1.12	0.22	0.011
Parasitology*	2 238	0.89	379	1.10	0.21	0.010
Chemistry, Analytical*	15 773	1.03	392	1.19	0.16	0.004
Engineering, Biomedical*	5 985	1.04	49	1.19	0.15	0.005
Physics, Particles & Fields*	11 084	1.05	128	1.19	0.14	0.005
Ethics*+	1 281	1.01	15	1.15	0.14	0.004
Chemistry, Medicinal*	8 833	1.00	11	1.14	0.14	0.003
Rehabilitation*	3 677	1.01	101	1.08	0.07	0.002
Oceanography*	4 351	1.09	111	1.16	0.07	0.002
Social Sciences, Interdisciplinary*	2 372	1.03	124	1.09	0.06	0.002
Linguistics*+	2 888	1.01	48	1.03	0.03	0.001
Neuroimaging*+	1 981	1.05	0	1.07	0.02	0.000

* chi-square test for independence results not statistically significant ($p > 0.01$)
+ expected value: < 5.

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In only one of the 14 subject areas was ϕ > 0.1, namely 'Engineering, Manufacturing' $\chi^2(1) = 84.7$, $p = 0.00$ (ϕ = 0.12, $p = 0.00$). The results for 'Engineering, Manufacturing' are presented in Table 6.14.

Table 6.14: Cross-tabulation of access status and presence among 1% most frequently cited for 'Engineering, Manufacturing' articles (2014)

	Presence among most frequently cited 1%				
	No		Yes		Total
Access status	n	%	n	%	n
Non-OA	5 546	99.2	47	0.8	5 593
OA	24	82.8	5	17.2	29
Total	5 570	99.1	52	0.9	5 622

While there were 86 subject areas in which the difference favoured non-OA journal articles, and which the difference was statistically significant, only one had ϕ > 0.1, namely 'Multidisciplinary Sciences' $\chi^2(1) = 1320.2$, $p = 0.00$ (ϕ = -0.16, $p = 0.00$). The results for 'Multidisciplinary Sciences' are presented in Table 6.15.

Table 6.15: Cross-tabulation of access status and presence among 1% most frequently cited for 'Multidisciplinary Sciences' articles (2014)

	Presence among most frequently cited 1%				
	No		Yes		Total
Access status	n	%	n	%	n
Non-OA	14 412	96.5	529	3.5	14 941
OA	39 781	99.9	23	0.1	39 804
Total	54 193	99.0	552	1.0	54 745

6.5.2. The 5% most frequently cited articles

The second of the percentile-based measures of citation advantage investigated in this study was the percentage of articles among the 5% most frequently cited articles.

6.5.2.1. Articles published during the entire time frame

In 29 subject areas, the percentage of articles among the among the 5% most frequently cited articles was higher for OA journal articles than for non-OA journal articles, when considering the period as a whole. The results for these 29 are presented in Table 6.16. The results for all subject areas are summarised in Addendum E.1. There were 21 subject areas that showed a statistically significant difference ($p < 0.05$) but only in one was the effect size of the relationship ϕ > 0.1, namely 'Primary Health Care' (ϕ = 0.103, $p = 0.00$).

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Table 6.16: Phi-coefficient and difference between percentage of open access and non-open access journal articles among the 5% most frequently cited articles for subject areas in which the difference favours open access journal articles (2005–2014)

	Non-OA		OA		Effect size	
Subject area	Total	% in 5%	Total	% in 5%	Diff.	ϕ
Primary Health Care	8017	3.7	4249	8.5	4.9	0.103
Virology	52748	4.3	8650	10.2	5.9	0.094
Toxicology	86330	4.3	7880	11.5	7.2	0.093
Optics	200305	4.5	36869	9.9	5.4	0.086
Literature, Slavic	3410	89.8	170	100.0	10.2	0.073
Engineering, Manufacturing	47084	4.9	426	20.7	15.7	0.067
Engineering, Petroleum	16234	4.0	1198	9.2	5.1	0.063
Classics	7294	13.1	371	22.9	9.8	0.061
Family Studies	18043	5.0	234	15.4	10.4	0.053
Biology	69904	4.6	17232	7.5	2.9	0.053
Life Sciences & Biomedicine – Other Topics	69904	4.6	17232	7.5	2.9	0.053
Mycology	17936	4.9	497	12.1	7.2	0.053
Parasitology	27828	4.3	17458	6.0	1.7	0.038
Meteorology & Atmospheric Sciences	80119	4.9	17676	6.6	1.6	0.028
Integrative & Complementary Medicine	19473	5.1	5389	6.3	1.3	0.023
Computer Science, Interdisciplinary Applications	110998	5.2	1174	9.8	4.6	0.021
Biochemistry & Molecular Biology	596525	4.9	46860	6.5	1.6	0.019
Geography, Physical	39242	5.3	1438	7.2	1.9	0.016
Physical Geography	39242	5.3	1438	7.2	1.9	0.016
Microbiology	159162	4.8	15941	5.8	1.0	0.014
Andrology*	3112	4.6	1060	5.1	0.5	0.011
Environmental Sciences	291221	5.2	15099	5.7	0.5	0.005
Water Resources*	92014	5.4	5794	5.7	0.4	0.004
Industrial Relations & Labor*	7099	5.0	791	5.3	0.3	0.004
Biochemical Research Methods*	137286	5.1	12254	5.5	0.3	0.004
Law*	40641	5.2	1322	5.7	0.5	0.004
Tropical Medicine*	14788	5.1	11776	5.2	0.2	0.004
Area Studies*	18194	5.1	155	5.8	0.7	0.003
Psychology, Social*+	32026	5.2	33	6.1	0.9	0.001

* chi-square test for independence results not statistically significant: $p > 0.01$

+ expected value: < 5.

In 191 subject areas the difference between OA journal articles and non-OA journal articles was statistically significant ($p < 0.05$), and favoured non-OA articles. In seven of these subject areas the effect size of the relationship was $0.1 \leq \phi < 0.3$.

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6.5.2.2. Articles published in 2014

In 42 subject areas, the percentage of articles among the 5% most frequently cited articles were higher for OA journal articles than for non-OA journal articles. Table 6.17 presents a summary of the subject areas in which the difference favoured OA journal articles. The results for all subject areas are summarised in Addendum E.2. Of the 42 subject areas, there were 26 in which this difference was statistically significant ($p < 0.05$). For eight subject areas, the expected value was < 5, in which case a Fischer's exact test was conducted to determine whether the difference was statistically significant. For three of the 23 subject areas the effect size of the relationship was $0.1 < \phi < 0.3$, namely 'Andrology', 'Biology', and 'Life Sciences & Biomedicine – Other Topics'[32].

Table 6.17: Phi-coefficient and difference between percentage of open access and non-open access journal articles among the 5% most frequently cited articles for subject areas in which the difference favours open access journal articles (2014)

	Non-OA		OA		Effect size	
Subject area	**Total**	**% in 5%**	**Total**	**% in 5%**	**Diff.**	**ϕ**
Andrology	354	3.1	125	10.4	7.3	0.147
Biology	8012	3.6	2884	9.4	5.8	0.115
Life Sciences & Biomedicine – Other Topics	8012	3.6	2884	9.4	5.8	0.115
Toxicology	9533	4.4	860	12.2	7.8	0.099
Art	4684	6.7	121	22.3	15.6	0.095
Primary Health Care	864	4.2	660	8.2	4.0	0.084
Virology	5524	4.1	1354	8.7	4.6	0.084
Family Studies⁺	2349	5.3	8	37.5	32.2	0.083
Physics, Nuclear	6934	4.9	1049	9.9	5.0	0.074
Engineering, Manufacturing⁺	5593	5.0	29	27.6	22.6	0.074
Mycology⁺	1887	4.7	91	12.1	7.4	0.071
Optics	23759	4.4	6058	7.6	3.2	0.059
Astronomy & Astrophysics	18118	5.0	1166	9.2	4.2	0.044
Classics*	875	11.0	48	16.7	5.7	0.040
Crystallography	6646	5.6	92	13.0	7.5	0.038
Tropical Medicine	1664	4.1	1868	5.8	1.6	0.037
Medical Informatics	3019	4.4	340	6.8	2.4	0.034
Geography, Physical	5333	5.0	362	8.0	3.0	0.033
Physical Geography	5333	5.0	362	8.0	3.0	0.033
Meteorology & Atmospheric Sciences	9712	4.8	2704	6.5	1.7	0.032

[32] Considered a duplicate of 'Biology', see Chapter 4 (sub-section 4.2.1.5).

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Subject area	Non-OA Total	Non-OA % in 5%	OA Total	OA % in 5%	Effect size Diff.	Effect size ϕ
Physiology	8802	4.8	1506	6.6	1.7	0.028
Literature, Romance*	1725	5.3	132	7.6	2.2	0.025
Computer Science, Interdisciplinary Applications	14152	4.8	198	9.1	4.3	0.023
Water Resources	12376	5.0	963	6.9	1.9	0.022
Mining & Mineral Processing*+	2679	5.4	74	8.1	2.7	0.019
Mineralogy*+	2665	5.1	79	7.6	2.5	0.018
Geosciences, Multidisciplinary	19272	5.1	2578	6.4	1.2	0.018
Biochemical Research Methods	14678	4.8	1681	5.9	1.1	0.016
Biochemistry & Molecular Biology	60892	4.9	6858	6.0	1.1	0.016
Geriatrics & Gerontology*	5210	5.0	979	5.8	0.9	0.014
Law*	4477	5.4	187	7.0	1.6	0.014
Microbiology*	16354	4.8	2891	5.6	0.8	0.013
Geology	21473	5.0	2899	5.9	0.9	0.013
Physics, Particles & Fields*	10614	5.2	1683	6.0	0.8	0.013
Integrative & Complementary Medicine*	2602	5.0	1214	5.5	0.5	0.011
Parasitology*	3017	4.9	3265	5.3	0.4	0.009
Engineering, Aerospace*+	3207	6.2	23	8.7	2.5	0.009
Engineering, Petroleum*	1981	5.5	128	6.3	0.8	0.008
Theater*+	1054	7.9	11	9.1	1.2	0.005
Gerontology*	2567	5.3	213	5.6	0.3	0.004
Limnology*+	1898	5.2	74	5.4	0.2	0.002
Public, Environmental & Occupational Health*	21727	5.1	6609	5.1	0.0	0.001

* chi-square test for independence results not statistically significant: $p > 0.01$
+ expected value: < 5.

In 140 subject areas the difference between OA journal articles and non-OA journal articles was statistically significant ($p < 0.05$), and favoured non-OA articles. For nine of these subject areas the effect size of the relationship was $0.1 \leq \phi < 0.3$.

6.5.3. The 10% most frequently cited articles

The last measure of citation advantage that was investigated for this study was the percentage of articles among the 10% most frequently cited articles.

6.5.3.1. Articles published during the entire time frame

In 31 subject areas, the percentage of articles among the 10% most frequently cited articles was higher for OA journal articles than for non-OA journal articles, when considering the period as a whole. The

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results for these are summarised in Table 6.18. The results for all the subject areas are summarised in Addendum F.1. Of these 31 subject areas, only for 'Psychology, Social' was the expected value < 5. In total, there were 23 subject areas in which the difference was statistically significant ($p < 0.05$). Of these, there were three subject areas in which $\phi > 0.1$, namely 'Optics', 'Primary Health Care', and 'Virology'.

Table 6.18: Phi-coefficient and difference between percentage of open access and non-open access journal articles among the 10% most frequently cited articles for subject areas in which the difference favours open access journal articles (2005–2014)

	Non-OA		OA		Effect size	
Subject area	**Total**	**% in 10%**	**Total**	**% in 10%**	**Diff.**	**ϕ**
Virology	52 748	8.7	8 650	19.5	10.8	0.124
Optics	200 305	9.1	36 869	18.3	9.1	0.108
Primary Health Care	8 017	8.5	4 249	15.5	6.9	0.106
Toxicology	86 330	9.2	7 880	18.3	9.1	0.084
Engineering, Petroleum	16 234	8.9	1 198	17.4	8.6	0.074
Parasitology	27 828	8.3	17 458	12.5	4.2	0.068
Classics	7 294	13.1	371	22.9	9.8	0.061
Family Studies	18 043	9.9	234	25.2	15.3	0.057
Engineering, Manufacturing	47 084	10.2	426	26.8	16.5	0.051
Meteorology & Atmospheric Sciences	80 119	10.0	17 676	13.3	3.3	0.041
Biology	69 904	9.7	17 232	12.1	2.4	0.032
Life Sciences & Biomedicine – Other Topics	69 904	9.7	17 232	12.1	2.4	0.032
Andrology	3 112	8.5	1 060	10.5	2.0	0.030
Mycology	17 936	10.0	497	15.1	5.1	0.027
Integrative & Complementary Medicine	19 473	10.2	5 389	12.0	1.9	0.025
Microbiology	159 162	9.6	15 941	11.6	2.0	0.019
Computer Science, Interdisciplinary Applications	110 998	10.3	1 174	15.4	5.1	0.017
Biochemistry & Molecular Biology	596 525	9.9	46 860	11.9	1.9	0.017
Area Studies	18 194	10.3	155	15.5	5.2	0.016
Tropical Medicine	14 788	10.1	11 776	11.0	0.8	0.013
Geography, Physical	39 242	10.7	1 438	12.8	2.1	0.012
Physical Geography	39 242	10.7	1 438	12.8	2.1	0.012
Biochemical Research Methods	137 286	10.1	12 254	11.4	1.3	0.012
Law	40 641	10.7	1 322	12.6	1.8	0.010
Industrial Relations & Labor	7 099	10.2	791	11.0	0.8	0.007
Education, Scientific Disciplines	26 661	10.2	3 607	10.7	0.5	0.005
Medical Informatics	25 061	10.3	1 831	10.8	0.5	0.004
Psychology, Social	32 026	10.4	33	12.1	1.8	0.002

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Subject area	Non-OA		OA		Effect size	
	Total	% in 10%	Total	% in 10%	Diff.	ϕ
Water Resources	92 014	10.7	5 794	10.9	0.2	0.002
Health Policy & Services	38 843	10.1	3 674	10.2	0.1	0.001
Environmental Sciences	291 221	10.4	15 099	10.5	0.1	0.001

* chi-square test for independence results not statistically significant: $p > 0.01$:
+ expected value: < 5.

There were 190 subject areas in which the difference favoured non-OA journal articles and in which the difference was statistically significant ($p < 0.05$). For 12 of these, the effect size of the relationship was $0.1 \leq \phi < 0.3$.

It should also be noted that in six subject areas, all the articles, whether published in OA journals or non-OA journals, were among the 10% most frequently cited. These subject areas were ‘Art’, ‘Film, Radio & Television’, as well as its duplicate, ‘Literature, Romance’, ‘Literature, Slavic’, and ‘Music’. This was due to the low percentage of articles that were cited within two years after publication in these subject areas, as shown in Table 6.19. More than 90% of the non-OA and OA journal articles remain uncited; thus any cited article is among the 10% most frequently cited.

Table 6.19: Mean normalised citation scores and percentage of articles cited, for open access and non-open access journal articles in selected subject areas

Subject area	Number of articles		MNCS		% cited	
	Non-OA	OA	Non-OA	OA	Non-OA	OA
Art	45 395	869	0.97	1.74	5.3	17.8
Film, Radio & Television	25 497	238	1.00	0.43	7.2	6.7
Literature, Romance	15 283	1 181	0.62	0.39	4.3	3.3
Literature, Slavic	3 410	170	0.68	0.29	4.5	2.4
Music	49 285	106	0.98	0.24	5.6	1.9

6.5.3.2. Articles published in 2014

In 43 subject areas, a higher percentage of OA than non-OA journal articles were among the 10% most frequently cited articles. The results for these are summarised in Table 6.20, and the results for all the subject areas can be found in Addendum F.2. For two of these 44 subject areas, ‘Family Studies’ and ‘Engineering, Manufacturing’, the expected value was < 5. The difference was statistically significant ($p < 0.05$) for 29 subject areas, and the effect size of the relationship was $0.1 < \phi < 0.3$ in six subject

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areas, namely 'Andrology', 'Biology', 'Engineering, Manufacturing', 'Life Sciences & Biomedicine – Other Topics[33]', 'Tropical Medicine', and 'Virology'.

Table 6.20: Phi-coefficient and difference between percentage of open access and non-open access journal articles among the 10% most frequently cited articles for subject areas in which the difference favours open access journal articles (2014)

	Non-OA		OA		Effect size	
Subject area	**Total**	**% in 10%**	**Total**	**% in 10%**	**Diff.**	**ϕ**
Andrology	354	8.2	125	18.4	10.2	0.144
Biology	8 012	8.3	2 884	15.3	7.0	0.102
Engineering, Manufacturing+	5 593	10.1	29	58.6	48.5	0.114
Life Sciences & Biomedicine – Other Topics	8 012	8.3	2 884	15.3	7.0	0.102
Tropical Medicine	1 664	6.6	1 868	13.2	6.6	0.109
Virology	5 524	8.2	1 354	18.2	10.1	0.132
Astronomy & Astrophysics	18 118	10.1	1 166	13.5	3.3	0.026
Biochemical Research Methods	14 678	9.7	1 681	11.9	2.2	0.022
Biochemistry & Molecular Biology	60 892	9.9	6 858	11.1	1.2	0.012
Crystallography	6 646	10.8	92	17.4	6.6	0.025
Education, Scientific Disciplines	3 002	9.5	592	12.8	3.3	0.041
Ethics	1 980	9.6	261	13.8	4.2	0.045
Family Studies+	2 349	10.0	8	37.5	27.5	0.053
Geography, Physical	5 333	10.6	362	14.6	4.1	0.032
Geology	21 473	10.0	2 899	11.7	1.7	0.018
Geosciences, Multidisciplinary	19 272	9.9	2 578	12.6	2.8	0.030
Geriatrics & Gerontology	5 210	9.8	979	12.6	2.7	0.033
Industrial Relations & Labor	894	9.7	81	19.8	10.0	0.090
Law	4 477	10.9	187	19.8	8.9	0.055
Meteorology & Atmospheric Sciences	9 712	9.8	2 704	14.8	5.0	0.067
Microbiology	16 354	9.7	2 891	11.8	2.1	0.026
Optics	23 759	9.0	6 058	15.1	6.1	0.081
Parasitology	3 017	8.5	3 265	11.4	2.8	0.047
Physical Geography	5 333	10.6	362	14.6	4.1	0.032
Physics, Nuclear	6 934	10.3	1 049	17.3	7.0	0.075
Physiology	8 802	9.8	1 506	13.5	3.7	0.042
Primary Health Care	864	7.9	660	12.9	5.0	0.083
Toxicology	9 533	9.3	860	17.9	8.6	0.079
Water Resources	12 376	10.1	963	12.9	2.8	0.024

[33] Considered a duplicate of 'Biology', see Chapter 4 (sub-section 4.2.1.5).

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Subject area	Non-OA Total	Non-OA % in 10%	OA Total	OA % in 10%	Effect size Diff.	Effect size ϕ
Audiology & Speech-Language Pathology*	2 087	10.1	74	10.8	0.7	0.005
Classics*	875	11.0	48	16.7	5.7	0.040
Computer Science, Interdisciplinary Applications*	14 152	9.9	198	11.6	1.7	0.007
Education & Educational Research*	13 333	10.4	1 161	12.0	1.5	0.014
Health Care Sciences & Services*	9 432	10.0	1 863	10.3	0.4	0.004
Integrative & Complementary Medicine*	2 602	10.4	1 214	11.0	0.7	0.010
Medical Ethics*	695	10.4	240	10.4	0.1	0.001
Medical Informatics*	3 019	9.0	340	11.2	2.1	0.022
Mineralogy*	2 665	11.2	79	11.4	0.2	0.001
Mining & Mineral Processing*	2 679	10.8	74	13.5	2.7	0.014
Mycology*	1 887	10.3	91	12.1	1.8	0.012
Physics, Multidisciplinary*	19 284	11.1	3 890	11.4	0.3	0.003
Physics, Particles & Fields*	10 614	10.4	1 683	11.3	0.9	0.010
Rehabilitation*	7 050	9.9	927	10.8	0.9	0.009

* chi-square test for independence results not statistically significant: $p > 0.01$.
+ expected value: < 5.

In 160 subject areas the difference between OA journal articles and non-OA journal articles was statistically significant ($p < 0.05$) and favoured non-OA articles. For 19 of these subject areas the effect size of the relationship was $0.1 \leq \phi < 0.3$. For one subject area, 'Multidisciplinary Sciences' this was $0.3 \leq \phi < 0.5$, in other words, the strength of the association was moderate. Similar to the previous discussion, when considering all the publication years, there are nine subject areas in which all articles were among the 10% most frequently cited, namely 'Art', 'Film, Radio & Television' and its duplicate, 'Folklore', 'Literature', 'Literature, Romance', 'Literature, Slavic', 'Music', 'and 'Theater'.

6.6. Chapter conclusion

The previous chapter showed that there was no general OA citation advantage for OA journal articles if all the articles published in the years 2005 to 2014, as indexed in WoS, were considered. However, the effect sizes were too small to conclude that there was any substantial association between access status and the measures of citation advantage. It was argued that this lack of substantial effect size could potentially be attributed to the fact that citation behaviour differs considerably between subject areas. This chapter determined whether this was the case by examining the OA citation advantage separately for subject areas.

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To provide some context for this analysis, the chapter started with a description of the presence of OA journal articles across subject areas. One of the first findings reported in this chapter was that OA journal publishing is a relatively new occurrence for some subject areas. In certain subject areas no OA journal articles were published for the total period. In other subject areas, OA journal publishing only started in later years, some in which OA journal articles were published for intermittent years. Such lack of consistent presence of OA journal articles raises questions regarding the reliability of the gold OA label in WoS. It could, however, also suggest that in those subject areas, the OA journal articles were published in single OA journals or newly launched journals. While this was not examined further, it complicates the conclusions that can be drawn about subject areas in which few OA journal articles were published.

Another result presented in this chapter is that, even if subject areas in which few OA journal articles were published or those in which such articles only published for intermittent years are excluded, the percentage of OA journal articles differs significantly between subject areas. No general statement can be formulated that would be valid for all subject areas, as not all subject areas experienced an increase in the percentage of OA journal articles published over the years. Even when the entire time frame is investigated, the percentage of OA journal articles differs considerably among the individual subject areas, and from the overall percentage of articles published in WoS indexed journals, as presented in Chapter 5. While the percentage of OA journal articles in the citation index as a whole was 8.6%, the majority of subject areas exhibited a lower percentage of between 0 and 5% for the years 2005 to 2014. The results regarding the percentage of OA journal articles in specific subject areas correspond in most cases with what was found for similar years by other studies.

A combination of tests for statistical significance and effect size to determine whether either non-OA journal articles or OA journal articles experience a citation advantage did not produce large enough effect sizes in most subject areas. This is the case even when only investigating articles published in a single year. The measure, that considered the 1% most frequently cited articles, produced an interpretable effect size in only one subject area, if all the articles published within the ten years are considered, and for two subject areas if only the articles published in 2014 are considered. This is likely due to the presence of subject areas in which there is little difference in their percentages, with the statistical test being sensitive to even small differences. For these measures, a two-year citation window could also be problematic, with articles not mature enough to allow for differentiation between them. When considering the measure based on the percentage of articles among the 10% most frequently cited articles, the statistically significant test for the articles published during the years 2005 to 2014 produced peculiar results for certain subject areas, due to the low percentage of

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articles that had been cited at all. This illustrates how percentile-based measures (specifically those based on short citation windows) are ill-suited for subject areas that receive only a few or no citations in the first two years after publication. However, it may also be due to the presence of additional confounding variables, the investigation of which was beyond the scope of this study.

The results reported in this chapter show that the measure of citation advantage that produced an interpretable effect size for the largest number of subject areas was whether an article was cited within the first two years after publication. This provided an interpretable effect size for the relationship between the variables in 61 of the subject areas, if all the articles from 2005 to 2014 were considered. The second measure, which compared MNCSs, provided such results for 30 of the subject areas. Of the three percentile measures, the presence among the 10% most cited articles produced statistically significant results with a sufficient effect size in the largest number of subject areas, but which was still only 15. A summary of this comparison is presented in Table 6.21.

Table 6.21: Number of subject areas that experienced an open access citation advantage (2005–2014)

Measure of citation advantage	OA higher score/percentage than non-OA	Subject areas with statistically significant difference between OA and non-OA journal articles		Subject areas with effect size ≥ 0.1	
		Total	OA	Total	OA
MNCS	29	225	20	30	2
Percentage cited	39	220	32	61	4
1%	35	182	19	1	0
5%	29	212	21	8	1
10%	31	213	23	15	3

Total subject areas in which any OA journal articles were published: 243.

Only five subject areas showed an OA citation advantage (with an effect size of ≥ 0.1) for any of the measures when examining articles published for all the years. These were ‘Engineering, Petroleum’, ‘Materials Science, Paper & Wood’, ‘Optics’, ‘Primary Health Care’, and ‘Virology’. For each measure, the number of subject areas that showed interpretable results were higher if only the articles published in 2014 were considered, as shown in Table 6.22.

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Table 6.22: Number of subject areas that experienced an open access citation advantage (2014)

Measure of citation advantage	OA higher score/percentage than non-OA	Subject areas with statistically significant difference between OA and non-OA journal articles		Subject areas with effect size ≥ 0.1	
		Total	OA	Total	OA
MNCS	43	191	20	41	7
Percentage cited	52	189	26	67	5
1%	40	100	14	2	1
5%	42	166	26	12	3
10%	43	189	29	26	6

Subject areas with OA journal articles: 242.

In 2014, there were 11 subject areas (one a potential duplicate) that experienced an OA citation advantage with an effect size of ≥ 0.1 for the relationship. These subject areas are ‘Andrology’, ‘Biology’, ‘Engineering, Manufacturing’, ‘Industrial Relations & Labor’, ‘Life Sciences & Biomedicine – Other Topics ‘[34], ‘Toxicology’, ‘Virology’, ‘Tropical Medicine’, ‘Primary Health Care’, ‘Physics, Nuclear’, and ‘Optics’. A very small number of subject areas thus experienced any type of OA citation advantage. However, this does not imply that all other subject areas experienced a non-OA journal citation advantage, as shown throughout this chapter.

[34] Considered a duplicate of ‘Biology’, see Chapter 4 (sub-section 4.2.1.5.)

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CHAPTER 7:
Conclusions and recommendations

7.1. Introduction

This chapter presents a summary of the results of the current study, and relates these to the relevant literature, specifically those discussions on the age of journals and perceptions of OA journals. This summary includes a reflection on the possible effect megajournals have on the number of citations OA journal articles receive. Additionally, the chapter reflects and comments on the nature of the OA tag in WoS, and how this had changed since the start of this study in 2015. Combining the insights gained from these, the chapter concludes with suggestions for future studies on OA citation advantage.

7.2. Presence of open access journal articles

OA journal articles have increased considerably over the years investigated, with 13.1% of all articles published in 2014 appearing in OA journals, while in 2005, this was the case for only 3.3% of articles. While the vast majority of subject areas had, by 2014, exhibited an increase in the percentage of articles published in OA journals, in only three of these were the majority of articles published in these journals, namely ‘Multidisciplinary Sciences’ (72.7%), ‘Tropical Medicine’ (52.9%), and ‘Parasitology’ (52.0%). Thus, although the growing popularity of this type of journal in certain subject areas is evident from the results, OA journals are far from replacing the subscription model of article distribution.

Indeed, in 31 subject areas, no OA journal articles were published during the ten years investigated. These results do not necessarily indicate a lack of OA to the academic literature in these subject areas, as OA can be obtained through other means, such as self-archiving. The results only indicate that, for these subject areas, no WoS-indexed journal made use of this publication model during the study period. On the other hand, most of the subject areas that had OA journal articles published from 2005 to 2014 exhibited an increase in the percentage of OA journal articles. This increase might be due to the inclusion of many newly launched journals indexed in WoS. For 52 subject areas, OA journal publishing (through WoS-indexed journals) seems to have begun relatively recently, i.e. after 2005. In two subject areas (‘Literature, Slavic’ and ‘Women’s Studies’), the first OA journal articles appeared only in 2014, which means that OA journal publishing is relatively new in these subject areas.

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7.3. Summary of findings regarding the open-access-citation-advantage hypothesis

This study set out to test the hypothesis that OA journal articles published from 2005 to 2014 and indexed in WoS experienced a citation advantage in comparison to non-OA journal articles. Three different measures of citation advantage were applied to determine whether this was the case. These three measures compared OA journal and non-OA journal articles in terms of the MNCS, the percentage of articles that are cited within two years after publication, and the percentage of articles that are among the highest cited articles.

When investigating all articles published from 2005 to 2014, without investigating the subject areas separately, no OA citation advantage was observed. Furthermore, not only was a higher percentage of non-OA journal articles cited, but their MNCS was also higher, and a higher percentage of articles was found among the 1%, 5%, and 10% most frequently cited articles. However, it was also noted that the strength of the association between the different measures of citation advantage on the one hand, and the access status of articles, on the other hand, was weak. Even when 'year of publication' was controlled for, no substantially stronger associations were observed. Thus, any general claim that publishing in an OA journal would necessarily lead to a citation disadvantage is unwarranted. A similar conclusion was reached by Dorta-González *et al.* (2017: 894). It is likely (as informed by the small effect size) that factors other than access status better explain differences between articles in terms of the number of citations they receive. It is possible that the differences between subject areas could account for the variability observed, as previous studies have found that articles in certain subject areas, and not others, experience an OA citation advantage.

Differences between subject areas were identified when they were investigated separately. In some subject areas, the differences between OA journal articles and non-OA journal articles, in terms of the measures of citation advantage, were statistically significant, and the OA journal articles experienced a citation advantage. However, the association for most subject areas was again weak, with access status accounting for less than 1% of the variability in the measures of citation advantage. When all the articles published in the ten years were considered, it was found that OA journal articles in five subject areas experienced a citation advantage for some of the measures, and access status accounted for 1% or more (but less than 9%) of the variability. These subject areas and the measure(s) for which they experienced an OA citation advantage are summarised in Table 7.1.

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Table 7.1: Subject areas that experienced an open access citation advantage with an effect size of ≥ 0.1 for any of the measures of citation advantage (2005–2014)

Subject area	MNCS	Cited	1%	5%	10%	Number of measures OA citation advantage
Primary Health Care	Yes	Yes		Yes	Yes	4
Virology	Yes				Yes	2
Optics		Yes			Yes	2
Engineering, Petroleum		Yes				1
Materials Science, Paper & Wood		Yes				1
Number of subject areas	2	4	0	1	3	

When only those articles published in 2014 were considered, 11 subject areas showed a citation advantage for OA journal articles on some of these measures, and in those areas, access status accounted for more than 1% (but less than 9%) of the variability in the measures. These subject areas, together with the measure(s) for which their OA journal articles experienced a citation advantage, are summarised in Table 7.2. The subject areas that experienced an OA citation advantage for at least one measure, applied to articles published in all the years and in 2014, were –

- 'Primary Health Care' (NCS);
- 'Optics' (for whether an article was cited); and
- 'Virology' (NCS, and whether an article was among the 10% most frequently cited articles).

Table 7.2: Subject areas that experienced an open access citation advantage with an effect size of ≥ 0.1 for any of the measures of citation advantage (2014)

Subject area	MNCS	Cited	1%	5%	10%	Number of measures with OA citation advantage
Andrology	Yes	Yes		Yes	Yes	4
Tropical Medicine	Yes	Yes			Yes	3
Virology	Yes				Yes	2
Engineering, Manufacturing	Yes		Yes		Yes	2
Biology				Yes	Yes	2
Life Sciences & Biomedicine – Other Topics				Yes	Yes	2
Industrial Relations & Labor	Yes	Yes				2
Toxicology	Yes					1
Primary Health Care	Yes					1
Physics, Nuclear		Yes				1
Optics		Yes				1
Number of subject areas	7	5	1	3	6	

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There were also subject areas in which non-OA journal articles experienced a citation advantage, and in which access status accounted for more than 1%, but less than 9%, of the variability. This was the case for 65 subject areas, when all the articles published in the ten years were considered (as summarised in Addendum H.1). When only those articles published in 2014 were considered, a citation advantage for non-OA journal articles was observed, with access status accounting for more than 1% of the variation in the measure of citation advantage for 69 subject areas (see Addendum H.2). For six of these subject areas, access status accounted for more than 9% (but less than 25%) of the variability. For five of these subject areas, this was observed for the measurement whether articles were cited within two years. These subject areas were 'Mathematics, Interdisciplinary Applications', 'Engineering, Multidisciplinary', 'Agricultural Economics & Policy', 'Anthropology' and 'Agricultural Engineering'. 'Multidisciplinary Sciences' showed a moderate effect size ($0.3 \leq \phi < 0.5$) for whether articles were among the 10% most frequently cited articles.

While there were subject areas where OA journal articles experienced a citation advantage, for most subject areas, there was substantial variation in the number of citations OA and non-OA journal articles receive. Investigating the individual subject areas clarified our understanding of the OA citation advantage, illustrating that, while access status affects the number of citations articles received, this association is weak. To be able to formulate more comprehensive claims about the characteristics of OA journal articles, and how these affect the number of citations such articles receive, factors beyond access status need to be investigated. This is required not only to identify potential confounding variables, but also to identify whether there are other factors, beyond access status, that explain a larger degree of the variance in the number of citations articles receive.

7.4. Relating the results to the literature

The literature review showed that various factors may influence the number of citations articles receive. Among the factors discussed were the various reasons why OA journal articles might experience a citation advantage, of which not all are necessarily related to the access status of the articles. Included in the review were also various explanations for why OA journal articles might not experience a citation advantage. These are related to social biases present in the process of citation, the characteristics of OA journals, and the presence of predatory journals. The following two sub-sections elaborate upon the way in which perceptions of OA journals and the characteristics of megajournals may explain some of the results summarised in the previous section.

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7.4.1. Suggested association between open access presence and open access citation advantage

The lack of a citation advantage for OA journal articles could be explained partially by the perception of the quality of the articles published in OA journals. The unscrupulous practices of predatory journals, have the potential to raise scepticism among authors when they encounter any unknown OA journal that requires them to pay an APC to publish their article in the journal. Due to the relatively new occurrence of OA journals, many of them are unknown, or at least less established in their fields, in comparison to some of the subscription-based journals, which have long publishing histories predating the Internet. There is also a perception that OA journals accept articles of lower quality (see Beall, 2016; Sotudeh & Horri, 2009; Van Noorden, 2013), and that they lack rigorous peer reviewing (Xia, 2010). Such perceptions may lead authors to publish their lower-quality articles in OA journals, i.e. those articles that would have received a low number of citations, regardless in which journal they were published. In turn, these publication and citation practices may lead to articles published in OA journals receiving a lower number of citations, due to factors related to the perception and prestige of the journals and not its access status (Sotudeh & Horri, 2008).

Based on the current study, it seems plausible that the misidentification of OA journals as predatory journals is more pervasive in subject areas in which OA publishing is a new or rare occurrence. There are 59 subject areas in which OA journal publishing does not yet seem to be established, as indicated by a lack of OA journal articles published in all of the years investigated. It could be argued that OA journal articles in these subject areas are unlikely to experience a citation advantage, due to the social biases against OA publishing. However, it is unlikely that the statistical tests applied in the current study would provide any conclusive evidence for most of these subject areas, due to the small number of publications rendering the results of such tests statistically not significant. While in some of these subject areas the OA journal articles had a higher MNCS, or their percentages for the other measure of citation advantage were higher and the difference was statistically significant, none of these showed a notable association between access status and any measure of citation advantage. To describe and understand the association between low presence of OA journals and citation advantage further would not only require journal-level analysis to gather more information regarding the number of OA journals in these subject areas, and whether these journals are long-established, but also an investigation into the perception of authors in these fields, which was beyond the scope of this study.

On the other hand, this issue could be approached from the opposite perspective. If the suggestion is that in subject areas in which OA journal publishing is new, or in which there are only a few such publications, OA journal articles are less likely to experience a citation advantage, then the question

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is whether OA journal articles published in subject areas in which OA journal publishing is more established, tend to experience a citation advantage. From a cursory examination of the 2014 results, this did not seem to be the case. Of the five subject areas with the highest percentages of articles published in OA journals –

- 'Tropical Medicine' (52.9%) and 'Primary Health Care' (43.3%) experienced a citation advantage for OA journal articles, based on their MNCS, with an effect size of > 0.1;
- 'Multidisciplinary Sciences' (72.7%) and 'Science & Technology – Other Topics' (48.3%) experienced a citation advantage for non-OA journal articles on multiple measures, with an effect size of > 0.1; and
- 'Parasitology' (52.0%) had a higher score for all the measures of citation advantage for OA journal articles than for non-OA journal articles, but the effect sizes were < 0.1.

The results for 'Multidisciplinary Sciences' and 'Science & Technology – Other Topics' could reflect the effect the policies of megajournals have on the number of citations of articles.

7.4.2. Megajournals

Megajournals potentially contribute a large proportion of the OA journal articles in those subject areas in which a comparatively large percentage of articles are OA journal articles. A notable example is *PLoS One*, which published over 29 700[35] articles in 2014 alone, accounting for approximately 2% of all articles published in that year, and 15% of all OA journal articles published in 2014. Articles published in *PLoS One* constituted more than 74% of all OA journal articles published in 'Multidisciplinary Sciences' in 2014 and more than 54% of all the articles published in 'Multidisciplinary Sciences' in that year. However, these estimates do not account for the possibility of individual articles in multidisciplinary journals being classified into other subject areas (Thomson Reuters, 2018: 7). The aforementioned statistics merely serve as an example to emphasise the need for further examination of the subject areas with a high percentage of OA journal articles and megajournals. Selected other megajournals indexed in WoS (Binfield, 2014: 158; Björk, 2013: 9; Eve, 2015: 147) and journals published by the Public Library of Science (PLoS) are listed in Table 7.3, together with their associated subject areas (as retrieved from the web portal of WoS on 30 June 2018), to highlight subject areas that could be investigated in future.

[35] Estimates based on counts for article-type documents published in *PLoS One*, as reported by the web version of WoS.

Table 7.3: Description of the Web of Science subject areas assigned to selected open access megajournals

Subject area	***PLoS One***	***PLoS Genetics***	***PLoS Pathogens***	***PLoS Neglected Tropical Diseases***	***PLoS Computational Biology***	***PLoS Biology***	***PLoS Medicine***	***PLoS Clinical Trials***	***PLoS Currents***	***Nature: Scientific Reports***	***Sage Open***
Multidisciplinary Sciences	*								*	*	
Parasitology			*	*							
Genetics Heredity		*									
Microbiology			*								
Virology			*								
Infectious Diseases				*							
Tropical Medicine				*							
Biochemical Research Methods					*						
Mathematical Computational Biology					*						
Biochemistry Molecular Biology						*					
Biology						*					
Medicine General Internal							*				
Medicine Research Experimental								*			
Pharmacology Pharmacy								*			
Social Sciences, Interdisciplinary											*

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A notable feature of *PLoS One*, and one common among megajournals, is the practice of publishing articles based on the methodological soundness of the content, but not necessarily its novelty (Binfield, 2014: 158; Björk, 2013: 9; Eve, 2015: 147). This may also influence the results of the measure of citation advantage observed for those subject areas in which megajournals are a prominent characteristic of the OA publishing scene, because quality and novelty have an effect on the number of citations an article receives. OA journal articles do not experience a citation advantage in 'Multidisciplinary Sciences'; rather, it is one of the subject areas which experiences a notable ($\phi \geq 0.1$) non-OA citation advantage, on the measure of the percentage of articles among the 10% most frequently cited. On the other hand, some of the PLoS journals, which are not megajournals, publish articles in the subject areas 'Virology', 'Tropical Medicine', and 'Biology', which do experience a citation advantage for OA journal articles on some of the measures. It would be informative to investigate the subject areas related to these journals, in order to identify the additional factors affecting the number of citations articles receive. This also highlights the need to investigate journal characteristics beyond the access status of the journal, when investigating the association between access status and the number of citations articles receive.

7.5. Methodological reflection on citation analysis and the open access tags of the Web of Science

This study commenced in 2015. In the preceding year (2014) WoS introduced a tag in their microdata that identifies those articles which are published in a fully OA journal (Thomson Reuters, 2014; Torres-Salinas *et al.*, 2016). This study is one of the first to use this new tag to examine, through large-scale citation analysis, whether OA journal articles experience a citation advantage. Due to the recent inclusion of this tag, few researchers have had the opportunity to reflect on the nature of this tag or on the methodological considerations that need to be taken into account when using it to identify OA journal articles.

As noted in Chapter 5, the percentage of OA journal articles have seen a considerable increase from 2005 to 2014. The increase in the percentage of articles published in OA journals reflects an increase in newly launched journals. This is because established non-OA journals, which converted into OA journals, would have had their pre-conversion articles also indexed as OA journal articles. Consequently, no considerable increase in the percentage of articles that are OA journal articles would be observed as a result of such conversions. The fact that a substantial number of articles from what are most likely newly launched OA journals were compared to non-OA journal articles from established journals, confounds the results of the measure of citation advantage, as newly launched journals tend to receive fewer citations than established journals (Sotudeh & Horri, 2008: 73). While previous studies have at least noted that OA journals are mostly young journals, future studies would need to be

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cognisant of this characteristic, and of the retrospective application of the OA tag. Not only is this relevant when reporting on the increase of OA journal publications, but the presence of a substantial number of new journals is also a factor that would need to be controlled for in future studies on the number of citations OA journal articles receive.

The aforementioned observation about the presence of new OA journals in WoS is informed by WoS's practice to tag all articles in an OA journal retrospectively as OA journal articles, including those published at the time when the journal was a subscription journal. This leads to a second consideration, i.e. that the citations counted for some OA journal articles were received when they were still non-OA journal articles. The proportion of journals that changed access status is unknown and arduous to determine, as it would require examining individual journals, a task outside the scope of this study.

In 2018, the WoS web portal added additional OA tags, which include a category of articles rendered OA through the hybrid-OA option of a journal. The WoS Core Collection Help website explains that the data for the classification of articles are obtained from ImpactStory and the DOAJ. The tags for these categories operate as if they were mutually exclusive. In July 2018 the tags WoS used, and which formed part of the data provided when an export of the full records was requested, are shown in Figure 7.1 (Clarivate Analytics, 2018):

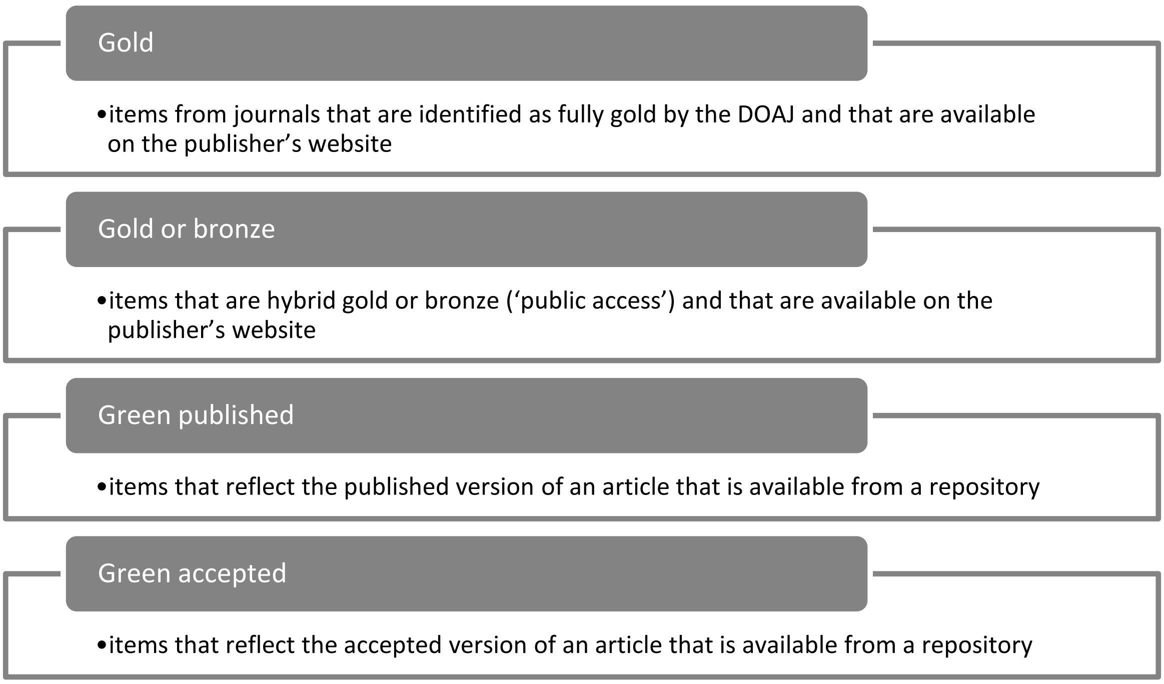

Figure 7.1: Open access tags available in the Web of Science online platform

This new classification system allows one to separate those articles rendered OA through other means than being published in fully OA journals, from the broader category of non-OA journal articles. However, the categories of the WoS platform are not truly mutually exclusive. For example, even when an article is published in a fully OA journal, it may also be uploaded to a repository, but the WoS

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platform will list it only as a gold OA journal article. Similar to the way in which subject categories were created for information retrieval, the OA tags seem to have been created primarily for article retrieval, rather than for citation analysis. Consequently, the broader category of 'gold or bronze' may also include articles rendered OA through transient or delay OA, because these are also available from the publisher's website. This renders it a particularly broad category and, while it would allow future citation analysts to compare – in the same journal and over a much larger scale than previously possible – the number of citations received for articles that are available for free with those that are not, the individual journal policies will still need to be investigated. It is unclear how to distinguish those articles that are OA articles due to a delayed OA policy from those whose authors elected to pay to render the article an OA article (in other words through a hybrid OA option). This also highlights the potential volatility[36] of the OA tag. It is unclear precisely what is included in the bronze OA tag. If delay and transient OA are also included in the definition, any data collection and analysis become particularly time-sensitive. This challenge is also applicable to green OA articles, as articles can be self-archived either before or after they have been published. It is clear that there is still much to be considered regarding the OA tags of WoS, which have seen several changes since their inception in 2014, to understand the methodological complications.

Due to the relative novelty of these tags, the extent of misclassification of publications is also unknown. Misclassification is present for other tags applied by WoS, for example, citation analysis studies often include both articles and reviews in their analysis, partially due to the known overlap of these categories (Harzing, 2013). Because of the extensive use of WoS microdata in research, the characteristics of their tags have become known, and future studies could be designed in a way that would take cognisance of these. However, such research has not yet been conducted in relation to the WoS OA tag. The current study identified some misclassification related to the OA journal tag, as discussed in Chapter 4. It was also observed, anecdotally, that the links for the green OA articles do not necessarily link to self-archived articles, but to grey literature with the same title as the published article. More studies investigating this tag are thus required to gain more clarity on its implementation in citation analysis.

[36] The OA tags and the content of the WoS Core Collection Help website, which were originally consulted for this study in 2018, were viewed again on 20 February 2019, in order to respond to examiners' requests for changes. It was clear that the 'Bronze' and 'Gold' OA tags had changed in the interim, which serves as another example of the volitatilty of the tag.

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7.6. Recommendations for future studies

The following two sub-sections present recommendations for future research informed by the findings of the current study. These pertain to additional factors, which should, ideally, be considered in combination with access status, when investigating the OA citation advantage, as well as potential case studies for future, in-depth analysis.

7.6.1. Additional factors to consider

The various factors identified in the literature as having an influence on the number of citations, were discussed in Chapter 3. The discussion specifically addressed those factors, which had either previously been investigated with access status (albeit for selected subject areas or other types of OA), or which could conceivably be associated with OA. However, due to the relatively limited scope of the current study, only the factors of 'subject area' and 'publication year' could be investigated. It is important to control for additional factors to gain a better understanding of the effect sizes observed. Previous studies (such as Atchison & Bull, 2015; Davis *et al.*, 2008; Vanclay, 2013) considered effect sizes when investigating the association between the number of citations and various other factors, such as access status (not limited to OA journal articles), although on a smaller scale. Vanclay, for example, studied a range of factors that could potentially have an effect on the number of citations of articles by the researchers in environmental science at the School of Environmental Science and Management received, and measured the strength of these associations by means of Pearson correlations (r) (see Bolboacă & Jäntschi, 2006). This provided a clearer understanding of the effect sizes observed in his study as the different relationships could be compared to each other, for example the number of authors an article has explained a larger degree of the variability (4.4%) in the number of citations that the articles received ($r = 0.21$) than the access status (2.9%) did ($r = 0.17$).

While additional factors could not be incorporated in the current study, as it ranged across multiple subject areas, in case studies, the following could prove useful to investigate:

- the previously mentioned additional access status tags now available in WoS;
- the year the journal was launched to determine whether it is a well-established journal;
- the language in which an article is published;
- the type of collaboration involved in producing an article, as deduced from the authors' affiliations;
- journal editorial policy related to novelty (particularly relevant to megajournals); and
- international or local scope of a journal.

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Earlier in this chapter, it was highlighted that a substantial number of OA journals might be newly launched journals. Future studies would either need to control for this by only comparing the articles from journals of a similar age, or by including the number of years since a journal had been launched as a variable and investigate its effect size on the measure(s) of citation advantage.

The language in which an article is published is an important factor in citation analysis, as it determines the audience that is able to use the article. However, as noted in the methodology chapter, in the WoS microdata, data on article language are available for only a small percentage of indexed articles. Not only is it, therefore, unknown whether OA journal articles are more likely than non-OA journal articles to be published in a language other than English, but it is also yet to be established to what extent this may account for the small effect sizes observed. For WoS as a whole, whether investigating only those articles that are known to be published in English, or all articles, leads to the same conclusion, as shown through the sensitivity analysis. However, this may not be the case for the individual subject areas. In the WoS microdata, language data are available for a larger percentage of articles published in more recent years (2015 and later) than in previous years. A study which only investigates more recent publications would thus be able to control for the effect language has on the number of citations articles receive.

Another factor that emerged from the literature review is that authors from developing countries are more likely than their counterparts in developed countries to use OA journals as their mode for providing gratis access to their articles (Sotudeh & Horri, 2009: 22). It has also been highlighted that many academic societies and local journals in developing countries have adopted the OA publishing model (Björk, 2011), for example through the SciELO platform, to increase the visibility of the content of these journals (Packer, 2014). Journals from developing countries might, therefore, be over-represented among the OA journal publications. These journals tend to have a local focus and articles published in them tend to receive fewer citations, which would better explain the absence of an OA journal citation advantage (Fukuzawa, 2017). Additionally, disciplines may differ in terms of the types of publishers of their OA journals, which range from small institutional publishers with a local focus, to large commercial publishers with an international focus (Torres-Salinas *et al.*, 2016: 23). These differences, especially between subject areas, provide a strong rationale for conducting focused case studies, in order to better understand OA publishing and the factors that influence whether articles in a subject area experience an OA journal citation advantage.

7.6.2. Subject areas for possible case studies

This study clearly showed that subject areas differ not only in terms of the presence of OA journal articles, but also in terms of any citation advantage derived from publishing in OA journals. To

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understand the unique dynamics operating in each subject area would require a case study approach to investigate these in more detail. One aspect already discussed in the current chapter that would require attention is the presence of megajournals in certain subject areas, and the way this may affect the number of citations OA journal articles receive.

Another factor which varies across subject areas is the presence of various OA mandates imposed by funders, such as the United States of America's national OA mandate for all research funded by the NIH (Caruso, Nicol & Archambault, 2014: 2). Certain subject areas also have large self-archiving repositories, for example arXiv, which cater for a range of subject areas, such as physics, mathematics, computer science, quantitative biology, quantitative finance, statistics and economics (Cornell University Library, 2018). It is conceivable that subject areas with a long history of pre-print circulation (such as physics) might not make use of OA journals, because within these subject areas gratis access is already achieved through self-archiving. To confirm whether this is the case, would require closer examination of self-archiving mandates, possibly using ROARMAP. ROARMAP serves as an online directory of funders, research organisations and sub-units of research organisations, which have self-archiving mandates (Gargouri *et al.*, 2010: 2). Consulting the SHERPA/RoMEO website (http://www.sherpa.ac.uk/romeo/search.php) could also assist in identifying the self-archiving policies of journals in a subject area. Additionally, openDOAR, a directory of OA repositories maintained by the University of Nottingham, which aims to list all OA repositories across the world, could be consulted to identify subject-specific repositories (Cullen & Chawner, 2011: 461).

Investigating individual subject areas also allows for the use of citation windows that are appropriate for the citation practices in a specific subject area. Using citation windows informed by the citation trends observed in a subject area would make measurements – such as whether an article is cited or not, or the percentile indicators – more meaningful. This is especially the case for those subject areas in which a substantially large percentage of articles were among the most frequently cited articles. For example, for 'Art', 'Film, Radio & Television', 'Literature', 'Music', and 'Theater', all the articles are among the 10% most frequently cited since more than 90% of articles have no citations in the two-year window; therefore, a two-year window seems inappropriate for these subject areas, as discussed in Chapter 4.

Lastly, when investigating individual subject areas or a small selection of subject areas, the changes across the years of each of the measures can be explored in more detail. For example, an examination of the two measures on which OA journal articles in 'Virology' experience a citation advantage, (with an effect size of > 0.1), shows that a considerable change occurred between 2006 and 2007, as presented in Figure 7.2 and Figure 7.3. This sudden change is not observed for the other subject areas in which OA journal articles experience a citation advantage, as is evident in Figure 7.4, which presents

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changes over time in the percentage of 'Optics' OA and non-OA journal articles that are cited within two years, and Figure 7.5, which compares the MNCS of OA journal and non-OA journal articles in 'Primary Health Care' over time. These subject areas would require further, in-depth analysis to understand the citation trends displayed by each better.

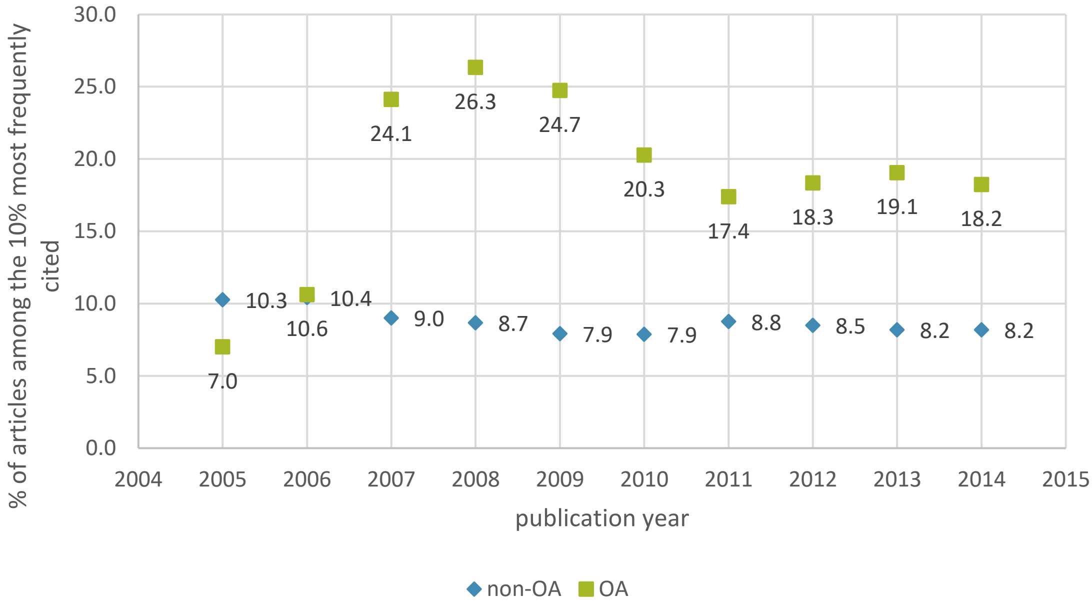

Figure 7.2: Percentage of 'Virology' open access and non-open access journal articles that are among the 10% most frequently cited articles (2005–2014)

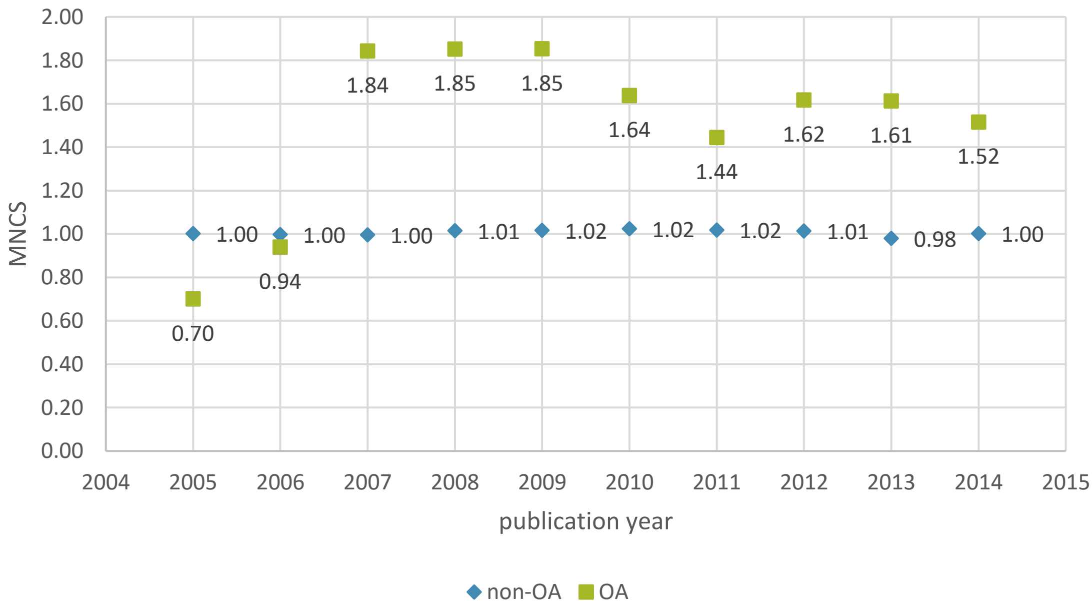

Figure 7.3: Mean normalised citation scores of 'Virology' open access and non-open access journal articles (2005–2014)

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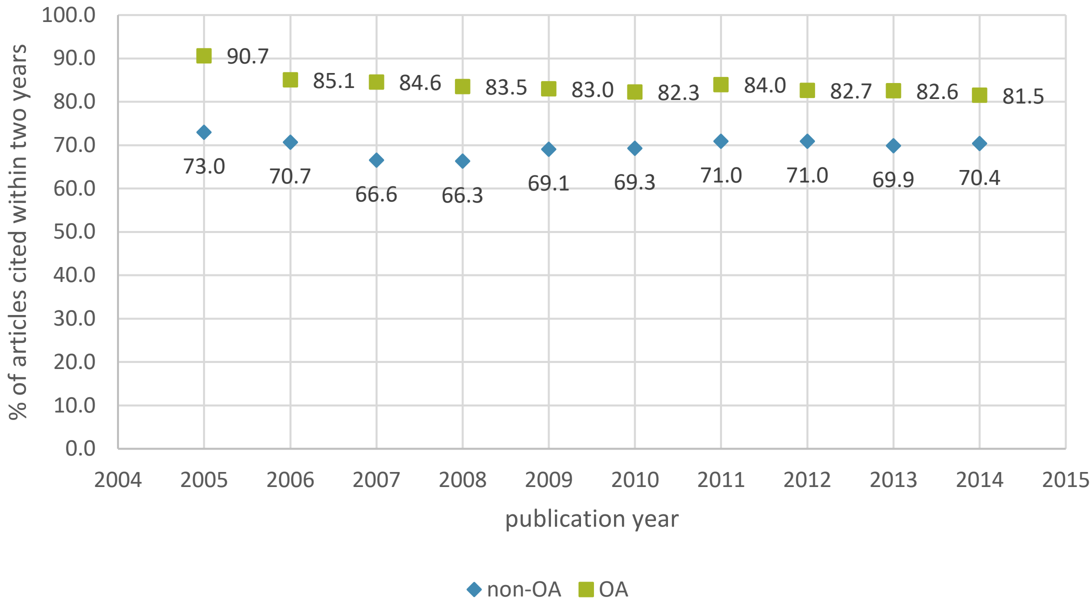

Figure 7.4: Percentage of 'Optics' open access and non-open access journal articles cited within two years (2005–2014)

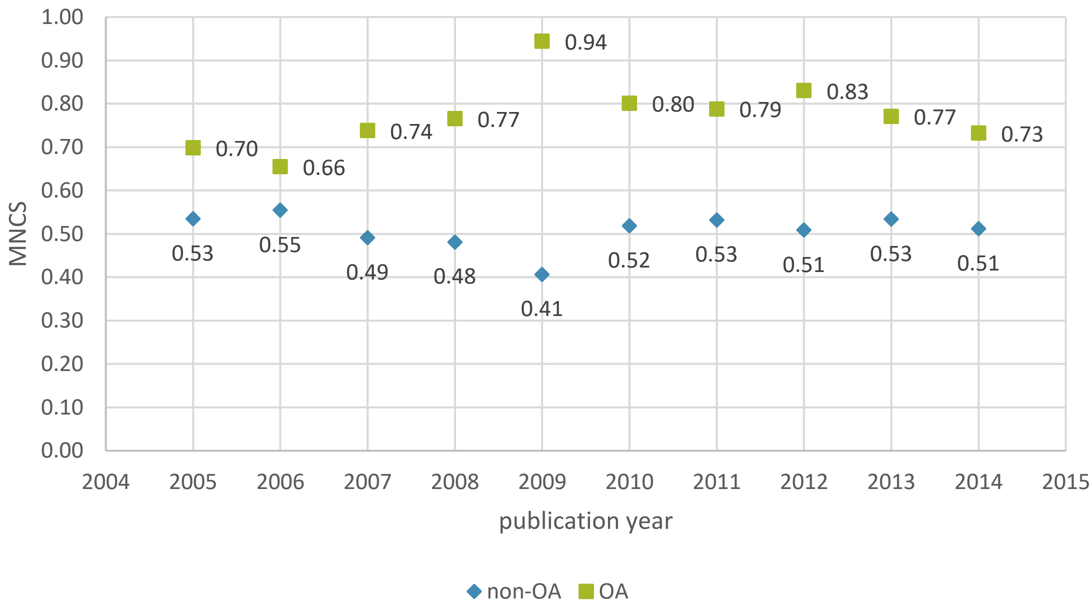

Figure 7.5: Mean normalised citation scores of 'Primary Health Care' open access and non-open access journal articles (2005–2014)

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7.7. Concluding remarks

This investigation of OA journal publication found a substantial increase in the number and percentage of OA journal articles, which was likely due to an increase in newly launched OA journals indexed in WoS. This finding emphasises the importance of understanding the characteristics of these journals and articles. At the same time, it is important to recognise that OA journal publishing is not the panacea it is sometimes made out to be. The nature of commercial academic publishing, the opportunities and drawbacks of digitalisation, predatory journals, public accessibility of science through the Internet, and the social biases involved in citation and publication all call for to a cautious approach to the promises of the OA movement.

While various advantages have been associated with OA publishing – from offering a potential reprieve from the serials crisis, to providing research articles to a larger number of scholars – the current study aimed to investigate empirical evidence pertaining to one specific, oft-repeated benefit, namely that OA publishing leads to a citation advantage. This issue was specifically investigated for OA journal articles in comparison to non-OA journal articles, as OA journal publishing has grown substantially over the past ten years, but in most subject areas, little is known about the number of citations articles published in such journals tend to receive.

This study determined that, for the majority of subject areas, OA journal articles do not experience a citation advantage. Thus, while it is reasonable to expect that OA journal articles would reach a wider audience, this is either not the case for the articles investigated, or an increased audience through OA journal publishing does not lead to significantly more citations. The relationship between the access status of an article and the number of citations it accrues seems to be more complex than the preceding argument implies. In most subject areas, access status and the measures of citation advantage investigated in this study show little association with each other, regardless of whether the measures favour OA or non-OA journal articles.

Nonetheless, investigating the strength of the relationships between access status and measures of citation advantage raised a number of intriguing issues, such as why in some subject areas, the articles experience a non-OA journal citation advantage the relationship experience an effect size of ≥ 0.3, while for none of the subject areas in which OA journal articles experience a citation advantage, is the effect size > 0.3. There are also questions regarding what distinguishes those subject areas in which the citation difference favours OA journal articles, but for which the effect size is too small to warrant the assessment that there is a noticeable association, from those in which it is merely small. For example, 'Virology' experienced an OA citation advantage, with an effect size of > 0.1, on the NCS for the year 2014, while 'Infectious Diseases', a similar subject area, did not experience an OA citation

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advantage. As elaborated upon in this concluding chapter, the issues of megajournals, the low percentage of OA journal articles in certain subject areas, and other factors that influence the number of citations articles receive could prove useful avenues for future research. The literature review conducted as part of this study emphasised additional factors that could be investigated to assist with our understanding of the effect sizes that are appropriate in studies of citation analysis, such as whether a journal is a well-established journal, and whether it is local or has an international focus.

The additional OA tags in WoS, and the direct links through these to gratis access versions of articles, themselves could increase the visibility of articles rendered OA and indexed in WoS, especially for green OA versions of these articles. Not only is the world of OA publishing growing and changing, but the data pertaining to it are also becoming more readily available, creating more options for investigating this publishing practice across multiple subject areas, and by using large-scale (citation) analysis. However, the characteristics of these data need to be understood in order to be applied appropriately. While this study was able to identify those selected subject areas in which OA journal articles experience a citation advantage, it also contributes to a more critical and therefore cautionary understanding of the OA tags, as applied by WoS. This should help pave the way for studies aiming to use these findings and tags to investigate OA publications further in future bibliometric studies.

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ADDENDUM A: Percentages and counts of open access journal articles

A.1. Subject areas in which no open access journal articles were published

The dataset for the current study comprised all articles and reviews published from 2005 to 2014 and indexed in WoS. It, therefore, included all the subject areas in which articles were published during those years. However, in some of those subject areas not a single OA journal article was published for those years. The table below lists those subject areas and the number of non-OA journal articles, i.e. all the published articles, in the ten years.

Subject area	Number of articles
Computer Science, Hardware & Architecture	39 394
Criminology & Penology	16 069
Cultural Studies	8 938
Dance	8 920
Education, Special	11 380
Engineering, Geological	20 346
Engineering, Ocean	9 695
Ergonomics	11 116
Ethnic Studies	5 191
History Of Social Sciences	8 382
Hospitality, Leisure, Sport & Tourism	13 885
Legal Medicine	15 237
Literary Reviews	19 272
Literature, African, Australian, Canadian	1 694
Literature, American	3 271
Literature, British Isles	4 028
Literature, German, Dutch, Scandinavian	4 793
Materials Science, Characterization & Testing	20 692
Materials Science, Coatings & Films	61 262
Materials Science, Composites	25 923
Medicine, Legal	15 237
Microscopy	10 325
Physics, Fluids & Plasmas	78 761
Planning & Development	22 998
Poetry	1 767
Psychology, Biological	14 069
Psychology, Developmental	36 715
Psychology, Mathematical	5 586
Psychology, Psychoanalysis	5 218
Transplantation	48 066
Transportation Science & Technology	26 014

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A.2. Subject areas in which open access journal articles were published consistently but not in all the years

While the previous addendum listed those subject areas in which no OA journal articles were published in the ten years investigated, this addendum lists the 54 subject areas, in which OA journal articles were published for consecutive years, but not in each of the ten years (2005–2014). This included two subject areas in which articles were only published in the year 2014, namely ‘Literature, Slavic’ and ‘Women’s Studies’.

	2006		2007		2008		2009		2010		2011		2012		2013		2014	
Subject area	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Agricultural Economics & Policy	0	0.0	0	0.0	31	5.0	41	6.2	57	8.9	66	9.4	107	15.0	85	11.4	137	17.6
Agricultural Engineering	0	0.0	0	0.0	3	0.1	11	0.5	178	6.2	183	5.2	228	6.8	352	8.0	390	10.8
Anatomy & Morphology	0	0.0	3	0.2	11	0.6	99	5.2	248	12.6	303	15.3	296	14.7	285	14.8	389	17.9
Anesthesiology	0	0.0	0	0.0	65	1.7	81	2.1	168	4.3	174	4.5	239	6.4	249	6.5	313	8.3
Archaeology	0	0.0	41	2.6	81	4.2	77	3.7	85	4.0	90	4.0	104	4.3	101	4.0	114	4.0
Area Studies	0	0.0	0	0.0	0	0.0	32	1.6	28	1.4	22	1.0	23	1.1	25	1.1	25	1.1
Audiology & Speech-Language Pathology	0	0.0	0	0.0	14	0.8	32	1.8	31	1.6	57	2.7	50	2.3	57	2.5	74	3.4
Behavioral Sciences	0	0.0	71	1.5	59	1.1	103	1.9	165	3.0	140	2.3	214	3.6	305	4.8	548	8.2
Biophysics	5	0.0	77	0.6	70	0.6	80	0.7	76	0.6	119	1.0	112	0.9	150	1.1	116	0.8
Business	0	0.0	89	2.3	212	4.6	328	6.3	669	12.0	1588	24.5	224	4.1	189	3.3	154	2.6
Cell & Tissue Engineering	19	1.1	19	1.1	18	0.9	11	0.4	82	2.8	112	3.9	232	7.2	202	6.0	463	12.9
Communication	0	0.0	47	2.6	45	2.0	84	3.3	102	4.3	145	5.3	117	4.1	166	5.6	167	5.3
Crystallography	0	0.0	0	0.0	3533	38.1	4148	40.7	4086	40.8	4462	40.1	742	9.9	32	0.5	92	1.4
Emergency Medicine	7	0.3	72	2.3	133	4.0	233	6.5	319	8.9	325	8.7	330	7.8	341	7.8	331	8.0
Engineering, Aerospace	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	24	0.9	22	0.8	23	0.7
Engineering, Civil	0	0.0	114	1.2	100	1.0	110	0.9	156	1.3	131	1.0	226	1.6	294	1.9	288	1.8
Engineering, Industrial	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	33	0.9	51	1.2	47	1.0	49	1.0
Engineering, Marine	0	0.0	0	0.0	9	1.0	31	4.5	41	6.3	48	6.8	56	7.6	64	8.5	110	13.3
Film, Radio & Television	0	0.0	0	0.0	12	0.4	22	0.9	9	0.4	7	0.3	18	0.7	234	9.2	238	9.7
Film, Radio, Television	0	0.0	0	0.0	12	0.4	22	0.9	9	0.4	7	0.3	18	0.7	234	9.2	238	9.7
Geography	24	1.1	87	3.5	225	7.8	94	3.1	200	6.1	129	3.5	208	5.5	201	4.8	256	5.8
Geriatrics & Gerontology	46	1.3	72	1.9	102	2.5	82	1.9	271	5.9	314	6.4	369	6.3	622	10.8	979	15.8
Gerontology	0	0.0	0	0.0	30	1.5	28	1.3	158	7.2	172	7.4	153	6.2	213	8.0	213	7.7
Imaging Science & Photographic Technology	0	0.0	43	1.9	82	3.2	73	2.9	87	3.2	66	2.2	38	1.1	83	2.2	72	1.6

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Subject area	2006		2007		2008		2009		2010		2011		2012		2013		2014	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
International Relations	0	0.0	31	1.4	35	1.2	32	1.1	53	1.7	41	1.3	53	1.6	38	1.2	55	1.6
Limnology	0	0.0	40	2.3	19	1.1	38	2.1	54	2.7	56	3.0	36	1.9	93	4.7	74	3.8
Literature, Slavic	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	170	28.8
Logic	29	4.9	36	6.5	58	9.0	50	6.9	69	8.7	84	10.9	117	12.0	106	11.5	97	10.4
Management	0	0.0	71	1.2	118	1.8	294	3.9	613	7.4	1532	16.3	165	2.0	135	1.6	147	1.7
Materials Science, Biomaterials	19	0.6	19	0.6	19	0.5	11	0.3	61	1.2	59	1.3	114	2.2	103	1.5	109	1.4
Materials Science, Paper & Wood	20	1.4	81	6.0	128	9.4	158	12.3	248	18.6	441	28.1	509	27.9	563	30.7	660	31.3
Mathematical Methods In Social Sciences	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	12	0.6	16	0.7	18	0.8	27	1.1
Medieval & Renaissance Studies	0	0.0	23	4.5	46	8.7	53	9.0	82	11.7	61	8.8	72	9.1	61	7.9	50	6.1
Mining & Mineral Processing	0	0.0	230	10.7	140	6.6	122	5.0	162	8.7	117	4.3	129	5.5	119	3.9	74	2.7
Music	0	0.0	19	0.4	14	0.3	13	0.3	14	0.3	11	0.2	13	0.3	10	0.2	12	0.3
Nanoscience & Nanotechnology	103	0.9	166	1.1	220	1.2	390	2.0	700	3.2	1734	6.6	2362	8.7	2384	8.1	3116	9.3
Neuroimaging	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	19	0.7	156	6.1	187	6.6
Nuclear Science & Technology	0	0.0	0	0.0	21	0.3	63	0.7	54	0.7	80	0.8	154	1.9	124	1.2	132	1.4
Nursing	0	0.0	272	6.4	343	6.4	529	9.1	504	8.2	629	9.9	676	10.0	437	5.9	379	5.0
Obstetrics & Gynecology	0	0.0	96	1.0	115	1.2	195	1.8	281	2.6	334	2.9	424	3.6	527	4.5	570	4.9
Operations Research & Management Science	0	0.0	9	0.2	10	0.2	10	0.1	11	0.2	15	0.2	11	0.1	13	0.2	16	0.2
Otorhinolaryngology	0	0.0	0	0.0	96	2.0	95	1.9	206	4.1	209	4.1	239	4.4	281	4.8	260	4.7
Psychology, Applied	0	0.0	15	0.6	15	0.5	49	1.6	21	0.7	47	1.5	46	1.4	71	2.1	54	1.5
Psychology, Educational	0	0.0	17	1.2	12	0.7	15	0.9	15	0.9	20	1.1	20	1.0	19	0.9	18	0.9
Psychology, Experimental	0	0.0	0	0.0	42	0.8	30	0.5	55	0.9	66	1.0	114	1.8	130	2.0	102	1.4
Public Administration	0	0.0	16	0.6	61	2.0	106	2.8	88	2.2	127	3.1	122	2.9	77	1.7	60	1.3
Remote Sensing	0	0.0	12	0.7	72	3.4	181	8.2	224	9.4	198	7.1	284	9.2	467	13.0	746	16.1
Robotics	0	0.0	0	0.0	48	4.8	39	3.2	61	4.8	105	7.7	295	18.4	445	24.7	234	14.0
Social Sciences, Mathematical Methods	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	12	0.6	16	0.7	18	0.8	27	1.1
Social Work	0	0.0	26	1.9	48	3.1	55	3.2	48	2.6	73	3.8	62	3.2	85	4.3	101	4.6
Substance Abuse	57	2.6	46	1.9	101	3.9	62	2.4	88	3.3	114	4.0	131	4.1	127	3.8	122	3.4
Theater	0	0.0	0	0.0	0	0.0	0	0.0	11	1.3	15	1.6	7	0.7	12	1.2	11	1.0
Transportation	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	29	0.7	29	0.7	29	0.6	33	0.6
Women's Studies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	8	0.5

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A.3. Percentages of open access journal articles in each subject area for the years 2005 and 2014, and articles published during the entire time frame

In Chapter 6 (sub-section 6.2.2), the percentage of OA journal articles for the total dataset (2005–2014), and the years 2005 and 2014 separately are discussed. While the discussion refers to the increase in the percentage for most subject areas and the substantial differences between subject areas, not all the subject areas could be discussed in the chapter. The percentage of OA journal articles for each of the 243 subject areas in which any OA journal articles were published in the ten years are listed in the table below. The table includes the number of OA journal articles, the percentage they constitute of the total articles as well as the number of articles in total published for the years 2005 and 2014, and for the whole dataset in each subject area.

	2005			2014			2005–2014		
	OA		Total	OA		Total	OA		Total
Subject area	n	%	n	n	%	n	n	%	n
Acoustics	78	2.2	3 477	255	5.6	4 550	976	2.4	40 552
Agricultural Economics & Policy	0	0.0	399	137	17.6	779	524	8.4	6 217
Agricultural Engineering	0	0.0	1 068	390	10.8	3 597	1 345	5.2	25 904
Agriculture	1 780	9.2	19 361	4 906	15.5	31 627	41 374	15.1	273 717
Agriculture, Dairy & Animal Science	892	17.9	4 985	911	13.6	6 695	10 480	16.7	62 874
Agriculture, Multidisciplinary	903	19.8	4 563	1 726	24.2	7 133	17 527	27.3	64 206
Agronomy	387	7.2	5 390	1 594	16.8	9 474	12 014	15.3	78 603
Allergy	56	2.8	2 008	227	9.5	2 396	1 397	6.2	22 411
Anatomy & Morphology	0	0.0	1 448	389	17.9	2 169	1 634	9.0	18 160
Andrology	60	18.1	331	125	26.1	479	1 060	25.4	4 172
Anesthesiology	0	0.0	3 576	313	8.3	3 772	1 289	3.4	37 839
Anthropology	62	2.9	2 107	447	13.0	3 431	2 326	7.7	30 402
Archaeology	0	0.0	1 195	114	4.0	2 823	693	3.4	20 168
Architecture	57	3.2	1 759	75	4.0	1 858	817	4.2	19 461
Area Studies	0	0.0	1 154	25	1.1	2 270	155	0.8	18 349
Art	42	0.9	4 543	121	2.5	4 805	869	1.9	46 264
Arts & Humanities – Other Topics	134	3.9	3 413	293	5.8	5 044	2 454	5.6	44 039
Asian Studies	29	3.9	748	44	3.6	1 213	403	4.0	10 021

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Subject area	2005			2014			2005–2014		
	OA		Total	OA		Total	OA		Total
	n	%	n	n	%	n	n	%	n
Astronomy & Astrophysics	391	2.7	14 457	1 166	6.0	19 284	4 220	2.5	172 011
Audiology & Speech-Language Pathology	0	0.0	1 512	74	3.4	2 161	315	1.6	19 150
Automation & Control Systems	86	2.2	3 991	214	2.4	8 790	1 850	2.8	65 943
Behavioral Sciences	0	0.0	4 295	548	8.2	6 660	1 605	2.9	55 264
Biochemical Research Methods	435	3.6	11 926	1 681	10.3	16 359	12 254	8.2	149 540
Biochemistry & Molecular Biology	2 490	4.3	57 895	6 858	10.1	67 750	46 860	7.3	643 385
Biodiversity & Conservation	92	3.3	2 765	442	8.9	4 975	3 040	7.9	38 407
Biodiversity Conservation	92	3.3	2 765	442	8.9	4 975	3 040	7.9	38 407
Biology	908	14.9	6 085	2 884	26.5	10 896	17 232	19.8	87 136
Biomedical Social Sciences	19	1.1	1 777	162	5.2	3 116	818	3.3	24 832
Biophysics	0	0.0	11 716	116	0.8	14 007	805	0.6	124 101
Biotechnology & Applied Microbiology	1 175	7.0	16 850	7 103	24.5	29 050	37 451	15.9	235 848
Business	0	0.0	3 310	154	2.6	5 830	3 453	7.0	49 373
Business & Economics	140	0.8	17 093	739	2.3	32 214	7 753	2.9	265 410
Business, Finance	30	1.2	2 421	14	0.3	4 346	238	0.7	34 317
Cardiac & Cardiovascular Systems	420	3.0	14 185	2 418	12.5	19 400	16 709	9.6	173 334
Cardiovascular System & Cardiology	469	2.4	19 502	2 685	10.0	26 830	17 817	7.5	237 614
Cell & Tissue Engineering	0	0.0	1 393	463	12.9	3 587	1 158	4.6	25 134
Cell Biology	260	1.2	21 681	4 142	14.2	29 237	13 615	5.4	251 884
Chemistry	1 800	1.6	109 327	7 730	4.4	175 539	46 261	3.3	1 400 712
Chemistry, Analytical	392	2.4	16 165	1 509	6.7	22 664	8 764	4.6	191 336
Chemistry, Applied	44	0.5	9 261	314	2.3	13 865	2 122	1.8	119 020
Chemistry, Inorganic & Nuclear	40	0.4	11 300	103	0.8	13 255	616	0.5	124 724
Chemistry, Medicinal	11	0.1	8 844	879	6.1	14 480	3 565	2.8	126 341
Chemistry, Multidisciplinary	1 070	3.5	30 413	3 598	5.8	62 397	23 328	5.3	442 371
Chemistry, Organic	233	1.2	18 853	1 911	9.0	21 269	10 253	5.1	202 917
Chemistry, Physical	61	0.2	36 678	376	0.6	60 260	1 772	0.4	480 270
Classics	19	3.1	621	48	5.2	923	371	4.8	7 665
Clinical Neurology	200	1.1	17 941	1 522	5.8	26 276	8 424	3.7	230 222
Communication	0	0.0	1 396	167	5.3	3 164	873	3.7	23 573
Computer Science	290	1.2	25 161	1 635	3.4	48 288	9 096	2.5	363 210

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	2005			2014			2005–2014		
	OA		Total	OA		Total	OA		Total
Subject area	n	%	n	n	%	n	n	%	n
Computer Science, Artificial Intelligence	126	2.3	5 573	522	4.1	12 613	3 374	3.7	90 346
Computer Science, Cybernetics	13	1.3	967	81	5.7	1 410	468	3.9	11 925
Computer Science, Information Systems	98	1.5	6 429	847	6.1	13 777	3 982	4.1	96 693
Computer Science, Interdisciplinary Applications	50	0.7	7 661	198	1.4	14 350	1 174	1.0	112 172
Computer Science, Software Engineering	94	1.8	5 200	143	1.7	8 585	1 200	1.7	69 324
Computer Science, Theory & Methods	53	0.9	5 812	82	0.9	9 276	731	1.0	73 538
Construction & Building Technology	26	1.0	2 583	155	2.2	7 140	979	2.2	44 711
Critical Care Medicine	189	4.6	4 150	471	9.8	4 804	3 412	7.5	45 530
Crystallography	0	0.0	8 514	92	1.4	6 738	17 095	18.9	90 656
Demography	55	10.3	532	173	17.6	985	1 102	14.3	7 718
Dentistry, Oral Surgery & Medicine	160	3.0	5 338	632	6.9	9 224	4 048	5.3	77 025
Dermatology	115	2.4	4 874	417	5.9	7 097	3 363	5.4	62 338
Developmental Biology	28	0.7	4 031	117	2.8	4 127	1 150	2.8	40 786
Ecology	257	2.1	12 279	1 595	9.0	17 650	8 347	5.5	152 979
Economics	74	0.8	9 287	521	2.9	18 237	3 594	2.4	148 682
Education & Educational Research	205	3.1	6 578	1 161	8.0	14 494	6 988	6.2	112 603
Education, Scientific Disciplines	108	5.0	2 143	592	16.5	3 594	3 607	11.9	30 268
Electrochemistry	49	0.8	6 039	1 915	12.9	14 824	9 677	9.3	103 529
Emergency Medicine	0	0.0	2 591	331	8.0	4 163	2 091	5.9	35 442
Endocrinology & Metabolism	266	1.9	13 777	1 537	8.3	18 476	8 131	5.0	163 043
Energy & Fuels	142	1.9	7 400	1 039	3.7	28 313	4 320	2.7	157 181
Engineering	1 127	1.3	87 894	8 399	5.3	158 188	41 337	3.4	1 221 353
Engineering, Aerospace	0	0.0	2 183	23	0.7	3 230	69	0.3	25 661
Engineering, Biomedical	49	0.8	6 034	1 678	12.3	13 697	7 779	7.8	99 471
Engineering, Chemical	259	1.5	16 755	670	2.3	29 207	4 961	2.2	223 592
Engineering, Civil	0	0.0	6 169	288	1.8	16 211	1 419	1.2	114 770
Engineering, Electrical & Electronic	288	0.9	32 678	3 178	6.0	52 822	19 041	4.4	429 812
Engineering, Environmental	0	0.0	6 391	150	1.2	12 595	292	0.3	97 857
Engineering, Industrial	0	0.0	3 310	49	1.0	4 913	180	0.4	40 395
Engineering, Manufacturing	100	2.7	3 711	29	0.5	5 622	426	0.9	47 510
Engineering, Marine	0	0.0	707	110	13.3	830	359	4.7	7 579

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Subject area	2005			2014			2005–2014		
	OA		Total	OA		Total	OA		Total
	n	%	n	n	%	n	n	%	n
Engineering, Mechanical	316	3.1	10 283	971	5.3	18 195	3 007	2.2	137 728
Engineering, Multidisciplinary	214	4.3	4 922	2 737	23.2	11 804	10 314	12.2	84 454
Engineering, Petroleum	114	6.0	1 896	128	6.1	2 109	1 198	6.9	17 432
Entomology	265	5.5	4 776	797	12.9	6 159	4 745	8.4	56 249
Environmental Sciences	656	3.2	20 232	2 838	6.8	41 818	15 099	4.9	306 320
Environmental Sciences & Ecology	913	2.8	32 158	4 432	7.3	60 505	23 349	5.0	463 079
Environmental Studies	56	2.1	2 702	788	10.6	7 420	2 483	4.9	50 703
Ethics	15	1.2	1 296	261	11.6	2 241	1 193	6.4	18 563
Evolutionary Biology	113	2.6	4 329	1 090	17.7	6 153	5 633	10.4	53 986
Family Studies	35	2.7	1 292	8	0.3	2 357	234	1.3	18 277
Film, Radio & Television	0	0.0	2 657	238	9.7	2 458	540	2.1	25 735
Film, Radio, Television	0	0.0	2 657	238	9.7	2 458	540	2.1	25 735
Fisheries	81	2.2	3 657	442	8.9	4 964	2 617	5.8	45 169
Folklore	37	16.4	225	63	18.3	345	492	16.3	3 018
Food Science & Technology	134	1.2	11 534	597	2.8	21 463	4 982	2.9	171 901
Forestry	45	1.5	3 064	952	18.7	5 104	4 887	11.9	41 048
Gastroenterology & Hepatology	86	0.9	9 475	2 622	20.5	12 784	12 166	11.1	109 860
General & Internal Medicine	2 971	15.9	18 725	9 101	32.7	27 854	60 027	24.9	241 150
Genetics & Heredity	948	6.1	15 623	4 511	20.8	21 668	27 072	14.6	184 875
Geochemistry & Geophysics	196	2.9	6 651	431	4.0	10 908	2 778	3.2	85 737
Geography	0	0.0	1 854	256	5.8	4 407	1 424	4.5	31 768
Geography, Physical	52	2.1	2 434	362	6.4	5 695	1 438	3.5	40 680
Geology	721	5.3	13 613	2 899	11.9	24 372	17 185	9.1	189 367
Geosciences, Multidisciplinary	706	5.9	11 876	2 578	11.8	21 850	15 249	9.1	167 297
Geriatrics & Gerontology	0	0.0	3 334	979	15.8	6 189	2 857	6.2	46 197
Gerontology	0	0.0	1 830	213	7.7	2 780	967	4.4	22 008
Government & Law	72	1.0	7 426	296	2.7	11 053	2 081	2.2	96 412
Health Care Sciences & Services	135	2.4	5 629	1 863	16.5	11 295	9 723	11.3	85 789
Health Policy & Services	16	0.6	2 845	686	11.7	5 853	3 674	8.6	42 517
Hematology	161	1.8	8 885	515	4.8	10 674	3 825	3.8	100 111
History	72	1.6	4 431	577	7.8	7 389	3 099	5.0	61 501

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Subject area	2005			2014			2005–2014		
	OA		Total	OA		Total	OA		Total
	n	%	n	n	%	n	n	%	n
History & Philosophy Of Science	25	2.2	1 133	167	7.1	2 346	1 352	7.3	18 639
Horticulture	12	0.5	2 344	313	8.9	3 516	2 768	9.0	30 852
Humanities, Multidisciplinary	97	3.5	2 756	180	4.6	3 880	1 514	4.4	34 739
Imaging Science & Photographic Technology	0	0.0	1 796	72	1.6	4 430	544	1.9	28 073
Immunology	640	3.3	19 109	2 403	10.8	22 221	13 799	6.7	205 476
Industrial Relations & Labor	66	11.8	558	81	8.3	975	791	10.0	7 890
Infectious Diseases	705	8.4	8 377	3 749	26.5	14 128	20 845	18.6	112 259
Information Science & Library Science	148	5.5	2 688	259	6.2	4 166	2 303	6.7	34 550
Instruments & Instrumentation	147	1.5	10 056	1 516	9.6	15 730	7 099	5.6	126 628
Integrative & Complementary Medicine	63	4.6	1 370	1 214	31.8	3 816	5 389	21.7	24 862
International Relations	0	0.0	1 978	55	1.6	3 429	338	1.2	28 228
Language & Linguistics	27	1.4	1 917	260	5.9	4 394	1 742	5.0	34 686
Law	71	2.1	3 319	187	4.0	4 664	1 322	3.2	41 963
Life Sciences & Biomedicine – Other Topics	908	14.9	6 085	2 884	26.5	10 896	17 232	19.8	87 136
Limnology	0	0.0	1 393	74	3.8	1 972	410	2.3	17 914
Linguistics	48	1.6	2 936	290	4.6	6 244	1 928	4.0	48 576
Literary Theory & Criticism	0	0.0	566	170	18.1	939	172	2.6	6 671
Literature	76	0.9	8 227	411	4.1	10 096	2 137	2.3	91 376
Literature, Romance	76	5.4	1 413	132	7.1	1 857	1 181	7.2	16 464
Literature, Slavic	0	0.0	226	170	28.8	590	170	4.7	3 580
Logic	0	0.0	501	97	10.4	929	646	8.7	7 422
Management	0	0.0	4 421	147	1.7	8 731	3 075	4.2	72 565
Marine & Freshwater Biology	178	2.1	8 447	721	6.0	12 050	5 171	4.8	107 364
Materials Science	617	1.1	53 865	6 318	5.8	109 512	28 660	3.6	792 360
Materials Science, Biomaterials	0	0.0	2 783	109	1.4	7 802	514	1.1	46 474
Materials Science, Ceramics	65	1.8	3 682	351	6.2	5 685	3 350	7.4	45 271
Materials Science, Multidisciplinary	437	1.1	38 663	4 926	6.0	81 469	20 084	3.4	592 665
Materials Science, Paper & Wood	0	0.0	1 449	660	31.3	2 110	2 808	18.0	15 557
Materials Science, Textiles	115	9.5	1 212	272	11.1	2 441	1 904	11.3	16 895
Mathematical & Computational Biology	476	14.5	3 284	2 093	31.7	6 609	14 122	27.3	51 690
Mathematical Methods In Social Sciences	0	0.0	1 409	27	1.1	2 408	73	0.4	19 649

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Subject area	2005			2014			2005–2014		
	OA		Total	OA		Total	OA		Total
	n	%	n	n	%	n	n	%	n
Mathematics	925	2.6	35 479	8 522	14.6	58 444	36 273	7.6	480 222
Mathematics, Applied	525	3.5	15 050	5 009	18.5	27 031	21 555	10.0	215 584
Mathematics, Interdisciplinary Applications	71	1.4	5 068	2 364	24.2	9 769	7 069	9.5	74 381
Mechanics	66	0.6	11 453	525	2.6	20 202	2 013	1.3	160 104
Medical Ethics	15	3.5	425	240	25.7	935	1 055	14.7	7 167
Medical Informatics	42	1.9	2 209	340	10.1	3 359	1 831	6.8	26 892
Medical Laboratory Technology	45	1.7	2 676	144	4.3	3 351	1 121	3.7	30 570
Medicine, General & Internal	2 782	18.9	14 725	8 583	37.4	22 947	56 568	28.8	196 109
Medicine, Research & Experimental	761	6.9	11 067	7 835	33.5	23 388	26 884	17.1	156 992
Medieval & Renaissance Studies	0	0.0	432	50	6.1	819	448	7.1	6 282
Metallurgy & Metallurgical Engineering	221	1.9	11 832	422	2.6	16 285	3 204	2.1	149 097
Meteorology & Atmospheric Sciences	944	14.0	6 732	2 704	21.8	12 416	17 676	18.1	97 795
Microbiology	212	1.5	14 601	2 891	15.0	19 245	15 941	9.1	175 103
Mineralogy	11	0.6	1 736	79	2.9	2 744	351	1.6	21 641
Mining & Mineral Processing	0	0.0	1 536	74	2.7	2 753	1 093	4.9	22 405
Multidisciplinary Sciences	909	8.9	10 203	39 804	72.7	54 745	142 687	56.2	253 681
Music	0	0.0	4 815	12	0.3	4 661	106	0.2	49 391
Mycology	14	0.9	1 639	91	4.6	1 978	497	2.7	18 433
Nanoscience & Nanotechnology	0	0.0	9 367	3 116	9.3	33 347	11 175	5.2	213 494
Neuroimaging	0	0.0	1 981	187	6.6	2 853	362	1.7	21 720
Neurosciences	573	2.0	28 003	5 132	13.3	38 517	20 981	6.3	332 340
Neurosciences & Neurology	742	1.8	40 440	6 693	11.8	56 632	28 768	5.9	491 569
Nuclear Science & Technology	0	0.0	7 942	132	1.4	9 263	628	0.7	87 961
Nursing	0	0.0	2 632	379	5.0	7 541	3 769	6.8	55 812
Nutrition & Dietetics	44	0.7	6 355	1 473	12.4	11 836	7 349	7.8	94 649
Obstetrics & Gynecology	0	0.0	8 168	570	4.9	11 600	2 542	2.5	103 652
Oceanography	111	2.5	4 462	604	8.8	6 825	4 062	7.3	55 455
Oncology	515	2.3	22 391	5 316	13.3	39 856	20 923	7.1	296 028
Operations Research & Management Science	0	0.0	4 332	16	0.2	8 546	95	0.1	70 352
Ophthalmology	221	3.4	6 537	1 297	14.9	8 709	8 724	10.8	80 449
Optics	1 308	7.7	16 906	6 058	20.3	29 817	36 869	15.5	237 174

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Subject area	2005			2014			2005–2014		
	OA		Total	OA		Total	OA		Total
	n	%	n	n	%	n	n	%	n
Ornithology	5	0.5	941	16	1.5	1 089	136	1.2	11 613
Orthopedics	207	3.1	6 736	1 276	10.8	11 828	6 918	7.4	93 854
Otorhinolaryngology	0	0.0	3 897	260	4.7	5 495	1 386	2.8	48 859
Paleontology	121	6.3	1 918	236	8.6	2 754	1 813	7.4	24 447
Parasitology	379	14.5	2 617	3 265	52.0	6 282	17 458	38.6	45 286
Pathology	104	1.6	6 306	1 875	19.4	9 666	7 329	9.2	79 677
Pediatrics	117	1.1	10 529	882	5.5	15 902	5 390	3.9	137 944
Peripheral Vascular Disease	49	0.6	8 593	267	2.6	10 136	1 108	1.2	94 155
Pharmacology & Pharmacy	592	1.9	31 652	3 731	8.0	46 643	21 452	5.3	407 214
Philosophy	28	0.7	3 907	329	4.9	6 711	2 138	3.9	54 659
Physical Geography	52	2.1	2 434	362	6.4	5 695	1 438	3.5	40 680
Physics	2 394	2.2	108 392	9 461	6.8	138 423	51 004	4.1	1 242 582
Physics, Applied	373	1.0	37 077	3 829	6.6	58 265	18 262	3.9	474 320
Physics, Atomic, Molecular & Chemical	28	0.2	13 962	316	1.9	16 944	1 197	0.8	151 155
Physics, Condensed Matter	409	1.6	25 149	495	1.7	28 915	4 351	1.5	283 869
Physics, Mathematical	28	0.3	8 629	224	2.2	10 033	1 409	1.4	99 035
Physics, Multidisciplinary	1 433	7.1	20 208	3 890	16.8	23 174	23 397	10.1	232 005
Physics, Nuclear	116	1.3	9 056	1 049	13.1	7 983	2 422	3.0	81 648
Physics, Particles & Fields	128	1.1	11 212	1 683	13.7	12 297	3 563	3.1	113 259
Physiology	174	1.9	9 385	1 506	14.6	10 308	6 961	6.8	102 564
Plant Sciences	283	1.9	14 896	3 040	13.9	21 937	17 347	9.5	183 373
Political Science	1	0.0	4 124	109	1.7	6 458	874	1.6	55 349
Polymer Science	36	0.3	13 549	474	2.5	19 001	2 412	1.5	163 496
Primary Health Care	229	28.6	800	660	43.3	1 524	4 249	34.6	12 266
Psychiatry	438	3.7	11 743	1 442	7.9	18 366	8 736	5.7	151 989
Psychology	216	1.0	21 382	3 003	7.9	38 208	11 671	3.9	299 393
Psychology, Applied	0	0.0	2 161	54	1.5	3 633	318	1.1	29 004
Psychology, Clinical	33	0.8	4 378	118	1.6	7 364	696	1.2	58 641
Psychology, Educational	0	0.0	1 228	18	0.9	2 116	136	0.8	17 184
Psychology, Experimental	0	0.0	4 026	102	1.4	7 184	539	0.9	57 070
Psychology, Multidisciplinary	183	4.2	4 393	1 824	21.0	8 703	7 525	12.0	62 966

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Subject area	2005			2014			2005–2014		
	OA		Total	OA		Total	OA		Total
	n	%	n	n	%	n	n	%	n
Psychology, Social	0	0.0	2 227	0	0.0	3 793	33	0.1	32 059
Public Administration	0	0.0	2 275	60	1.3	4 755	657	1.8	35 898
Public, Environmental & Occupational Health	1 180	8.4	14 077	6 609	23.3	28 336	37 923	17.6	214 997
Radiology, Nuclear Medicine & Medical Imaging	125	0.9	13 161	1 502	7.8	19 373	7 195	4.3	166 489
Rehabilitation	101	2.7	3 778	927	11.6	7 977	4 331	7.3	59 176
Religion	171	9.1	1 870	354	10.4	3 413	2 883	10.1	28 510
Remote Sensing	0	0.0	1 535	746	16.1	4 646	2 184	8.5	25 754
Reproductive Biology	169	4.6	3 674	359	7.9	4 554	2 602	6.1	42 453
Research & Experimental Medicine	761	6.9	11 067	7 835	33.5	23 388	26 884	17.1	156 992
Respiratory System	146	2.2	6 661	508	5.9	8 650	2 632	3.5	75 760
Rheumatology	262	7.7	3 386	873	18.3	4 780	5 534	12.9	42 738
Robotics	0	0.0	721	234	14.0	1 667	1 227	9.9	12 363
Science & Technology – Other Topics	909	4.5	20 071	43 017	48.3	89 021	154 508	32.6	474 597
Social Issues	53	4.4	1 194	126	7.2	1 746	1 072	7.1	15 163
Social Sciences – Other Topics	139	3.0	4 670	813	7.4	10 958	4 231	5.3	80 343
Social Sciences, Biomedical	19	1.1	1 777	162	5.2	3 116	818	3.3	24 832
Social Sciences, Interdisciplinary	124	5.0	2 496	552	10.0	5 502	3 038	7.5	40 524
Social Sciences, Mathematical Methods	0	0.0	1 409	27	1.1	2 408	73	0.4	19 649
Social Work	0	0.0	1 166	101	4.6	2 219	498	2.9	17 015
Sociology	53	1.7	3 184	222	4.1	5 354	1 619	3.7	44 047
Soil Science	107	3.4	3 150	386	8.8	4 378	3 157	8.2	38 329
Spectroscopy	38	0.5	7 029	72	0.8	9 153	350	0.4	78 504
Sport Sciences	118	2.1	5 494	507	5.7	8 922	3 704	5.1	72 104
Statistics & Probability	112	1.8	6 116	555	5.9	9 328	3 411	4.3	79 895
Substance Abuse	0	0.0	1 982	122	3.4	3 608	848	3.1	27 465
Surgery	149	0.6	24 671	1 539	4.4	35 024	8 479	2.8	307 977
Telecommunications	220	3.0	7 307	1 343	9.8	13 706	8 688	8.3	104 294
Theater	0	0.0	963	11	1.0	1 065	56	0.6	9 058
Thermodynamics	114	1.9	5 918	875	7.4	11 829	2 766	3.4	81 812
Toxicology	548	7.2	7 627	860	8.3	10 393	7 880	8.4	94 210
Transportation	0	0.0	1 482	33	0.6	5 293	120	0.3	35 196

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Subject area	2005			2014			2005–2014		
	OA		Total	OA		Total	OA		Total
	n	%	n	n	%	n	n	%	n
Tropical Medicine	414	27.1	1 528	1 868	52.9	3 532	11 776	44.3	26 564
Urban Studies	17	1.5	1 123	36	1.5	2 420	222	1.3	16 746
Urology & Nephrology	184	2.1	8 561	895	8.5	10 499	4 790	4.8	99 921
Veterinary Sciences	1 569	13.5	11 630	2 918	21.5	13 553	26 419	19.1	138 415
Virology	157	3.2	4 857	1 354	19.7	6 878	8 650	14.1	61 398
Water Resources	229	3.7	6 205	963	7.2	13 339	5 794	5.9	97 808
Women's Studies	0	0.0	989	8	0.5	1 523	8	0.1	13 307
Zoology	415	4.5	9 269	1 708	12.9	13 232	11 062	9.4	118 138

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ADDENDUM B:
Measure of citation advantage – mean normalised citation score

B.1. Results for all articles for each of the subject areas

Chapter 6 presents the results for the three measures of citation advantage for each of the subject areas for all articles published from 2005 to 2014. The first measure that was investigated was to compare the NCSs of OA and non-OA journal articles, the calculation of which is elaborated upon in Chapter 4 sub-section 4.2.2.6.1. A three-fold method was applied to determine whether OA or non-OA journal articles in a subject area experienced a citation advantage, as elaborated upon in Chapter 4.

In Chapter 6 (section 6.3), only those subject areas which experienced a citation advantage for their OA journal articles are named, and their results are reported in the chapter. The results for all the subject areas in which any OA journal articles were published in the ten years are listed in the table below.

	MNCS			**Levene's test for equality variances**			**Point-biserial correlation**	
					Equal variance			
Subject area	**Non-OA**	**OA**	**Diff.**	***p*-value**	**Assumed (*p*-value)**	**Not assumed (*p*-value)**	***p*-value**	**r_{pb}**
Acoustics	1.03	0.32	-0.71	0.00	0.00	0.00	0.00	-0.06
Agricultural Economics & Policy	0.86	0.23	-0.63	0.00	0.00	0.00	0.00	-0.14
Agricultural Engineering	1.54	0.25	-1.30	0.00	0.00	0.00	0.00	-0.14
Agriculture	1.11	0.35	-0.76	0.00	0.00	0.00	0.00	-0.17
Agriculture, Dairy & Animal Science	1.01	0.42	-0.59	0.00	0.00	0.00	0.00	-0.15
Agriculture, Multidisciplinary	1.10	0.32	-0.78	0.00	0.00	0.00	0.00	-0.24
Agronomy	1.10	0.34	-0.76	0.00	0.00	0.00	0.00	-0.17

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	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
Subject area	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Allergy	1.01	0.40	-0.60	0.00	0.00	0.00	0.00	-0.11
Anatomy & Morphology	0.91	0.42	-0.49	0.00	0.00	0.00	0.00	-0.11
Andrology	0.76	0.81	0.05	0.99	0.15	0.15	0.15	0.02
Anesthesiology	0.95	0.83	-0.11	0.76	0.00	0.01	0.00	-0.02
Anthropology	1.13	0.30	-0.83	0.00	0.00	0.00	0.00	-0.12
Archaeology	1.19	0.36	-0.83	0.00	0.00	0.00	0.00	-0.07
Architecture	0.97	0.56	-0.42	0.00	0.08	0.00	0.08	-0.01
Area Studies	1.04	1.08	0.04	0.31	0.82	0.82	0.82	0.00
Art	0.97	1.74	0.77	0.00	0.00	0.00	0.00	0.02
Arts & Humanities – Other Topics	1.05	0.38	-0.68	0.00	0.00	0.00	0.00	-0.04
Asian Studies	0.83	0.64	-0.18	0.00	0.14	0.04	0.14	-0.01
Astronomy & Astrophysics	1.11	0.70	-0.41	0.00	0.00	0.00	0.00	-0.02
Audiology & Speech-Language Pathology	1.10	0.94	-0.15	0.00	0.06	0.03	0.06	-0.01
Automation & Control Systems	1.29	1.22	-0.07	0.63	0.22	0.37	0.22	0.00
Behavioral Sciences	1.15	0.73	-0.43	0.00	0.00	0.00	0.00	-0.05
Biochemical Research Methods	1.07	1.07	0.00	0.10	0.95	0.87	0.95	0.00
Biochemistry & Molecular Biology	1.07	1.28	0.21	0.00	0.00	0.00	0.00	0.02
Biodiversity & Conservation	1.06	0.35	-0.71	0.00	0.00	0.00	0.00	-0.11
Biodiversity Conservation	1.06	0.35	-0.71	0.00	0.00	0.00	0.00	-0.11
Biology	0.98	1.08	0.10	0.00	0.00	0.00	0.00	0.02
Biomedical Social Sciences	1.09	0.53	-0.56	0.00	0.00	0.00	0.00	-0.07
Biophysics	0.97	0.35	-0.62	0.00	0.00	0.00	0.00	-0.01
Biotechnology & Applied Microbiology	1.14	0.69	-0.45	0.00	0.00	0.00	0.00	-0.06
Business	1.23	0.22	-1.01	0.00	0.00	0.00	0.00	-0.14

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Subject area	MNCS			Levene's test for equality variances	Equal variance		Point-biserial correlation	
	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Business & Economics	1.06	0.32	-0.75	0.00	0.00	0.00	0.00	-0.07
Business, Finance	1.03	0.46	-0.57	0.00	0.00	0.00	0.00	-0.02
Cardiac & Cardiovascular Systems	1.11	0.51	-0.59	0.00	0.00	0.00	0.00	-0.07
Cardiovascular System & Cardiology	1.06	0.52	-0.54	0.00	0.00	0.00	0.00	-0.06
Cell & Tissue Engineering	1.69	0.95	-0.74	0.00	0.00	0.00	0.00	-0.07
Cell Biology	1.31	0.74	-0.57	0.00	0.00	0.00	0.00	-0.05
Chemistry	1.15	0.45	-0.70	0.00	0.00	0.00	0.00	-0.05
Chemistry, Analytical	0.96	0.78	-0.18	0.00	0.00	0.00	0.00	-0.03
Chemistry, Applied	1.02	0.26	-0.76	0.00	0.00	0.00	0.00	-0.07
Chemistry, Inorganic & Nuclear	0.85	0.49	-0.36	0.00	0.00	0.00	0.00	-0.02
Chemistry, Medicinal	0.92	0.75	-0.16	0.00	0.00	0.00	0.00	-0.02
Chemistry, Multidisciplinary	1.41	0.30	-1.11	0.00	0.00	0.00	0.00	-0.08
Chemistry, Organic	0.97	0.56	-0.41	0.00	0.00	0.00	0.00	-0.06
Chemistry, Physical	1.29	0.45	-0.84	0.00	0.00	0.00	0.00	-0.02
Classics	0.97	1.49	0.52	0.00	0.00	0.00	0.00	0.04
Clinical Neurology	0.96	0.55	-0.41	0.00	0.00	0.00	0.00	-0.05
Communication	1.46	0.69	-0.77	0.00	0.00	0.00	0.00	-0.04
Computer Science	1.10	0.74	-0.36	0.00	0.00	0.00	0.00	-0.02
Computer Science, Artificial Intelligence	1.26	0.97	-0.29	0.00	0.00	0.00	0.00	-0.02
Computer Science, Cybernetics	0.95	0.26	-0.69	0.00	0.00	0.00	0.00	-0.07
Computer Science, Information Systems	1.04	0.42	-0.62	0.00	0.00	0.00	0.00	-0.05
Computer Science, Interdisciplinary Applications	1.23	1.97	0.74	0.00	0.00	0.00	0.00	0.02
Computer Science, Software Engineering	0.92	0.50	-0.42	0.00	0.00	0.00	0.00	-0.03
Computer Science, Theory & Methods	1.20	0.44	-0.76	0.00	0.00	0.00	0.00	-0.02

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Subject area	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Construction & Building Technology	0.88	0.24	-0.64	0.00	0.00	0.00	0.00	-0.07
Critical Care Medicine	1.11	1.02	-0.09	0.00	0.01	0.00	0.01	-0.01
Crystallography	1.07	0.26	-0.81	0.00	0.00	0.00	0.00	-0.02
Demography	1.07	0.66	-0.41	0.00	0.00	0.00	0.00	-0.08
Dentistry, Oral Surgery & Medicine	0.99	0.58	-0.41	0.00	0.00	0.00	0.00	-0.07
Dermatology	0.98	0.47	-0.51	0.00	0.00	0.00	0.00	-0.08
Developmental Biology	1.18	0.68	-0.49	0.00	0.00	0.00	0.00	-0.05
Ecology	1.16	0.85	-0.31	0.00	0.00	0.00	0.00	-0.04
Economics	1.00	0.28	-0.72	0.00	0.00	0.00	0.00	-0.06
Education & Educational Research	0.99	0.91	-0.08	0.00	0.00	0.00	0.00	-0.01
Education, Scientific Disciplines	0.96	1.01	0.05	0.00	0.13	0.05	0.13	0.01
Electrochemistry	1.17	0.80	-0.37	0.00	0.00	0.00	0.00	-0.07
Emergency Medicine	1.07	0.42	-0.66	0.00	0.00	0.00	0.00	-0.08
Endocrinology & Metabolism	1.05	0.58	-0.47	0.00	0.00	0.00	0.00	-0.07
Energy & Fuels	1.44	0.70	-0.74	0.00	0.00	0.00	0.00	-0.05
Engineering	1.01	0.58	-0.43	0.00	0.00	0.00	0.00	-0.04
Engineering, Aerospace	0.67	0.36	-0.32	0.09	0.04	0.01	0.04	-0.01
Engineering, Biomedical	1.16	0.96	-0.19	0.00	0.00	0.00	0.00	-0.03
Engineering, Chemical	1.06	0.36	-0.70	0.00	0.00	0.00	0.00	-0.06
Engineering, Civil	0.92	0.22	-0.70	0.00	0.00	0.00	0.00	-0.05
Engineering, Electrical & Electronic	1.06	0.77	-0.29	0.00	0.00	0.00	0.00	-0.03
Engineering, Environmental	1.43	0.37	-1.06	0.00	0.00	0.00	0.00	-0.03
Engineering, Industrial	1.01	0.08	-0.93	0.00	0.00	0.00	0.00	-0.04
Engineering, Manufacturing	0.90	2.34	1.44	0.00	0.00	0.00	0.00	0.09

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Subject area	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Engineering, Marine	0.60	0.32	-0.29	0.00	0.00	0.00	0.00	-0.05
Engineering, Mechanical	0.88	0.28	-0.60	0.00	0.00	0.00	0.00	-0.06
Engineering, Multidisciplinary	0.95	0.44	-0.51	0.00	0.00	0.00	0.00	-0.09
Engineering, Petroleum	0.40	0.78	0.39	0.00	0.00	0.00	0.00	0.09
Entomology	1.06	0.47	-0.59	0.00	0.00	0.00	0.00	-0.09
Environmental Sciences	1.13	1.03	-0.09	0.00	0.00	0.00	0.00	-0.01
Environmental Sciences & Ecology	1.11	0.97	-0.13	0.04	0.00	0.00	0.00	-0.02
Environmental Studies	1.07	0.78	-0.29	0.00	0.00	0.00	0.00	-0.04
Ethics	0.90	0.82	-0.08	0.92	0.05	0.06	0.05	-0.01
Evolutionary Biology	1.28	0.84	-0.43	0.00	0.00	0.00	0.00	-0.02
Family Studies	0.98	2.05	1.07	0.00	0.00	0.00	0.00	0.08
Film, Radio & Television	1.00	0.43	-0.57	0.00	0.01	0.00	0.01	-0.02
Film, Radio, Television	1.00	0.43	-0.57	0.00	0.01	0.00	0.01	-0.02
Fisheries	1.03	0.62	-0.41	0.00	0.00	0.00	0.00	-0.07
Folklore	0.97	0.44	-0.53	0.00	0.00	0.00	0.00	-0.07
Food Science & Technology	1.04	0.31	-0.73	0.00	0.00	0.00	0.00	-0.09
Forestry	1.06	0.41	-0.65	0.00	0.00	0.00	0.00	-0.14
Gastroenterology & Hepatology	1.08	0.60	-0.48	0.00	0.00	0.00	0.00	-0.09
General & Internal Medicine	1.22	0.41	-0.81	0.00	0.00	0.00	0.00	-0.10
Genetics & Heredity	1.15	0.96	-0.19	0.00	0.00	0.00	0.00	-0.02
Geochemistry & Geophysics	1.05	0.39	-0.65	0.00	0.00	0.00	0.00	-0.07
Geography	1.11	0.10	-1.01	0.00	0.00	0.00	0.00	-0.13
Geography, Physical	1.07	1.02	-0.05	0.00	0.25	0.37	0.25	-0.01
Geology	1.02	0.95	-0.07	0.00	0.00	0.00	0.00	-0.01

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Subject area	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Geosciences, Multidisciplinary	1.03	1.02	-0.01	0.00	0.43	0.40	0.43	0.00
Geriatrics & Gerontology	0.99	0.78	-0.20	0.00	0.00	0.00	0.00	-0.04
Gerontology	0.93	0.48	-0.45	0.00	0.00	0.00	0.00	-0.07
Government & Law	0.98	0.71	-0.26	0.00	0.00	0.00	0.00	-0.02
Health Care Sciences & Services	1.06	1.04	-0.02	0.00	0.23	0.21	0.23	0.00
Health Policy & Services	1.02	1.04	0.03	0.72	0.30	0.31	0.30	0.01
Hematology	1.03	0.97	-0.07	0.00	0.01	0.00	0.01	-0.01
History	0.93	0.37	-0.56	0.00	0.00	0.00	0.00	-0.05
History & Philosophy of Science	0.92	0.19	-0.72	0.00	0.00	0.00	0.00	-0.11
Horticulture	0.98	0.25	-0.73	0.00	0.00	0.00	0.00	-0.16
Humanities, Multidisciplinary	1.04	0.25	-0.79	0.00	0.00	0.00	0.00	-0.05
Imaging Science & Photographic Technology	1.19	0.33	-0.86	0.00	0.00	0.00	0.00	-0.06
Immunology	1.07	0.81	-0.26	0.00	0.00	0.00	0.00	-0.04
Industrial Relations & Labor	0.80	0.84	0.04	0.04	0.38	0.47	0.38	0.01
Infectious Diseases	1.08	0.97	-0.11	0.00	0.00	0.00	0.00	-0.03
Information Science & Library Science	1.14	0.52	-0.62	0.00	0.00	0.00	0.00	-0.08
Instruments & Instrumentation	0.92	0.90	-0.03	0.00	0.20	0.14	0.20	0.00
Integrative & Complementary Medicine	0.94	0.98	0.03	0.00	0.07	0.08	0.07	0.01
International Relations	0.98	0.33	-0.64	0.00	0.00	0.00	0.00	-0.04
Language & Linguistics	0.86	0.47	-0.39	0.00	0.00	0.00	0.00	-0.04
Law	0.95	0.96	0.01	0.18	0.87	0.87	0.87	0.00
Life Sciences & Biomedicine – Other Topics	0.98	1.08	0.10	0.00	0.00	0.00	0.00	0.02
Limnology	0.99	0.62	-0.36	0.00	0.00	0.00	0.00	-0.04
Linguistics	1.01	0.61	-0.40	0.00	0.00	0.00	0.00	-0.04

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Subject area	MNCS			Levene's test for equality variances	Equal variance		Point-biserial correlation	
	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Literary Theory & Criticism	1.36	0.29	-1.07	0.00	0.00	0.00	0.00	-0.04
Literature	0.97	0.34	-0.63	0.00	0.00	0.00	0.00	-0.02
Literature, Romance	0.62	0.39	-0.23	0.00	0.02	0.00	0.02	-0.02
Literature, Slavic	0.68	0.29	-0.39	0.00	0.13	0.02	0.13	-0.03
Logic	0.51	0.19	-0.32	0.00	0.00	0.00	0.00	-0.08
Management	1.28	0.21	-1.07	0.00	0.00	0.00	0.00	-0.11
Marine & Freshwater Biology	1.02	0.48	-0.53	0.00	0.00	0.00	0.00	-0.09
Materials Science	1.17	0.57	-0.59	0.00	0.00	0.00	0.00	-0.05
Materials Science, Biomaterials	1.42	1.13	-0.29	0.00	0.00	0.00	0.00	-0.02
Materials Science, Ceramics	0.81	0.25	-0.56	0.00	0.00	0.00	0.00	-0.12
Materials Science, Multidisciplinary	1.23	0.60	-0.63	0.00	0.00	0.00	0.00	-0.05
Materials Science, Paper & Wood	0.72	0.78	0.07	0.00	0.04	0.01	0.04	0.02
Materials Science, Textiles	0.82	0.40	-0.42	0.00	0.00	0.00	0.00	-0.08
Mathematical & Computational Biology	1.32	1.02	-0.30	0.00	0.00	0.00	0.00	-0.03
Mathematical Methods In Social Sciences	1.05	0.65	-0.40	0.05	0.10	0.00	0.10	-0.01
Mathematics	1.00	0.59	-0.41	0.00	0.00	0.00	0.00	-0.04
Mathematics, Applied	1.08	0.59	-0.49	0.00	0.00	0.00	0.00	-0.07
Mathematics, Interdisciplinary Applications	1.16	0.43	-0.73	0.00	0.00	0.00	0.00	-0.10
Mechanics	1.04	0.41	-0.64	0.00	0.00	0.00	0.00	-0.04
Medical Ethics	1.19	0.88	-0.31	0.00	0.00	0.00	0.00	-0.06
Medical Informatics	1.63	1.38	-0.25	0.01	0.12	0.00	0.12	-0.01
Medical Laboratory Technology	0.94	0.27	-0.67	0.00	0.00	0.00	0.00	-0.07
Medicine, General & Internal	1.26	0.37	-0.88	0.00	0.00	0.00	0.00	-0.10
Medicine, Research & Experimental	1.07	0.66	-0.41	0.00	0.00	0.00	0.00	-0.08

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Subject area	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Medieval & Renaissance Studies	1.16	0.72	-0.44	0.00	0.01	0.00	0.01	-0.03
Metallurgy & Metallurgical Engineering	0.84	0.45	-0.39	0.00	0.00	0.00	0.00	-0.04
Meteorology & Atmospheric Sciences	0.97	1.14	0.17	0.00	0.00	0.00	0.00	0.03
Microbiology	1.10	1.07	-0.03	0.00	0.06	0.06	0.06	0.00
Mineralogy	0.98	0.41	-0.57	0.00	0.00	0.00	0.00	-0.05
Mining & Mineral Processing	0.89	0.17	-0.72	0.00	0.00	0.00	0.00	-0.10
Multidisciplinary Sciences	1.90	0.57	-1.33	0.00	0.00	0.00	0.00	-0.21
Music	0.98	0.24	-0.74	0.00	0.14	0.00	0.14	-0.01
Mycology	0.95	1.37	0.43	0.00	0.00	0.00	0.00	0.05
Nanoscience & Nanotechnology	1.56	0.64	-0.93	0.00	0.00	0.00	0.00	-0.07
Neuroimaging	1.23	1.01	-0.23	0.00	0.01	0.00	0.01	-0.02
Neurosciences	1.15	0.73	-0.42	0.00	0.00	0.00	0.00	-0.06
Neurosciences & Neurology	1.07	0.68	-0.39	0.00	0.00	0.00	0.00	-0.06
Nuclear Science & Technology	0.74	0.58	-0.16	0.68	0.01	0.01	0.01	-0.01
Nursing	0.93	0.36	-0.57	0.00	0.00	0.00	0.00	-0.11
Nutrition & Dietetics	1.11	0.65	-0.46	0.00	0.00	0.00	0.00	-0.09
Obstetrics & Gynecology	0.98	0.60	-0.37	0.00	0.00	0.00	0.00	-0.04
Oceanography	1.06	0.55	-0.51	0.00	0.00	0.00	0.00	-0.09
Oncology	1.08	0.68	-0.40	0.00	0.00	0.00	0.00	-0.03
Operations Research & Management Science	1.13	0.38	-0.75	0.00	0.00	0.00	0.00	-0.02
Ophthalmology	1.00	0.57	-0.43	0.00	0.00	0.00	0.00	-0.09
Optics	0.91	1.39	0.49	0.00	0.00	0.00	0.00	0.08
Ornithology	0.94	0.57	-0.37	0.00	0.00	0.00	0.00	-0.03
Orthopedics	1.00	0.66	-0.34	0.00	0.00	0.00	0.00	-0.06

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	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
Subject area	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Otorhinolaryngology	0.93	0.70	-0.23	0.00	0.00	0.00	0.00	-0.03
Paleontology	0.97	0.75	-0.22	0.00	0.00	0.00	0.00	-0.04
Parasitology	1.06	1.35	0.28	0.00	0.00	0.00	0.00	0.09
Pathology	0.97	0.52	-0.45	0.00	0.00	0.00	0.00	-0.09
Pediatrics	0.90	0.50	-0.40	0.00	0.00	0.00	0.00	-0.05
Peripheral Vascular Disease	1.18	0.67	-0.52	0.00	0.00	0.00	0.00	-0.02
Pharmacology & Pharmacy	1.00	0.50	-0.50	0.00	0.00	0.00	0.00	-0.07
Philosophy	1.65	0.05	-1.60	0.00	0.00	0.00	0.00	-0.06
Physical Geography	1.07	1.02	-0.05	0.00	0.25	0.37	0.25	-0.01
Physics	1.04	0.70	-0.34	0.00	0.00	0.00	0.00	-0.03
Physics, Applied	1.06	0.90	-0.17	0.00	0.00	0.00	0.00	-0.01
Physics, Atomic, Molecular & Chemical	0.96	0.34	-0.62	0.00	0.00	0.00	0.00	-0.03
Physics, Condensed Matter	1.17	0.16	-1.01	0.00	0.00	0.00	0.00	-0.04
Physics, Mathematical	0.96	0.40	-0.56	0.00	0.00	0.00	0.00	-0.03
Physics, Multidisciplinary	1.13	0.68	-0.45	0.00	0.00	0.00	0.00	-0.04
Physics, Nuclear	0.89	0.91	0.02	0.55	0.88	0.69	0.88	0.00
Physics, Particles & Fields	1.15	0.92	-0.23	0.01	0.00	0.00	0.00	-0.01
Physiology	0.97	0.77	-0.20	0.00	0.00	0.00	0.00	-0.03
Plant Sciences	1.04	0.48	-0.56	0.00	0.00	0.00	0.00	-0.10
Political Science	1.00	0.25	-0.75	0.00	0.00	0.00	0.00	-0.05
Polymer Science	1.04	0.60	-0.43	0.00	0.00	0.00	0.00	-0.03
Primary Health Care	0.51	0.78	0.27	0.00	0.00	0.00	0.00	0.15
Psychiatry	1.08	0.48	-0.60	0.00	0.00	0.00	0.00	-0.09
Psychology	1.09	0.67	-0.42	0.00	0.00	0.00	0.00	-0.04

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Subject area	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Psychology, Applied	1.20	0.29	-0.90	0.00	0.00	0.00	0.00	-0.04
Psychology, Clinical	1.06	0.77	-0.29	0.00	0.00	0.00	0.00	-0.02
Psychology, Educational	1.01	0.81	-0.19	0.07	0.28	0.02	0.28	-0.01
Psychology, Experimental	1.31	0.52	-0.79	0.00	0.00	0.00	0.00	-0.03
Psychology, Multidisciplinary	1.05	0.57	-0.47	0.00	0.00	0.00	0.00	-0.08
Psychology, Social	1.00	1.09	0.08	0.85	0.75	0.72	0.75	0.00
Public Administration	1.07	0.16	-0.91	0.00	0.00	0.00	0.00	-0.07
Public, Environmental & Occupational Health	1.03	0.89	-0.14	0.04	0.00	0.00	0.00	-0.03
Radiology, Nuclear Medicine & Medical Imaging	1.00	0.69	-0.31	0.00	0.00	0.00	0.00	-0.04
Rehabilitation	1.03	0.71	-0.31	0.00	0.00	0.00	0.00	-0.05
Religion	0.93	0.65	-0.28	0.00	0.00	0.00	0.00	-0.04
Remote Sensing	1.10	0.86	-0.24	0.00	0.00	0.00	0.00	-0.04
Reproductive Biology	1.16	0.77	-0.39	0.00	0.00	0.00	0.00	-0.06
Research & Experimental Medicine	1.07	0.66	-0.41	0.00	0.00	0.00	0.00	-0.08
Respiratory System	1.02	0.72	-0.30	0.00	0.00	0.00	0.00	-0.03
Rheumatology	1.07	0.81	-0.27	0.00	0.00	0.00	0.00	-0.06
Robotics	1.04	0.24	-0.79	0.00	0.00	0.00	0.00	-0.14
Science & Technology – Other Topics	1.66	0.58	-1.08	0.00	0.00	0.00	0.00	-0.17
Social Issues	1.07	0.11	-0.96	0.00	0.00	0.00	0.00	-0.14
Social Sciences – Other Topics	1.00	0.72	-0.28	0.06	0.00	0.00	0.00	-0.04
Social Sciences, Biomedical	1.09	0.53	-0.56	0.00	0.00	0.00	0.00	-0.07
Social Sciences, Interdisciplinary	1.05	0.68	-0.37	0.00	0.00	0.00	0.00	-0.05
Social Sciences, Mathematical Methods	1.05	0.65	-0.40	0.05	0.10	0.00	0.10	-0.01
Social Work	0.96	0.71	-0.25	0.03	0.00	0.00	0.00	-0.03

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Subject area	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Sociology	1.13	0.29	-0.83	0.00	0.00	0.00	0.00	-0.07
Soil Science	1.14	0.38	-0.76	0.00	0.00	0.00	0.00	-0.13
Spectroscopy	0.90	0.16	-0.74	0.00	0.00	0.00	0.00	-0.03
Sport Sciences	1.01	0.35	-0.65	0.00	0.00	0.00	0.00	-0.09
Statistics & Probability	1.18	0.99	-0.20	0.12	0.01	0.00	0.01	-0.01
Substance Abuse	1.00	0.63	-0.37	0.00	0.00	0.00	0.00	-0.05
Surgery	0.93	0.38	-0.54	0.00	0.00	0.00	0.00	-0.06
Telecommunications	1.05	0.85	-0.20	0.00	0.00	0.00	0.00	-0.02
Theater	1.06	1.61	0.56	0.29	0.38	0.20	0.38	0.01
Thermodynamics	0.99	0.30	-0.69	0.00	0.00	0.00	0.00	-0.08
Toxicology	0.98	1.38	0.40	0.00	0.00	0.00	0.00	0.07
Transportation	1.02	0.34	-0.68	0.00	0.00	0.00	0.00	-0.02
Tropical Medicine	0.90	0.96	0.05	0.01	0.00	0.00	0.00	0.02
Urban Studies	0.97	0.18	-0.79	0.00	0.00	0.00	0.00	-0.06
Urology & Nephrology	1.01	0.49	-0.52	0.00	0.00	0.00	0.00	-0.07
Veterinary Sciences	1.08	0.48	-0.60	0.00	0.00	0.00	0.00	-0.15
Virology	1.01	1.59	0.58	0.00	0.00	0.00	0.00	0.14
Water Resources	0.95	1.01	0.06	0.97	0.00	0.00	0.00	0.01
Women's Studies	0.86	0.00	-0.86	0.03	0.09	0.00	0.09	-0.01
Zoology	0.94	0.63	-0.32	0.00	0.00	0.00	0.00	-0.06

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B.2. Results for articles published in 2014, for each of the subject areas

The same analysis as discussed in Addendum B.1 was conducted a second time, only considering the articles published in 2014 to control for the potential confounding effect of the variance between years. The table below presents the results for all subject areas in which any OA journal articles were published in 2014.

	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
					Assumed	Not assumed		
Subject area	Non-OA	OA	Diff.	*p*-value	(*p*-value)	(*p*-value)	*p*-value	r_{pb}
Acoustics	0.99	0.31	-0.67	0.00	0.00	0.00	0.00	-0.11
Agricultural Economics & Policy	1.05	0.20	-0.85	0.00	0.00	0.00	0.00	-0.21
Agricultural Engineering	1.53	0.24	-1.29	0.00	0.00	0.00	0.00	-0.23
Agriculture	1.10	0.34	-0.76	0.00	0.00	0.00	0.00	-0.19
Agriculture, Dairy & Animal Science	0.93	0.53	-0.40	0.00	0.00	0.00	0.00	-0.11
Agriculture, Multidisciplinary	1.01	0.33	-0.68	0.00	0.00	0.00	0.00	-0.22
Agronomy	1.15	0.33	-0.82	0.00	0.00	0.00	0.00	-0.20
Allergy	1.12	0.46	-0.66	0.00	0.00	0.00	0.00	-0.12
Anatomy & Morphology	0.90	0.67	-0.22	0.08	0.00	0.00	0.00	-0.07
Andrology	0.66	1.14	0.48	0.00	0.00	0.00	0.00	0.19
Anesthesiology	0.98	0.52	-0.46	0.00	0.00	0.00	0.00	-0.10
Anthropology	1.18	0.20	-0.99	0.00	0.00	0.00	0.00	-0.21
Archaeology	1.13	0.49	-0.64	0.04	0.01	0.00	0.01	-0.05
Architecture	0.96	0.40	-0.56	0.23	0.49	0.02	0.49	-0.02
Area Studies	0.99	0.62	-0.37	0.24	0.31	0.16	0.31	-0.02
Art	0.95	1.73	0.78	0.08	0.16	0.05	0.16	0.02
Arts & Humanities – Other Topics	1.05	0.27	-0.78	0.00	0.00	0.00	0.00	-0.06
Asian Studies	0.83	0.28	-0.54	0.00	0.07	0.00	0.07	-0.05
Astronomy & Astrophysics	1.06	1.25	0.19	0.01	0.08	0.01	0.08	0.01
Audiology & Speech-Language Pathology	1.04	1.12	0.08	0.72	0.66	0.70	0.66	0.01
Automation & Control Systems	1.39	1.54	0.16	0.00	0.40	0.75	0.40	0.01

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	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
Subject area	**Non-OA**	**OA**	**Diff.**	***p*-value**	**Assumed (*p*-value)**	**Not assumed (*p*-value)**	***p*-value**	**r_{pb}**
Behavioral Sciences	1.11	0.81	-0.30	0.00	0.00	0.00	0.00	-0.05
Biochemical Research Methods	1.04	1.07	0.03	0.74	0.84	0.69	0.84	0.00
Biochemistry & Molecular Biology	1.03	1.29	0.27	0.00	0.00	0.00	0.00	0.02
Biodiversity & Conservation	1.03	0.31	-0.73	0.00	0.00	0.00	0.00	-0.14
Biodiversity Conservation	1.03	0.31	-0.73	0.00	0.00	0.00	0.00	-0.14
Biology	0.87	1.20	0.33	0.00	0.00	0.00	0.00	0.09
Biomedical Social Sciences	1.04	0.64	-0.40	0.00	0.00	0.00	0.00	-0.07
Biophysics	0.93	0.35	-0.59	0.00	0.00	0.00	0.00	-0.04
Biotechnology & Applied Microbiology	1.19	0.67	-0.52	0.00	0.00	0.00	0.00	-0.05
Business	1.24	0.17	-1.07	0.00	0.00	0.00	0.00	-0.09
Business & Economics	1.06	0.42	-0.64	0.00	0.00	0.00	0.00	-0.06
Business, Finance	0.99	0.32	-0.67	0.16	0.13	0.03	0.13	-0.02
Cardiac & Cardiovascular Systems	1.14	0.61	-0.54	0.00	0.00	0.00	0.00	-0.05
Cardiovascular System & Cardiology	1.06	0.60	-0.47	0.00	0.00	0.00	0.00	-0.05
Cell & Tissue Engineering	1.50	1.06	-0.44	0.00	0.00	0.00	0.00	-0.08
Cell Biology	1.32	0.95	-0.38	0.00	0.00	0.00	0.00	-0.06
Chemistry	1.19	0.54	-0.65	0.00	0.00	0.00	0.00	-0.05
Chemistry, Analytical	0.97	0.89	-0.07	0.24	0.08	0.07	0.08	-0.01
Chemistry, Applied	1.03	0.24	-0.79	0.00	0.00	0.00	0.00	-0.08
Chemistry, Inorganic & Nuclear	0.79	0.26	-0.53	0.00	0.00	0.00	0.00	-0.04
Chemistry, Medicinal	0.92	0.81	-0.11	0.01	0.02	0.01	0.02	-0.02
Chemistry, Multidisciplinary	1.44	0.41	-1.04	0.00	0.00	0.00	0.00	-0.07
Chemistry, Organic	0.93	0.62	-0.31	0.00	0.00	0.00	0.00	-0.06
Chemistry, Physical	1.37	0.26	-1.11	0.00	0.00	0.00	0.00	-0.03
Classics	0.94	1.83	0.88	0.00	0.05	0.25	0.05	0.06
Clinical Neurology	0.98	0.60	-0.38	0.00	0.00	0.00	0.00	-0.06
Communication	1.42	1.14	-0.28	0.03	0.25	0.04	0.25	-0.02
Computer Science	1.10	0.60	-0.50	0.00	0.00	0.00	0.00	-0.02
Computer Science, Artificial Intelligence	1.25	0.91	-0.34	0.43	0.00	0.11	0.00	-0.03

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	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
					Assumed	Not assumed		
Subject area	**Non-OA**	**OA**	**Diff.**	***p*-value**	**(*p*-value)**	**(*p*-value)**	***p*-value**	**r_{pb}**
Computer Science, Cybernetics	1.02	0.16	-0.86	0.00	0.00	0.00	0.00	-0.11
Computer Science, Information Systems	1.04	0.32	-0.72	0.00	0.00	0.00	0.00	-0.07
Computer Science, Interdisciplinary Applications	1.24	1.60	0.36	0.14	0.42	0.20	0.42	0.01
Computer Science, Software Engineering	0.86	0.41	-0.45	0.00	0.00	0.00	0.00	-0.03
Computer Science, Theory & Methods	1.25	0.12	-1.13	0.15	0.18	0.00	0.18	-0.01
Construction & Building Technology	0.96	0.29	-0.68	0.00	0.00	0.00	0.00	-0.07
Critical Care Medicine	1.14	1.03	-0.12	0.01	0.10	0.04	0.10	-0.02
Crystallography	0.75	1.25	0.50	0.01	0.06	0.04	0.06	0.02
Demography	1.11	0.61	-0.50	0.00	0.00	0.00	0.00	-0.11
Dentistry, Oral Surgery & Medicine	0.99	0.63	-0.36	0.00	0.00	0.00	0.00	-0.06
Dermatology	0.98	0.51	-0.46	0.00	0.00	0.00	0.00	-0.08
Developmental Biology	1.09	0.69	-0.40	0.00	0.00	0.00	0.00	-0.05
Ecology	1.12	0.87	-0.25	0.00	0.00	0.00	0.00	-0.05
Economics	0.97	0.33	-0.65	0.00	0.00	0.00	0.00	-0.06
Education & Educational Research	1.01	1.01	0.00	0.69	0.95	0.94	0.95	0.00
Education, Scientific Disciplines	0.99	1.10	0.12	0.64	0.14	0.09	0.14	0.02
Electrochemistry	1.23	0.81	-0.43	0.00	0.00	0.00	0.00	-0.09
Emergency Medicine	1.07	0.49	-0.58	0.00	0.00	0.00	0.00	-0.08
Endocrinology & Metabolism	1.08	0.66	-0.42	0.00	0.00	0.00	0.00	-0.07
Energy & Fuels	1.58	0.56	-1.02	0.00	0.00	0.00	0.00	-0.07
Engineering	1.04	0.45	-0.59	0.00	0.00	0.00	0.00	-0.07
Engineering, Aerospace	0.69	0.54	-0.16	0.74	0.58	0.58	0.58	-0.01
Engineering, Biomedical	1.01	1.00	-0.01	0.34	0.79	0.80	0.79	0.00
Engineering, Chemical	1.16	0.32	-0.85	0.00	0.00	0.00	0.00	-0.06
Engineering, Civil	0.92	0.43	-0.49	0.00	0.00	0.00	0.00	-0.05
Engineering, Electrical & Electronic	1.06	0.61	-0.46	0.00	0.00	0.00	0.00	-0.05
Engineering, Environmental	1.49	0.45	-1.04	0.00	0.00	0.00	0.00	-0.06
Engineering, Industrial	1.09	0.13	-0.96	0.00	0.00	0.00	0.00	-0.06
Engineering, Manufacturing	0.95	3.09	2.14	0.00	0.00	0.01	0.00	0.11

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	MNCS			Levene's test for equality variances			Point-biserial correlation	
					Equal variance			
Subject area	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Engineering, Marine	0.83	0.33	-0.50	0.00	0.00	0.00	0.00	-0.13
Engineering, Mechanical	0.89	0.27	-0.62	0.00	0.00	0.00	0.00	-0.10
Engineering, Multidisciplinary	1.07	0.29	-0.79	0.00	0.00	0.00	0.00	-0.19
Engineering, Petroleum	0.45	0.48	0.03	0.14	0.73	0.62	0.73	0.01
Entomology	1.09	0.45	-0.64	0.00	0.00	0.00	0.00	-0.13
Environmental Sciences	1.17	0.88	-0.29	0.00	0.00	0.00	0.00	-0.03
Environmental Sciences & Ecology	1.13	0.88	-0.25	0.00	0.00	0.00	0.00	-0.03
Environmental Studies	1.17	0.71	-0.46	0.00	0.00	0.00	0.00	-0.07
Ethics	0.88	0.95	0.06	0.09	0.45	0.46	0.45	0.02
Evolutionary Biology	1.18	0.94	-0.25	0.00	0.00	0.00	0.00	-0.06
Family Studies	0.94	2.52	1.58	0.00	0.00	0.09	0.00	0.07
Film, Radio & Television	1.04	0.37	-0.67	0.00	0.01	0.00	0.01	-0.06
Film, Radio, Television	1.04	0.37	-0.67	0.00	0.01	0.00	0.01	-0.06
Fisheries	1.04	0.59	-0.45	0.00	0.00	0.00	0.00	-0.09
Folklore	0.96	0.00	-0.96	0.00	0.01	0.00	0.01	-0.14
Food Science & Technology	1.01	0.35	-0.67	0.00	0.00	0.00	0.00	-0.08
Forestry	1.05	0.55	-0.50	0.00	0.00	0.00	0.00	-0.13
Gastroenterology & Hepatology	1.10	0.76	-0.34	0.00	0.00	0.00	0.00	-0.08
General & Internal Medicine	1.31	0.44	-0.87	0.00	0.00	0.00	0.00	-0.10
Genetics & Heredity	1.10	0.94	-0.16	0.00	0.00	0.00	0.00	-0.03
Geochemistry & Geophysics	1.05	0.54	-0.51	0.00	0.00	0.00	0.00	-0.07
Geography	1.12	0.21	-0.91	0.00	0.00	0.00	0.00	-0.11
Geography, Physical	1.07	1.16	0.09	0.09	0.33	0.30	0.33	0.01
Geology	1.02	1.08	0.05	0.55	0.11	0.08	0.11	0.01
Geosciences, Multidisciplinary	1.03	1.17	0.13	0.16	0.00	0.00	0.00	0.02
Geriatrics & Gerontology	0.98	1.02	0.04	0.93	0.41	0.33	0.41	0.01
Gerontology	0.92	0.72	-0.20	0.53	0.07	0.02	0.07	-0.03
Government & Law	0.99	0.78	-0.20	0.16	0.06	0.01	0.06	-0.02
Health Care Sciences & Services	1.04	1.07	0.03	0.60	0.43	0.42	0.43	0.01

Stellenbosch University https://scholar.sun.ac.za

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	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Health Policy & Services	0.97	0.98	0.01	0.04	0.83	0.80	0.83	0.00
Hematology	1.03	0.88	-0.15	0.00	0.04	0.00	0.04	-0.02
History	0.92	0.49	-0.42	0.00	0.00	0.00	0.00	-0.05
History & Philosophy of Science	0.92	0.24	-0.67	0.00	0.00	0.00	0.00	-0.09
Horticulture	0.93	0.24	-0.70	0.00	0.00	0.00	0.00	-0.16
Humanities, Multidisciplinary	1.05	0.19	-0.86	0.00	0.00	0.00	0.00	-0.06
Imaging Science & Photographic Technology	1.13	0.59	-0.54	0.02	0.02	0.00	0.02	-0.04
Immunology	1.07	0.85	-0.22	0.00	0.00	0.00	0.00	-0.04
Industrial Relations & Labor	0.80	1.30	0.49	0.98	0.00	0.00	0.00	0.10
Infectious Diseases	1.08	0.96	-0.12	0.00	0.00	0.00	0.00	-0.04
Information Science & Library Science	1.10	0.48	-0.62	0.00	0.00	0.00	0.00	-0.08
Instruments & Instrumentation	0.97	0.93	-0.04	0.00	0.43	0.35	0.43	-0.01
Integrative & Complementary Medicine	1.03	0.89	-0.14	0.02	0.00	0.00	0.00	-0.06
International Relations	1.02	0.20	-0.82	0.00	0.00	0.00	0.00	-0.06
Language & Linguistics	0.86	0.48	-0.38	0.00	0.00	0.00	0.00	-0.05
Law	0.87	1.11	0.24	0.02	0.04	0.04	0.04	0.03
Life Sciences & Biomedicine – Other Topics	0.87	1.20	0.33	0.00	0.00	0.00	0.00	0.09
Limnology	0.99	0.75	-0.25	0.14	0.16	0.07	0.16	-0.03
Linguistics	1.01	0.64	-0.37	0.01	0.00	0.00	0.00	-0.04
Literary Theory & Criticism	1.28	0.29	-1.00	0.00	0.00	0.00	0.00	-0.11
Literature	0.97	0.44	-0.53	0.00	0.03	0.00	0.03	-0.02
Literature, Romance	0.62	0.74	0.12	0.43	0.65	0.62	0.65	0.01
Literature, Slavic	0.73	0.29	-0.44	0.00	0.15	0.07	0.15	-0.06
Logic	0.46	0.27	-0.19	0.02	0.04	0.03	0.04	-0.07
Management	1.26	0.17	-1.09	0.00	0.00	0.00	0.00	-0.08
Marine & Freshwater Biology	1.01	0.55	-0.46	0.00	0.00	0.00	0.00	-0.08
Materials Science	1.22	0.54	-0.68	0.00	0.00	0.00	0.00	-0.06
Materials Science, Biomaterials	1.28	0.79	-0.49	0.01	0.00	0.00	0.00	-0.04
Materials Science, Ceramics	0.85	0.19	-0.66	0.00	0.00	0.00	0.00	-0.14

Stellenbosch University https://scholar.sun.ac.za

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Materials Science, Multidisciplinary	1.31	0.57	-0.74	0.00	0.00	0.00	0.00	-0.06
Materials Science, Paper & Wood	0.86	0.62	-0.24	0.00	0.01	0.00	0.01	-0.06
Materials Science, Textiles	0.83	0.27	-0.57	0.00	0.00	0.00	0.00	-0.10
Mathematical & Computational Biology	1.34	0.93	-0.41	0.00	0.08	0.01	0.08	-0.02
Mathematical Methods In Social Sciences	0.98	0.40	-0.58	0.08	0.13	0.00	0.13	-0.03
Mathematics	1.04	0.45	-0.59	0.00	0.00	0.00	0.00	-0.06
Mathematics, Applied	1.12	0.49	-0.63	0.00	0.00	0.00	0.00	-0.11
Mathematics, Interdisciplinary Applications	1.24	0.26	-0.97	0.00	0.00	0.00	0.00	-0.18
Mechanics	1.08	0.51	-0.56	0.00	0.00	0.00	0.00	-0.05
Medical Ethics	1.02	1.01	-0.01	0.49	0.96	0.96	0.96	0.00
Medical Informatics	1.77	1.43	-0.34	0.31	0.62	0.18	0.62	-0.01
Medical Laboratory Technology	0.98	0.47	-0.51	0.01	0.00	0.00	0.00	-0.07
Medicine, General & Internal	1.37	0.40	-0.97	0.00	0.00	0.00	0.00	-0.10
Medicine, Research & Experimental	1.09	0.69	-0.39	0.00	0.00	0.00	0.00	-0.10
Medieval & Renaissance Studies	1.05	0.87	-0.18	0.30	0.65	0.55	0.65	-0.02
Metallurgy & Metallurgical Engineering	0.86	0.53	-0.34	0.00	0.00	0.00	0.00	-0.04
Meteorology & Atmospheric Sciences	0.97	1.15	0.17	0.33	0.00	0.00	0.00	0.04
Microbiology	1.09	1.19	0.10	0.05	0.00	0.00	0.00	0.02
Mineralogy	0.95	0.84	-0.11	0.81	0.49	0.43	0.49	-0.01
Mining & Mineral Processing	0.91	0.93	0.02	0.60	0.89	0.88	0.89	0.00
Multidisciplinary Sciences	2.26	0.60	-1.66	0.00	0.00	0.00	0.00	-0.25
Music	0.97	1.07	0.10	0.88	0.93	0.93	0.93	0.00
Mycology	0.94	1.26	0.32	0.00	0.05	0.30	0.05	0.04
Nanoscience & Nanotechnology	1.71	0.63	-1.08	0.00	0.00	0.00	0.00	-0.09
Neuroimaging	1.27	1.19	-0.08	0.01	0.57	0.41	0.57	-0.01
Neurosciences	1.14	0.88	-0.26	0.00	0.00	0.00	0.00	-0.05
Neurosciences & Neurology	1.07	0.82	-0.26	0.00	0.00	0.00	0.00	-0.05
Nuclear Science & Technology	0.72	0.36	-0.36	0.01	0.00	0.00	0.00	-0.04
Nursing	0.93	0.38	-0.55	0.00	0.00	0.00	0.00	-0.09

Stellenbosch University https://scholar.sun.ac.za

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					Equal variance			
	Non-OA	OA	Diff.	*p*-value	Assumed (*p*-value)	Not assumed (*p*-value)	*p*-value	r_{pb}
Nutrition & Dietetics	1.15	0.71	-0.44	0.00	0.00	0.00	0.00	-0.11
Obstetrics & Gynecology	1.00	0.91	-0.08	0.00	0.17	0.06	0.17	-0.01
Oceanography	1.00	0.72	-0.28	0.01	0.00	0.00	0.00	-0.06
Oncology	1.10	0.71	-0.39	0.00	0.00	0.00	0.00	-0.03
Operations Research & Management Science	1.17	0.27	-0.89	0.03	0.04	0.00	0.04	-0.02
Ophthalmology	1.04	0.48	-0.56	0.00	0.00	0.00	0.00	-0.13
Optics	0.89	1.20	0.32	0.00	0.00	0.00	0.00	0.05
Ornithology	0.98	0.29	-0.69	0.08	0.15	0.00	0.15	-0.04
Orthopedics	1.02	0.64	-0.39	0.00	0.00	0.00	0.00	-0.08
Otorhinolaryngology	0.97	0.80	-0.17	0.10	0.06	0.01	0.06	-0.03
Paleontology	0.92	0.66	-0.25	0.01	0.00	0.00	0.00	-0.06
Parasitology	1.04	1.28	0.24	0.05	0.00	0.00	0.00	0.07
Pathology	0.98	0.65	-0.34	0.00	0.00	0.00	0.00	-0.10
Pediatrics	0.90	0.63	-0.27	0.00	0.00	0.00	0.00	-0.04
Peripheral Vascular Disease	1.13	0.51	-0.62	0.00	0.01	0.00	0.01	-0.03
Pharmacology & Pharmacy	1.00	0.66	-0.34	0.00	0.00	0.00	0.00	-0.06
Philosophy	1.79	0.08	-1.70	0.00	0.00	0.00	0.00	-0.06
Physical Geography	1.07	1.16	0.09	0.09	0.33	0.30	0.33	0.01
Physics	1.05	0.77	-0.28	0.00	0.00	0.00	0.00	-0.02
Physics, Applied	1.11	0.72	-0.39	0.00	0.00	0.00	0.00	-0.03
Physics, Atomic, Molecular & Chemical	0.95	0.21	-0.75	0.00	0.00	0.00	0.00	-0.05
Physics, Condensed Matter	1.32	0.15	-1.17	0.00	0.00	0.00	0.00	-0.05
Physics, Mathematical	0.93	0.25	-0.68	0.00	0.00	0.00	0.00	-0.05
Physics, Multidisciplinary	1.02	0.96	-0.07	0.08	0.21	0.09	0.21	-0.01
Physics, Nuclear	0.95	1.35	0.41	0.20	0.09	0.00	0.09	0.02
Physics, Particles & Fields	1.16	1.15	-0.01	0.89	0.95	0.90	0.95	0.00
Physiology	0.89	0.99	0.11	0.01	0.00	0.00	0.00	0.03
Plant Sciences	1.03	0.70	-0.33	0.00	0.00	0.00	0.00	-0.08
Political Science	1.08	0.22	-0.86	0.00	0.00	0.00	0.00	-0.06

Stellenbosch University https://scholar.sun.ac.za

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					Equal variance			
Subject area	**Non-OA**	**OA**	**Diff.**	***p*-value**	**Assumed (*p*-value)**	**Not assumed (*p*-value)**	***p*-value**	**r_{pb}**
Polymer Science	1.03	0.70	-0.33	0.00	0.00	0.00	0.00	-0.03
Primary Health Care	0.51	0.73	0.22	0.00	0.00	0.00	0.00	0.12
Psychiatry	1.08	0.71	-0.36	0.00	0.00	0.00	0.00	-0.06
Psychology	1.08	0.78	-0.30	0.00	0.00	0.00	0.00	-0.04
Psychology, Applied	1.11	0.36	-0.75	0.01	0.01	0.00	0.01	-0.04
Psychology, Clinical	1.06	0.67	-0.39	0.00	0.00	0.00	0.00	-0.03
Psychology, Educational	1.09	1.25	0.15	0.46	0.75	0.50	0.75	0.01
Psychology, Experimental	1.29	0.45	-0.85	0.00	0.00	0.00	0.00	-0.04
Psychology, Multidisciplinary	1.10	0.75	-0.35	0.00	0.00	0.00	0.00	-0.07
Public Administration	1.11	0.14	-0.97	0.00	0.00	0.00	0.00	-0.07
Public, Environmental & Occupational Health	0.99	0.95	-0.04	0.00	0.18	0.27	0.18	-0.01
Radiology, Nuclear Medicine & Medical Imaging	0.97	0.74	-0.23	0.00	0.00	0.00	0.00	-0.05
Rehabilitation	0.97	0.95	-0.01	0.97	0.82	0.82	0.82	0.00
Religion	0.92	0.65	-0.27	0.00	0.02	0.01	0.02	-0.04
Remote Sensing	1.12	0.96	-0.16	0.00	0.03	0.00	0.03	-0.03
Reproductive Biology	1.14	0.73	-0.41	0.00	0.00	0.00	0.00	-0.07
Research & Experimental Medicine	1.09	0.69	-0.39	0.00	0.00	0.00	0.00	-0.10
Respiratory System	1.04	0.74	-0.30	0.00	0.00	0.00	0.00	-0.04
Rheumatology	1.08	0.73	-0.35	0.00	0.00	0.00	0.00	-0.07
Robotics	1.04	0.31	-0.73	0.00	0.00	0.00	0.00	-0.17
Science & Technology – Other Topics	1.86	0.60	-1.26	0.00	0.00	0.00	0.00	-0.20
Social Issues	1.02	0.18	-0.83	0.00	0.00	0.00	0.00	-0.15
Social Sciences – Other Topics	1.01	0.62	-0.38	0.00	0.00	0.00	0.00	-0.06
Social Sciences, Biomedical	1.04	0.64	-0.40	0.00	0.00	0.00	0.00	-0.07
Social Sciences, Interdisciplinary	1.03	0.47	-0.56	0.00	0.00	0.00	0.00	-0.10
Social Sciences, Mathematical Methods	0.98	0.40	-0.58	0.08	0.13	0.00	0.13	-0.03
Social Work	0.97	0.50	-0.48	0.00	0.00	0.00	0.00	-0.08
Sociology	1.12	0.35	-0.77	0.00	0.00	0.00	0.00	-0.08
Soil Science	1.24	0.37	-0.87	0.00	0.00	0.00	0.00	-0.15

Stellenbosch University https://scholar.sun.ac.za

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Subject area	Non-OA	OA	Diff.	*p*-value	(*p*-value)	(*p*-value)	*p*-value	r_{pb}
Spectroscopy	0.86	0.14	-0.72	0.00	0.00	0.00	0.00	-0.04
Sport Sciences	1.01	0.51	-0.50	0.00	0.00	0.00	0.00	-0.08
Statistics & Probability	1.23	0.81	-0.42	0.18	0.20	0.00	0.20	-0.01
Substance Abuse	1.05	0.73	-0.32	0.00	0.03	0.00	0.03	-0.04
Surgery	0.95	0.46	-0.48	0.00	0.00	0.00	0.00	-0.07
Telecommunications	1.16	0.27	-0.89	0.00	0.00	0.00	0.00	-0.07
Theater	1.00	0.71	-0.29	0.61	0.80	0.70	0.80	-0.01
Thermodynamics	1.07	0.25	-0.82	0.00	0.00	0.00	0.00	-0.14
Toxicology	0.94	1.47	0.53	0.00	0.00	0.00	0.00	0.11
Transportation	1.03	0.27	-0.76	0.00	0.01	0.00	0.01	-0.04
Tropical Medicine	0.75	1.04	0.29	0.00	0.00	0.00	0.00	0.11
Urban Studies	0.99	0.28	-0.71	0.01	0.01	0.00	0.01	-0.05
Urology & Nephrology	1.02	0.59	-0.44	0.00	0.00	0.00	0.00	-0.06
Veterinary Sciences	1.06	0.60	-0.46	0.00	0.00	0.00	0.00	-0.13
Virology	1.00	1.52	0.51	0.00	0.00	0.00	0.00	0.13
Water Resources	0.93	1.12	0.19	0.09	0.00	0.00	0.00	0.04
Women's Studies	0.91	0.00	-0.91	0.01	0.05	0.00	0.05	-0.05
Zoology	0.93	0.70	-0.23	0.00	0.00	0.00	0.00	-0.05

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ADDENDUM C:
Measure of citation advantage – cited within two years

C.1. Results for all years and all subject areas

Chapter 6 presents the results for the three measures of citation advantage for each of the subject areas for all articles published from 2005 to 2014. The second measure that was investigated was comparing the percentage of articles that were cited within two years of publications for OA and non-OA journal articles. A three-fold method was applied to determine whether OA or non-OA journal articles in a subject area experienced a citation advantage, as elaborated upon in Chapter 4.

In Chapter 6 (section 6.4), only those subject areas which experienced a citation advantage for their OA journal articles are named, and their results are reported in the chapter. The results for all the subject areas in which any OA journal articles were published in the ten years are listed in the table below.

	% cited			*p*-value			Effect size	
Subject area	**Non-OA**	**OA**	**Diff.**	**Expected value < 5**	**χ^2**	**Fisher's exact**	**ϕ**	***p*-value**
Acoustics	69.7	40.9	-28.8	no	0.00	0.00	0.10	0.00
Agricultural Economics & Policy	60.7	25.6	-35.2	no	0.00	0.00	0.20	0.00
Agricultural Engineering	82.4	43.2	-39.2	no	0.00	0.00	0.22	0.00
Agriculture	69.4	39.8	-29.6	no	0.00	0.00	0.22	0.00
Agriculture, Dairy & Animal Science	65.2	40.4	-24.8	no	0.00	0.00	0.19	0.00
Agriculture, Multidisciplinary	67.5	37.0	-30.5	no	0.00	0.00	0.28	0.00
Agronomy	69.6	40.3	-29.3	no	0.00	0.00	0.22	0.00
Allergy	83.6	75.6	-8.1	no	0.00	0.00	0.05	0.00
Anatomy & Morphology	73.2	40.6	-32.6	no	0.00	0.00	0.20	0.00
Andrology	79.1	86.1	7.0	no	0.00	0.00	-0.08	0.00

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Subject area	% cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Anesthesiology	80.0	72.9	-7.1	no	0.00	0.00	0.03	0.00
Anthropology	62.3	28.3	-34.0	no	0.00	0.00	0.18	0.00
Archaeology	52.2	17.2	-35.1	no	0.00	0.00	0.13	0.00
Architecture	6.6	5.4	-1.2	no	0.18	0.20	0.01	0.18
Area Studies	41.2	34.8	-6.3	no	0.11	0.12	0.01	0.11
Art	5.3	17.8	12.5	no	0.00	0.00	-0.07	0.00
Arts & Humanities – Other Topics	13.8	6.3	-7.5	no	0.00	0.00	0.05	0.00
Asian Studies	16.1	15.9	-0.2	no	0.91	0.94	0.00	0.91
Astronomy & Astrophysics	84.0	68.8	-15.2	no	0.00	0.00	0.06	0.00
Audiology & Speech-Language Pathology	73.9	77.1	3.2	no	0.19	0.22	-0.01	0.19
Automation & Control Systems	69.6	66.4	-3.1	no	0.00	0.00	0.01	0.00
Behavioral Sciences	87.5	86.2	-1.3	no	0.14	0.13	0.01	0.14
Biochemical Research Methods	85.0	87.5	2.5	no	0.00	0.00	-0.02	0.00
Biochemistry & Molecular Biology	87.3	86.7	-0.6	no	0.00	0.00	0.00	0.00
Biodiversity & Conservation	75.6	46.1	-29.5	no	0.00	0.00	0.18	0.00
Biodiversity Conservation	75.6	46.1	-29.5	no	0.00	0.00	0.18	0.00
Biology	72.6	66.3	-6.3	no	0.00	0.00	0.06	0.00
Biomedical Social Sciences	78.5	45.2	-33.3	no	0.00	0.00	0.14	0.00
Biophysics	84.6	64.6	-20.0	no	0.00	0.00	0.04	0.00
Biotechnology & Applied Microbiology	81.2	72.7	-8.5	no	0.00	0.00	0.08	0.00
Business	72.8	28.1	-44.7	no	0.00	0.00	0.25	0.00
Business & Economics	64.4	31.9	-32.5	no	0.00	0.00	0.11	0.00
Business, Finance	58.9	41.6	-17.3	no	0.00	0.00	0.03	0.00
Cardiac & Cardiovascular Systems	81.7	70.6	-11.1	no	0.00	0.00	0.08	0.00
Cardiovascular System & Cardiology	82.3	71.6	-10.7	no	0.00	0.00	0.07	0.00
Cell & Tissue Engineering	93.3	83.2	-10.0	no	0.00	0.00	0.08	0.00
Cell Biology	91.0	81.3	-9.7	no	0.00	0.00	0.07	0.00
Chemistry	80.0	63.9	-16.1	no	0.00	0.00	0.07	0.00
Chemistry, Analytical	81.3	75.4	-6.0	no	0.00	0.00	0.03	0.00
Chemistry, Applied	77.9	50.9	-27.0	no	0.00	0.00	0.09	0.00
Chemistry, Inorganic & Nuclear	75.5	64.0	-11.5	no	0.00	0.00	0.02	0.00

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	% cited			*p*-value			Effect size	
Subject area	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Chemistry, Medicinal	83.6	76.2	-7.4	no	0.00	0.00	0.03	0.00
Chemistry, Multidisciplinary	77.1	56.9	-20.2	no	0.00	0.00	0.11	0.00
Chemistry, Organic	82.5	72.7	-9.7	no	0.00	0.00	0.06	0.00
Chemistry, Physical	84.4	63.8	-20.6	no	0.00	0.00	0.03	0.00
Classics	13.7	22.9	9.2	no	0.00	0.00	-0.06	0.00
Clinical Neurology	81.5	69.3	-12.2	no	0.00	0.00	0.06	0.00
Communication	61.3	49.0	-12.3	no	0.00	0.00	0.05	0.00
Computer Science	67.7	51.1	-16.6	no	0.00	0.00	0.06	0.00
Computer Science, Artificial Intelligence	74.3	62.3	-12.0	no	0.00	0.00	0.05	0.00
Computer Science, Cybernetics	64.0	38.2	-25.7	no	0.00	0.00	0.10	0.00
Computer Science, Information Systems	64.3	46.9	-17.4	no	0.00	0.00	0.07	0.00
Computer Science, Interdisciplinary Applications	74.0	65.5	-8.5	no	0.00	0.00	0.02	0.00
Computer Science, Software Engineering	60.1	45.9	-14.2	no	0.00	0.00	0.04	0.00
Computer Science, Theory & Methods	65.2	30.5	-34.7	no	0.00	0.00	0.07	0.00
Construction & Building Technology	64.2	36.7	-27.5	no	0.00	0.00	0.08	0.00
Critical Care Medicine	85.8	90.9	5.2	no	0.00	0.00	-0.04	0.00
Crystallography	60.4	23.1	-37.3	no	0.00	0.00	0.29	0.00
Demography	67.1	51.7	-15.4	no	0.00	0.00	0.11	0.00
Dentistry, Oral Surgery & Medicine	75.5	62.9	-12.6	no	0.00	0.00	0.06	0.00
Dermatology	75.7	56.3	-19.5	no	0.00	0.00	0.10	0.00
Developmental Biology	88.5	91.8	3.3	no	0.00	0.00	-0.02	0.00
Ecology	82.7	72.2	-10.5	no	0.00	0.00	0.06	0.00
Economics	60.6	29.2	-31.4	no	0.00	0.00	0.10	0.00
Education & Educational Research	58.5	61.1	2.5	no	0.00	0.00	-0.01	0.00
Education, Scientific Disciplines	62.2	72.2	10.0	no	0.00	0.00	-0.07	0.00
Electrochemistry	85.3	78.9	-6.4	no	0.00	0.00	0.05	0.00
Emergency Medicine	74.7	45.4	-29.3	no	0.00	0.00	0.16	0.00
Endocrinology & Metabolism	88.3	77.9	-10.5	no	0.00	0.00	0.07	0.00
Energy & Fuels	79.9	67.5	-12.4	no	0.00	0.00	0.05	0.00
Engineering	67.6	51.1	-16.5	no	0.00	0.00	0.06	0.00
Engineering, Aerospace	47.2	23.2	-24.0	no	0.00	0.00	0.02	0.00

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Subject area	% cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Engineering, Biomedical	79.8	79.5	-0.3	no	0.54	0.55	0.00	0.54
Engineering, Chemical	71.4	48.9	-22.5	no	0.00	0.00	0.07	0.00
Engineering, Civil	64.8	30.9	-33.9	no	0.00	0.00	0.08	0.00
Engineering, Electrical & Electronic	66.7	62.2	-4.5	no	0.00	0.00	0.02	0.00
Engineering, Environmental	84.8	69.5	-15.3	no	0.00	0.00	0.02	0.00
Engineering, Industrial	72.1	21.7	-50.5	no	0.00	0.00	0.07	0.00
Engineering, Manufacturing	69.5	43.0	-26.5	no	0.00	0.00	0.05	0.00
Engineering, Marine	34.3	32.9	-1.4	no	0.59	0.61	0.01	0.59
Engineering, Mechanical	62.6	37.7	-25.0	no	0.00	0.00	0.08	0.00
Engineering, Multidisciplinary	59.0	35.2	-23.8	no	0.00	0.00	0.16	0.00
Engineering, Petroleum	27.4	47.1	19.7	no	0.00	0.00	-0.11	0.00
Entomology	63.0	43.7	-19.3	no	0.00	0.00	0.11	0.00
Environmental Sciences	80.6	74.2	-6.4	no	0.00	0.00	0.03	0.00
Environmental Sciences & Ecology	80.2	73.8	-6.5	no	0.00	0.00	0.04	0.00
Environmental Studies	75.3	82.0	6.7	no	0.00	0.00	-0.03	0.00
Ethics	58.8	52.4	-6.4	no	0.00	0.00	0.03	0.00
Evolutionary Biology	87.6	88.9	1.3	no	0.00	0.00	-0.01	0.00
Family Studies	68.8	89.7	20.9	no	0.00	0.00	-0.05	0.00
Film, Radio & Television	7.2	6.7	-0.6	no	0.61	0.67	0.00	0.61
Film, Radio, Television	7.2	6.7	-0.6	no	0.61	0.67	0.00	0.61
Fisheries	72.0	57.3	-14.7	no	0.00	0.00	0.08	0.00
Folklore	11.4	6.9	-4.5	no	0.00	0.00	0.05	0.00
Food Science & Technology	74.4	46.0	-28.4	no	0.00	0.00	0.11	0.00
Forestry	70.8	44.1	-26.7	no	0.00	0.00	0.18	0.00
Gastroenterology & Hepatology	84.6	82.4	-2.2	no	0.00	0.00	0.02	0.00
General & Internal Medicine	71.6	63.3	-8.3	no	0.00	0.00	0.08	0.00
Genetics & Heredity	85.1	86.0	0.9	no	0.00	0.00	-0.01	0.00
Geochemistry & Geophysics	77.8	53.2	-24.5	no	0.00	0.00	0.10	0.00
Geography	71.9	13.8	-58.2	no	0.00	0.00	0.26	0.00
Geography, Physical	80.1	69.5	-10.6	no	0.00	0.00	0.05	0.00
Geology	74.1	74.8	0.6	no	0.07	0.07	0.00	0.07

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	% cited			*p*-value			Effect size	
Subject area	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Geosciences, Multidisciplinary	74.6	77.6	2.9	no	0.00	0.00	-0.02	0.00
Geriatrics & Gerontology	79.9	74.6	-5.3	no	0.00	0.00	0.03	0.00
Gerontology	76.9	53.4	-23.5	no	0.00	0.00	0.11	0.00
Government & Law	52.5	43.5	-9.0	no	0.00	0.00	0.03	0.00
Health Care Sciences & Services	77.6	79.2	1.5	no	0.00	0.00	-0.01	0.00
Health Policy & Services	76.9	78.3	1.4	no	0.06	0.06	-0.01	0.06
Hematology	87.8	87.3	-0.5	no	0.36	0.35	0.00	0.36
History	19.8	8.8	-11.0	no	0.00	0.00	0.06	0.00
History & Philosophy Of Science	45.3	16.0	-29.4	no	0.00	0.00	0.15	0.00
Horticulture	64.9	31.1	-33.8	no	0.00	0.00	0.20	0.00
Humanities, Multidisciplinary	13.6	4.7	-8.9	no	0.00	0.00	0.05	0.00
Imaging Science & Photographic Technology	75.7	44.7	-31.0	no	0.00	0.00	0.10	0.00
Immunology	88.5	85.3	-3.2	no	0.00	0.00	0.02	0.00
Industrial Relations & Labor	53.1	51.7	-1.4	no	0.45	0.45	0.01	0.45
Infectious Diseases	87.2	84.5	-2.7	no	0.00	0.00	0.03	0.00
Information Science & Library Science	63.5	37.1	-26.3	no	0.00	0.00	0.14	0.00
Instruments & Instrumentation	66.1	76.9	10.8	no	0.00	0.00	-0.05	0.00
Integrative & Complementary Medicine	78.3	71.9	-6.4	no	0.00	0.00	0.06	0.00
International Relations	54.6	33.7	-20.8	no	0.00	0.00	0.05	0.00
Language & Linguistics	33.6	19.7	-13.9	no	0.00	0.00	0.06	0.00
Law	53.9	49.8	-4.1	no	0.00	0.00	0.01	0.00
Life Sciences & Biomedicine – Other Topics	72.6	66.3	-6.3	no	0.00	0.00	0.06	0.00
Limnology	76.2	73.7	-2.5	no	0.23	0.24	0.01	0.23
Linguistics	44.8	25.1	-19.7	no	0.00	0.00	0.08	0.00
Literary Theory & Criticism	16.7	2.3	-14.4	no	0.00	0.00	0.06	0.00
Literature	9.0	3.7	-5.3	no	0.00	0.00	0.03	0.00
Literature, Romance	4.3	3.3	-1.0	no	0.10	0.10	0.01	0.10
Literature, Slavic	4.5	2.4	-2.1	no	0.19	0.25	0.02	0.19
Logic	37.0	18.1	-18.9	no	0.00	0.00	0.11	0.00
Management	75.2	28.6	-46.6	no	0.00	0.00	0.21	0.00
Marine & Freshwater Biology	78.5	57.0	-21.4	no	0.00	0.00	0.11	0.00

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Subject area	% cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Materials Science	75.1	61.3	-13.8	no	0.00	0.00	0.06	0.00
Materials Science, Biomaterials	88.6	82.9	-5.7	no	0.00	0.00	0.02	0.00
Materials Science, Ceramics	64.1	40.2	-23.8	no	0.00	0.00	0.13	0.00
Materials Science, Multidisciplinary	76.6	65.5	-11.1	no	0.00	0.00	0.05	0.00
Materials Science, Paper & Wood	45.9	64.4	18.5	no	0.00	0.00	-0.14	0.00
Materials Science, Textiles	54.7	43.9	-10.8	no	0.00	0.00	0.07	0.00
Mathematical & Computational Biology	75.5	83.0	7.5	no	0.00	0.00	-0.08	0.00
Mathematical Methods In Social Sciences	60.5	53.4	-7.1	no	0.22	0.23	0.01	0.22
Mathematics	51.5	34.7	-16.7	no	0.00	0.00	0.09	0.00
Mathematics, Applied	52.5	32.3	-20.2	no	0.00	0.00	0.12	0.00
Mathematics, Interdisciplinary Applications	63.7	38.1	-25.6	no	0.00	0.00	0.15	0.00
Mechanics	69.2	43.9	-25.3	no	0.00	0.00	0.06	0.00
Medical Ethics	68.6	54.6	-14.0	no	0.00	0.00	0.11	0.00
Medical Informatics	80.6	84.6	4.0	no	0.00	0.00	-0.03	0.00
Medical Laboratory Technology	75.0	34.6	-40.4	no	0.00	0.00	0.17	0.00
Medicine, General & Internal	67.8	61.6	-6.1	no	0.00	0.00	0.06	0.00
Medicine, Research & Experimental	80.1	75.8	-4.3	no	0.00	0.00	0.04	0.00
Medieval & Renaissance Studies	16.5	11.2	-5.4	no	0.00	0.00	0.04	0.00
Metallurgy & Metallurgical Engineering	57.9	35.9	-22.0	no	0.00	0.00	0.06	0.00
Meteorology & Atmospheric Sciences	78.0	83.9	5.9	no	0.00	0.00	-0.06	0.00
Microbiology	86.9	77.5	-9.5	no	0.00	0.00	0.08	0.00
Mineralogy	73.2	43.6	-29.6	no	0.00	0.00	0.08	0.00
Mining & Mineral Processing	58.6	19.1	-39.5	no	0.00	0.00	0.17	0.00
Multidisciplinary Sciences	77.8	83.7	5.9	no	0.00	0.00	-0.07	0.00
Music	5.6	1.9	-3.7	no	0.10	0.13	0.01	0.10
Mycology	74.9	65.4	-9.6	no	0.00	0.00	0.04	0.00
Nanoscience & Nanotechnology	84.4	76.6	-7.7	no	0.00	0.00	0.05	0.00
Neuroimaging	89.0	93.1	4.1	no	0.01	0.02	-0.02	0.01
Neurosciences	87.8	78.1	-9.7	no	0.00	0.00	0.07	0.00
Neurosciences & Neurology	84.8	75.5	-9.3	no	0.00	0.00	0.06	0.00
Nuclear Science & Technology	55.2	34.6	-20.6	no	0.00	0.00	0.03	0.00

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	% cited			p-value			Effect size	
Subject area	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Nursing	66.2	37.7	-28.5	no	0.00	0.00	0.15	0.00
Nutrition & Dietetics	85.4	77.5	-7.9	no	0.00	0.00	0.06	0.00
Obstetrics & Gynecology	77.3	55.7	-21.6	no	0.00	0.00	0.08	0.00
Oceanography	77.3	55.9	-21.4	no	0.00	0.00	0.13	0.00
Oncology	87.8	82.8	-5.0	no	0.00	0.00	0.04	0.00
Operations Research & Management Science	71.4	35.8	-35.7	no	0.00	0.00	0.03	0.00
Ophthalmology	77.3	69.3	-8.0	no	0.00	0.00	0.06	0.00
Optics	69.7	83.2	13.5	no	0.00	0.00	-0.11	0.00
Ornithology	60.3	61.0	0.7	no	0.86	0.93	0.00	0.86
Orthopedics	76.2	69.6	-6.6	no	0.00	0.00	0.04	0.00
Otorhinolaryngology	70.3	63.2	-7.1	no	0.00	0.00	0.03	0.00
Paleontology	69.9	60.6	-9.3	no	0.00	0.00	0.05	0.00
Parasitology	80.3	84.5	4.3	no	0.00	0.00	-0.05	0.00
Pathology	80.9	68.7	-12.1	no	0.00	0.00	0.09	0.00
Pediatrics	74.5	58.6	-15.9	no	0.00	0.00	0.07	0.00
Peripheral Vascular Disease	85.2	86.4	1.2	no	0.27	0.29	0.00	0.27
Pharmacology & Pharmacy	83.8	63.0	-20.8	no	0.00	0.00	0.12	0.00
Philosophy	37.9	7.9	-30.0	no	0.00	0.00	0.12	0.00
Physical Geography	80.1	69.5	-10.6	no	0.00	0.00	0.05	0.00
Physics	72.5	61.8	-10.8	no	0.00	0.00	0.05	0.00
Physics, Applied	73.2	75.1	1.9	no	0.00	0.00	-0.01	0.00
Physics, Atomic, Molecular & Chemical	79.8	58.5	-21.3	no	0.00	0.00	0.05	0.00
Physics, Condensed Matter	74.9	37.5	-37.4	no	0.00	0.00	0.11	0.00
Physics, Mathematical	64.7	48.6	-16.1	no	0.00	0.00	0.04	0.00
Physics, Multidisciplinary	67.3	56.3	-11.0	no	0.00	0.00	0.07	0.00
Physics, Nuclear	62.8	74.8	12.0	no	0.00	0.00	-0.04	0.00
Physics, Particles & Fields	72.2	69.2	-3.0	no	0.00	0.00	0.01	0.00
Physiology	85.2	78.9	-6.3	no	0.00	0.00	0.04	0.00
Plant Sciences	77.1	56.9	-20.2	no	0.00	0.00	0.14	0.00
Political Science	51.4	28.5	-23.0	no	0.00	0.00	0.06	0.00
Polymer Science	77.7	60.7	-16.9	no	0.00	0.00	0.05	0.00

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Subject area	% cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Primary Health Care	67.1	78.1	11.0	no	0.00	0.00	-0.12	0.00
Psychiatry	80.5	62.6	-17.9	no	0.00	0.00	0.10	0.00
Psychology	74.9	64.7	-10.2	no	0.00	0.00	0.05	0.00
Psychology, Applied	75.1	45.0	-30.1	no	0.00	0.00	0.07	0.00
Psychology, Clinical	78.6	74.4	-4.2	no	0.01	0.01	0.01	0.01
Psychology, Educational	67.0	69.1	2.1	no	0.60	0.64	0.00	0.60
Psychology, Experimental	79.5	73.3	-6.3	no	0.00	0.00	0.02	0.00
Psychology, Multidisciplinary	68.5	55.9	-12.5	no	0.00	0.00	0.09	0.00
Psychology, Social	73.7	84.8	11.1	no	0.15	0.17	-0.01	0.15
Public Administration	65.0	18.7	-46.3	no	0.00	0.00	0.13	0.00
Public, Environmental & Occupational Health	76.7	68.2	-8.5	no	0.00	0.00	0.08	0.00
Radiology, Nuclear Medicine & Medical Imaging	80.2	76.8	-3.4	no	0.00	0.00	0.02	0.00
Rehabilitation	72.9	59.3	-13.6	no	0.00	0.00	0.08	0.00
Religion	23.7	14.2	-9.5	no	0.00	0.00	0.07	0.00
Remote Sensing	76.5	71.1	-5.5	no	0.00	0.00	0.04	0.00
Reproductive Biology	86.1	79.6	-6.6	no	0.00	0.00	0.05	0.00
Research & Experimental Medicine	80.1	75.8	-4.3	no	0.00	0.00	0.04	0.00
Respiratory System	84.3	82.2	-2.1	no	0.00	0.00	0.01	0.00
Rheumatology	86.6	82.0	-4.6	no	0.00	0.00	0.04	0.00
Robotics	71.5	39.1	-32.4	no	0.00	0.00	0.21	0.00
Science & Technology – Other Topics	81.1	82.9	1.8	no	0.00	0.00	-0.02	0.00
Social Issues	60.1	13.8	-46.3	no	0.00	0.00	0.24	0.00
Social Sciences – Other Topics	59.1	36.4	-22.6	no	0.00	0.00	0.10	0.00
Social Sciences, Biomedical	78.5	45.2	-33.3	no	0.00	0.00	0.14	0.00
Social Sciences, Interdisciplinary	58.8	30.2	-28.6	no	0.00	0.00	0.15	0.00
Social Sciences, Mathematical Methods	60.5	53.4	-7.1	no	0.22	0.23	0.01	0.22
Social Work	60.6	44.0	-16.6	no	0.00	0.00	0.06	0.00
Sociology	58.0	23.7	-34.3	no	0.00	0.00	0.13	0.00
Soil Science	75.7	50.1	-25.6	no	0.00	0.00	0.16	0.00
Spectroscopy	69.5	35.1	-34.3	no	0.00	0.00	0.05	0.00
Sport Sciences	76.4	48.6	-27.9	no	0.00	0.00	0.14	0.00

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Subject area	% cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Statistics & Probability	58.6	48.5	-10.1	no	0.00	0.00	0.04	0.00
Substance Abuse	79.9	73.0	-6.9	no	0.00	0.00	0.03	0.00
Surgery	75.8	56.8	-19.0	no	0.00	0.00	0.07	0.00
Telecommunications	61.9	58.3	-3.6	no	0.00	0.00	0.02	0.00
Theater	8.6	21.4	12.8	yes	0.00	0.00	-0.04	0.00
Thermodynamics	71.8	42.4	-29.4	no	0.00	0.00	0.12	0.00
Toxicology	84.4	75.8	-8.6	no	0.00	0.00	0.06	0.00
Transportation	63.8	42.5	-21.3	no	0.00	0.00	0.03	0.00
Tropical Medicine	75.0	77.5	2.4	no	0.00	0.00	-0.03	0.00
Urban Studies	67.6	28.4	-39.3	no	0.00	0.00	0.10	0.00
Urology & Nephrology	80.1	70.8	-9.3	no	0.00	0.00	0.05	0.00
Veterinary Sciences	62.8	40.9	-21.9	no	0.00	0.00	0.17	0.00
Virology	89.0	92.5	3.6	no	0.00	0.00	-0.04	0.00
Water Resources	73.9	77.8	3.9	no	0.00	0.00	-0.02	0.00
Women's Studies	57.5	0.0	-57.5	yes	0.00	0.00	0.03	0.00
Zoology	66.1	49.9	-16.2	no	0.00	0.00	0.10	0.00

C.2. Results for articles published in 2014, for each of the subject areas

The same analysis as discussed in Addendum C.1 was conducted a second time, only considering the articles published in 2014 to control for the potential confounding effect of the variance between years. The table below presents the results for all subject areas in which any OA journal articles were published in 2014.

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Subject area	% cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Acoustics	74.2	45.5	-28.7	no	0.00	0.00	0.15	0.00
Agricultural Economics & Policy	67.9	26.3	-41.6	no	0.00	0.00	0.32	0.00
Agricultural Engineering	85.8	42.6	-43.3	no	0.00	0.00	0.34	0.00
Agriculture	72.3	42.4	-29.9	no	0.00	0.00	0.23	0.00
Agriculture, Dairy & Animal Science	66.3	46.7	-19.6	no	0.00	0.00	0.14	0.00
Agriculture, Multidisciplinary	69.0	41.6	-27.4	no	0.00	0.00	0.24	0.00
Agronomy	73.2	42.4	-30.8	no	0.00	0.00	0.25	0.00
Allergy	87.1	78.4	-8.7	no	0.00	0.00	0.07	0.00
Anatomy & Morphology	70.8	54.5	-16.3	no	0.00	0.00	0.13	0.00
Andrology	78.8	92.0	13.2	no	0.00	0.00	-0.15	0.00
Anesthesiology	83.0	71.6	-11.5	no	0.00	0.00	0.08	0.00
Anthropology	69.6	23.0	-46.6	no	0.00	0.00	0.33	0.00
Archaeology	53.0	17.5	-35.4	no	0.00	0.00	0.14	0.00
Architecture	12.6	8.0	-4.6	no	0.24	0.29	0.03	0.24
Area Studies	43.2	32.0	-11.2	no	0.26	0.31	0.02	0.26
Art	7.1	22.3	15.2	no	0.00	0.00	-0.09	0.00
Arts & Humanities – Other Topics	16.2	5.8	-10.4	no	0.00	0.00	0.07	0.00
Asian Studies	19.6	11.4	-8.2	no	0.17	0.24	0.04	0.17
Astronomy & Astrophysics	84.2	77.0	-7.2	no	0.00	0.00	0.05	0.00
Audiology & Speech-Language Pathology	73.6	77.0	3.4	no	0.52	0.59	-0.01	0.52
Automation & Control Systems	78.2	73.4	-4.8	no	0.09	0.09	0.02	0.09
Behavioral Sciences	87.2	88.7	1.5	no	0.30	0.35	-0.01	0.30
Biochemical Research Methods	84.4	85.2	0.9	no	0.36	0.37	-0.01	0.36
Biochemistry & Molecular Biology	86.2	86.9	0.7	no	0.12	0.13	-0.01	0.12
Biodiversity & Conservation	75.3	48.4	-26.9	no	0.00	0.00	0.17	0.00
Biodiversity Conservation	75.3	48.4	-26.9	no	0.00	0.00	0.17	0.00
Biology	73.2	71.9	-1.3	no	0.18	0.18	0.01	0.18
Biomedical Social Sciences	79.5	60.5	-19.0	no	0.00	0.00	0.10	0.00
Biophysics	83.3	62.1	-21.3	no	0.00	0.00	0.05	0.00
Biotechnology & Applied Microbiology	82.8	74.5	-8.2	no	0.00	0.00	0.09	0.00

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Subject area	% cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Business	78.0	27.9	-50.1	no	0.00	0.00	0.19	0.00
Business & Economics	69.3	43.8	-25.4	no	0.00	0.00	0.08	0.00
Business, Finance	64.6	21.4	-43.2	yes	0.00	0.00	0.05	0.00
Cardiac & Cardiovascular Systems	84.2	78.8	-5.5	no	0.00	0.00	0.05	0.00
Cardiovascular System & Cardiology	84.3	79.3	-5.0	no	0.00	0.00	0.04	0.00
Cell & Tissue Engineering	92.3	92.7	0.4	no	0.78	0.85	0.00	0.78
Cell Biology	90.9	89.5	-1.3	no	0.01	0.01	0.02	0.01
Chemistry	83.1	70.1	-13.0	no	0.00	0.00	0.07	0.00
Chemistry, Analytical	82.9	80.7	-2.1	no	0.03	0.03	0.01	0.03
Chemistry, Applied	82.6	54.5	-28.1	no	0.00	0.00	0.11	0.00
Chemistry, Inorganic & Nuclear	76.2	47.6	-28.6	no	0.00	0.00	0.06	0.00
Chemistry, Medicinal	83.5	82.1	-1.3	no	0.30	0.30	0.01	0.30
Chemistry, Multidisciplinary	81.8	65.3	-16.6	no	0.00	0.00	0.10	0.00
Chemistry, Organic	82.8	77.2	-5.6	no	0.00	0.00	0.04	0.00
Chemistry, Physical	87.3	52.9	-34.3	no	0.00	0.00	0.08	0.00
Classics	11.4	16.7	5.2	no	0.27	0.25	-0.04	0.27
Clinical Neurology	84.3	73.9	-10.4	no	0.00	0.00	0.07	0.00
Communication	65.3	68.9	3.5	no	0.35	0.40	-0.02	0.35
Computer Science	70.6	49.8	-20.8	no	0.00	0.00	0.08	0.00
Computer Science, Artificial Intelligence	77.3	62.5	-14.8	no	0.00	0.00	0.07	0.00
Computer Science, Cybernetics	74.0	34.6	-39.5	no	0.00	0.00	0.20	0.00
Computer Science, Information Systems	67.5	46.9	-20.6	no	0.00	0.00	0.10	0.00
Computer Science, Interdisciplinary Applications	76.6	67.2	-9.5	no	0.00	0.00	0.03	0.00
Computer Science, Software Engineering	61.4	49.7	-11.7	no	0.00	0.01	0.03	0.00
Computer Science, Theory & Methods	66.0	11.0	-55.0	no	0.00	0.00	0.11	0.00
Construction & Building Technology	73.1	43.9	-29.2	no	0.00	0.00	0.10	0.00
Critical Care Medicine	88.0	90.7	2.7	no	0.09	0.10	-0.02	0.09
Crystallography	70.6	78.3	7.6	no	0.11	0.13	-0.02	0.11
Demography	72.4	60.1	-12.3	no	0.00	0.00	0.10	0.00
Dentistry, Oral Surgery & Medicine	76.1	64.1	-12.0	no	0.00	0.00	0.07	0.00
Dermatology	77.6	57.1	-20.5	no	0.00	0.00	0.11	0.00

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Subject area	% cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	p-value
Developmental Biology	85.4	86.3	0.9	no	0.79	0.89	0.00	0.79
Ecology	83.5	78.4	-5.1	no	0.00	0.00	0.04	0.00
Economics	64.8	38.6	-26.2	no	0.00	0.00	0.09	0.00
Education & Educational Research	63.4	65.2	1.8	no	0.23	0.24	-0.01	0.23
Education, Scientific Disciplines	66.4	76.0	9.6	no	0.00	0.00	-0.08	0.00
Electrochemistry	90.4	81.1	-9.3	no	0.00	0.00	0.10	0.00
Emergency Medicine	76.2	50.5	-25.7	no	0.00	0.00	0.16	0.00
Endocrinology & Metabolism	89.2	79.0	-10.2	no	0.00	0.00	0.09	0.00
Energy & Fuels	87.6	72.7	-14.9	no	0.00	0.00	0.08	0.00
Engineering	73.7	49.9	-23.8	no	0.00	0.00	0.12	0.00
Engineering, Aerospace	57.2	26.1	-31.1	no	0.00	0.00	0.05	0.00
Engineering, Biomedical	78.4	82.7	4.2	no	0.00	0.00	-0.03	0.00
Engineering, Chemical	79.0	56.3	-22.7	no	0.00	0.00	0.08	0.00
Engineering, Civil	71.3	58.0	-13.3	no	0.00	0.00	0.04	0.00
Engineering, Electrical & Electronic	71.6	62.9	-8.7	no	0.00	0.00	0.05	0.00
Engineering, Environmental	88.8	77.3	-11.5	no	0.00	0.00	0.04	0.00
Engineering, Industrial	78.7	34.7	-44.0	no	0.00	0.00	0.11	0.00
Engineering, Manufacturing	77.3	58.6	-18.7	no	0.02	0.02	0.03	0.02
Engineering, Marine	63.3	41.8	-21.5	no	0.00	0.00	0.15	0.00
Engineering, Mechanical	69.9	40.3	-29.6	no	0.00	0.00	0.14	0.00
Engineering, Multidisciplinary	67.9	31.4	-36.5	no	0.00	0.00	0.31	0.00
Engineering, Petroleum	37.0	55.5	18.5	no	0.00	0.00	-0.09	0.00
Entomology	65.6	43.8	-21.8	no	0.00	0.00	0.15	0.00
Environmental Sciences	83.4	77.9	-5.5	no	0.00	0.00	0.04	0.00
Environmental Sciences & Ecology	82.6	78.1	-4.5	no	0.00	0.00	0.03	0.00
Environmental Studies	79.5	80.8	1.3	no	0.38	0.40	-0.01	0.38
Ethics	62.7	63.2	0.5	no	0.88	0.89	0.00	0.88
Evolutionary Biology	87.9	89.6	1.7	no	0.11	0.12	-0.02	0.11
Family Studies	71.0	87.5	16.5	yes	0.30	0.45	-0.02	0.30
Film, Radio & Television	11.4	5.9	-5.5	no	0.01	0.01	0.05	0.01
Film, Radio, Television	11.4	5.9	-5.5	no	0.01	0.01	0.05	0.01

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Subject area	% cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Fisheries	71.7	56.8	-14.9	no	0.00	0.00	0.09	0.00
Folklore	12.4	0.0	-12.4	no	0.00	0.00	0.16	0.00
Food Science & Technology	78.5	55.1	-23.4	no	0.00	0.00	0.09	0.00
Forestry	71.2	50.3	-20.9	no	0.00	0.00	0.17	0.00
Gastroenterology & Hepatology	86.6	86.5	-0.1	no	0.86	0.87	0.00	0.86
General & Internal Medicine	73.2	68.0	-5.2	no	0.00	0.00	0.05	0.00
Genetics & Heredity	83.3	86.7	3.4	no	0.00	0.00	-0.04	0.00
Geochemistry & Geophysics	81.2	60.8	-20.4	no	0.00	0.00	0.10	0.00
Geography	76.7	23.4	-53.3	no	0.00	0.00	0.28	0.00
Geography, Physical	84.4	78.7	-5.6	no	0.00	0.01	0.04	0.00
Geology	78.8	80.3	1.5	no	0.07	0.07	-0.01	0.07
Geosciences, Multidisciplinary	79.2	83.8	4.6	no	0.00	0.00	-0.04	0.00
Geriatrics & Gerontology	82.2	84.7	2.5	no	0.06	0.06	-0.02	0.06
Gerontology	79.7	66.2	-13.5	no	0.00	0.00	0.09	0.00
Government & Law	56.3	45.9	-10.4	no	0.00	0.00	0.03	0.00
Health Care Sciences & Services	77.5	80.9	3.4	no	0.00	0.00	-0.03	0.00
Health Policy & Services	75.9	81.8	5.9	no	0.00	0.00	-0.04	0.00
Hematology	86.1	85.2	-0.9	no	0.57	0.56	0.01	0.57
History	21.9	11.8	-10.1	no	0.00	0.00	0.07	0.00
History & Philosophy Of Science	46.9	22.8	-24.1	no	0.00	0.00	0.12	0.00
Horticulture	65.5	32.9	-32.6	no	0.00	0.00	0.19	0.00
Humanities, Multidisciplinary	16.3	4.4	-11.8	no	0.00	0.00	0.07	0.00
Imaging Science & Photographic Technology	78.7	56.9	-21.7	no	0.00	0.00	0.07	0.00
Immunology	88.1	84.1	-4.0	no	0.00	0.00	0.04	0.00
Industrial Relations & Labor	55.0	87.7	32.6	no	0.00	0.00	-0.18	0.00
Infectious Diseases	86.9	86.1	-0.7	no	0.26	0.26	0.01	0.26
Information Science & Library Science	67.8	42.9	-24.9	no	0.00	0.00	0.13	0.00
Instruments & Instrumentation	70.3	81.3	10.9	no	0.00	0.00	-0.07	0.00
Integrative & Complementary Medicine	81.4	64.5	-16.9	no	0.00	0.00	0.18	0.00
International Relations	63.0	25.5	-37.6	no	0.00	0.00	0.10	0.00
Language & Linguistics	37.4	23.8	-13.6	no	0.00	0.00	0.07	0.00

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Subject area	% cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Law	53.5	55.1	1.6	no	0.67	0.71	-0.01	0.67
Life Sciences & Biomedicine – Other Topics	73.2	71.9	-1.3	no	0.18	0.18	0.01	0.18
Limnology	77.4	79.7	2.3	no	0.64	0.78	-0.01	0.64
Linguistics	48.5	30.3	-18.2	no	0.00	0.00	0.08	0.00
Literary Theory & Criticism	17.3	2.4	-14.9	no	0.00	0.00	0.16	0.00
Literature	10.1	4.9	-5.3	no	0.00	0.00	0.03	0.00
Literature, Romance	5.3	7.6	2.2	no	0.28	0.32	-0.03	0.28
Literature, Slavic	4.5	2.4	-2.2	no	0.22	0.25	0.05	0.22
Logic	35.6	19.6	-16.0	no	0.00	0.00	0.10	0.00
Management	78.5	29.3	-49.3	no	0.00	0.00	0.15	0.00
Marine & Freshwater Biology	78.6	59.4	-19.2	no	0.00	0.00	0.11	0.00
Materials Science	80.9	65.1	-15.7	no	0.00	0.00	0.09	0.00
Materials Science, Biomaterials	89.1	72.5	-16.6	no	0.00	0.00	0.06	0.00
Materials Science, Ceramics	74.4	37.9	-36.5	no	0.00	0.00	0.20	0.00
Materials Science, Multidisciplinary	82.1	67.9	-14.2	no	0.00	0.00	0.09	0.00
Materials Science, Paper & Wood	57.9	67.3	9.3	no	0.00	0.00	-0.09	0.00
Materials Science, Textiles	61.3	42.6	-18.6	no	0.00	0.00	0.12	0.00
Mathematical & Computational Biology	71.1	78.5	7.4	no	0.00	0.00	-0.08	0.00
Mathematical Methods In Social Sciences	59.7	44.4	-15.3	no	0.11	0.12	0.03	0.11
Mathematics	51.7	30.4	-21.3	no	0.00	0.00	0.15	0.00
Mathematics, Applied	53.8	29.6	-24.2	no	0.00	0.00	0.19	0.00
Mathematics, Interdisciplinary Applications	64.0	29.1	-35.0	no	0.00	0.00	0.30	0.00
Mechanics	74.2	55.0	-19.2	no	0.00	0.00	0.07	0.00
Medical Ethics	69.9	65.8	-4.1	no	0.24	0.26	0.04	0.24
Medical Informatics	78.8	85.9	7.1	no	0.00	0.00	-0.05	0.00
Medical Laboratory Technology	77.3	42.4	-34.9	no	0.00	0.00	0.17	0.00
Medicine, General & Internal	69.1	66.7	-2.4	no	0.00	0.00	0.03	0.00
Medicine, Research & Experimental	80.3	73.1	-7.1	no	0.00	0.00	0.08	0.00
Medieval & Renaissance Studies	17.3	18.0	0.7	no	0.90	0.85	0.00	0.90
Metallurgy & Metallurgical Engineering	69.3	49.8	-19.6	no	0.00	0.00	0.07	0.00
Meteorology & Atmospheric Sciences	80.6	86.7	6.1	no	0.00	0.00	-0.07	0.00

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	% cited			p-value			Effect size	
Subject area	**Non-OA**	**OA**	**Diff.**	**Expected value < 5**	**χ^2**	**Fisher's exact**	**ϕ**	***p*-value**
Microbiology	87.4	87.7	0.3	no	0.71	0.74	0.00	0.71
Mineralogy	77.9	65.8	-12.1	no	0.01	0.02	0.05	0.01
Mining & Mineral Processing	70.0	66.2	-3.7	no	0.49	0.52	0.01	0.49
Multidisciplinary Sciences	77.9	82.5	4.6	no	0.00	0.00	-0.05	0.00
Music	7.5	8.3	0.8	yes	0.92	0.61	0.00	0.92
Mycology	76.2	58.2	-17.9	no	0.00	0.00	0.09	0.00
Nanoscience & Nanotechnology	87.3	76.2	-11.1	no	0.00	0.00	0.09	0.00
Neuroimaging	90.8	97.3	6.6	no	0.00	0.00	-0.06	0.00
Neurosciences	87.8	84.9	-2.9	no	0.00	0.00	0.03	0.00
Neurosciences & Neurology	86.2	82.7	-3.4	no	0.00	0.00	0.03	0.00
Nuclear Science & Technology	59.1	29.5	-29.6	no	0.00	0.00	0.07	0.00
Nursing	68.8	44.3	-24.5	no	0.00	0.00	0.11	0.00
Nutrition & Dietetics	87.1	79.7	-7.4	no	0.00	0.00	0.07	0.00
Obstetrics & Gynecology	80.2	84.4	4.2	no	0.01	0.01	-0.02	0.01
Oceanography	75.8	64.7	-11.1	no	0.00	0.00	0.07	0.00
Oncology	88.1	84.0	-4.1	no	0.00	0.00	0.04	0.00
Operations Research & Management Science	75.1	43.8	-31.4	yes	0.00	0.01	0.03	0.00
Ophthalmology	80.5	67.1	-13.4	no	0.00	0.00	0.12	0.00
Optics	70.4	81.5	11.1	no	0.00	0.00	-0.10	0.00
Ornithology	60.7	56.3	-4.4	no	0.72	0.80	0.01	0.72
Orthopedics	81.4	71.5	-10.0	no	0.00	0.00	0.08	0.00
Otorhinolaryngology	75.2	68.8	-6.3	no	0.02	0.03	0.03	0.02
Paleontology	73.6	60.2	-13.5	no	0.00	0.00	0.08	0.00
Parasitology	79.6	87.0	7.4	no	0.00	0.00	-0.10	0.00
Pathology	81.2	77.2	-4.0	no	0.00	0.00	0.04	0.00
Pediatrics	76.2	66.3	-9.9	no	0.00	0.00	0.05	0.00
Peripheral Vascular Disease	86.4	83.9	-2.5	no	0.25	0.24	0.01	0.25
Pharmacology & Pharmacy	83.6	71.5	-12.1	no	0.00	0.00	0.09	0.00
Philosophy	39.6	11.9	-27.7	no	0.00	0.00	0.12	0.00
Physical Geography	84.4	78.7	-5.6	no	0.00	0.01	0.04	0.00
Physics	74.7	66.3	-8.4	no	0.00	0.00	0.05	0.00

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Subject area	% cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	p-value
Physics, Applied	76.2	75.8	-0.4	no	0.56	0.56	0.00	0.56
Physics, Atomic, Molecular & Chemical	80.3	48.4	-31.8	no	0.00	0.00	0.11	0.00
Physics, Condensed Matter	79.7	37.2	-42.6	no	0.00	0.00	0.14	0.00
Physics, Mathematical	65.3	39.7	-25.6	no	0.00	0.00	0.08	0.00
Physics, Multidisciplinary	66.5	64.0	-2.6	no	0.00	0.00	0.02	0.00
Physics, Nuclear	66.2	83.3	17.2	no	0.00	0.00	-0.12	0.00
Physics, Particles & Fields	74.9	74.1	-0.8	no	0.46	0.47	0.01	0.46
Physiology	83.2	85.7	2.4	no	0.02	0.02	-0.02	0.02
Plant Sciences	78.1	65.9	-12.3	no	0.00	0.00	0.10	0.00
Political Science	58.4	30.3	-28.1	no	0.00	0.00	0.07	0.00
Polymer Science	80.2	65.0	-15.3	no	0.00	0.00	0.06	0.00
Primary Health Care	68.9	77.3	8.4	no	0.00	0.00	-0.09	0.00
Psychiatry	81.9	73.8	-8.1	no	0.00	0.00	0.06	0.00
Psychology	76.6	75.4	-1.2	no	0.15	0.15	0.01	0.15
Psychology, Applied	73.8	55.6	-18.3	no	0.00	0.00	0.05	0.00
Psychology, Clinical	79.5	80.5	1.0	no	0.79	0.91	0.00	0.79
Psychology, Educational	71.7	88.9	17.2	no	0.11	0.12	-0.04	0.11
Psychology, Experimental	81.3	72.5	-8.7	no	0.02	0.03	0.03	0.02
Psychology, Multidisciplinary	72.4	70.2	-2.2	no	0.06	0.06	0.02	0.06
Public Administration	71.6	28.3	-43.3	no	0.00	0.00	0.11	0.00
Public, Environmental & Occupational Health	76.7	70.3	-6.4	no	0.00	0.00	0.06	0.00
Radiology, Nuclear Medicine & Medical Imaging	81.1	79.5	-1.6	no	0.12	0.12	0.01	0.12
Rehabilitation	74.0	72.6	-1.4	no	0.37	0.38	0.01	0.37
Religion	26.2	15.8	-10.3	no	0.00	0.00	0.07	0.00
Remote Sensing	81.4	81.1	-0.3	no	0.83	0.84	0.00	0.83
Reproductive Biology	86.0	78.0	-8.0	no	0.00	0.00	0.06	0.00
Research & Experimental Medicine	80.3	73.1	-7.1	no	0.00	0.00	0.08	0.00
Respiratory System	86.2	83.7	-2.6	no	0.10	0.11	0.02	0.10
Rheumatology	87.7	80.4	-7.3	no	0.00	0.00	0.08	0.00
Robotics	77.7	48.3	-29.4	no	0.00	0.00	0.23	0.00
Science & Technology – Other Topics	83.3	81.9	-1.4	no	0.00	0.00	0.02	0.00

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Subject area	% cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Social Issues	63.5	20.6	-42.8	no	0.00	0.00	0.23	0.00
Social Sciences – Other Topics	62.5	41.1	-21.4	no	0.00	0.00	0.11	0.00
Social Sciences, Biomedical	79.5	60.5	-19.0	no	0.00	0.00	0.10	0.00
Social Sciences, Interdisciplinary	62.3	30.6	-31.7	no	0.00	0.00	0.19	0.00
Social Sciences, Mathematical Methods	59.7	44.4	-15.3	no	0.11	0.12	0.03	0.11
Social Work	66.0	45.5	-20.5	no	0.00	0.00	0.09	0.00
Sociology	62.3	35.6	-26.7	no	0.00	0.00	0.11	0.00
Soil Science	80.7	51.8	-28.9	no	0.00	0.00	0.20	0.00
Spectroscopy	70.0	40.3	-29.7	no	0.00	0.00	0.06	0.00
Sport Sciences	79.5	63.9	-15.5	no	0.00	0.00	0.09	0.00
Statistics & Probability	57.3	46.7	-10.6	no	0.00	0.00	0.05	0.00
Substance Abuse	81.5	85.2	3.7	no	0.30	0.34	-0.02	0.30
Surgery	78.6	64.0	-14.6	no	0.00	0.00	0.07	0.00
Telecommunications	68.7	42.7	-26.0	no	0.00	0.00	0.16	0.00
Theater	10.2	9.1	-1.1	yes	0.91	1.00	0.00	0.91
Thermodynamics	78.6	38.6	-40.0	no	0.00	0.00	0.24	0.00
Toxicology	85.4	84.5	-0.8	no	0.50	0.52	0.01	0.50
Transportation	69.1	36.4	-32.8	no	0.00	0.00	0.06	0.00
Tropical Medicine	71.7	84.2	12.5	no	0.00	0.00	-0.15	0.00
Urban Studies	73.1	44.4	-28.7	no	0.00	0.00	0.08	0.00
Urology & Nephrology	80.2	76.4	-3.8	no	0.01	0.01	0.03	0.01
Veterinary Sciences	66.8	45.0	-21.8	no	0.00	0.00	0.18	0.00
Virology	87.8	92.8	5.0	no	0.00	0.00	-0.06	0.00
Water Resources	76.6	81.5	5.0	no	0.00	0.00	-0.03	0.00
Women's Studies	59.9	0.0	-59.9	yes	0.00	0.00	0.09	0.00
Zoology	63.9	53.7	-10.2	no	0.00	0.00	0.07	0.00

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ADDENDUM D: Measure of citation advantage – percentage of articles among the 1% most frequently cited

D.1. Results for all years and all subject areas

Chapter 6 presents the results for the three measures of citation advantage for each of the subject areas for all articles published from 2005 to 2014. The third measure that was investigated was the percentage of OA and non-OA journal articles among the 1%, 5%, and 10% most frequently cited articles. These are referred to as 'percentile-based citation indicators'. The results of the first percentile-based citation indicator, 1%, are presented in this addendum. A three-fold method was applied to determine whether OA or non-OA journal articles in a subject area experienced a citation advantage, as elaborated upon in Chapter 4 (sub-section 4.2.3.3).

In Chapter 6 (sub-section 6.5.1), only those subject areas which experienced a citation advantage for their OA journal articles are named, and their results are reported in the chapter. The results for all the subject areas in which any OA journal articles were published in the ten years are listed in the table below.

	% among the 1% most cited			*p*-value			Effect size	
Subject area	**Non-OA**	**OA**	**Diff.**	**Expected value < 5**	**χ^2**	**Fisher's exact**	**ϕ**	***p*-value**
Acoustics	1.05	0.00	-1.05	no	0.00	0.00	-0.02	0.00
Agricultural Economics & Policy	1.25	0.00	-1.25	no	0.01	0.00	-0.03	0.01
Agricultural Engineering	1.12	0.00	-1.12	no	0.00	0.00	-0.02	0.00
Agriculture	1.12	0.09	-1.03	no	0.00	0.00	-0.04	0.00
Agriculture, Dairy & Animal Science	1.07	0.27	-0.81	no	0.00	0.00	-0.03	0.00

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Subject area	% among the 1% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Agriculture, Multidisciplinary	1.39	0.07	-1.32	no	0.00	0.00	-0.06	0.00
Agronomy	1.15	0.06	-1.09	no	0.00	0.00	-0.04	0.00
Allergy	1.19	0.00	-1.19	no	0.00	0.00	-0.03	0.00
Anatomy & Morphology	1.05	0.12	-0.93	no	0.00	0.00	-0.03	0.00
Andrology	1.09	0.66	-0.43	no	0.22	0.28	-0.02	0.22
Anesthesiology	1.02	1.40	0.38	no	0.18	0.20	0.01	0.18
Anthropology	1.11	0.04	-1.07	no	0.00	0.00	-0.03	0.00
Archaeology	1.10	0.14	-0.96	no	0.02	0.01	-0.02	0.02
Architecture	2.23	1.59	-0.64	no	0.22	0.27	-0.01	0.22
Area Studies	1.16	1.29	0.13	yes	0.88	0.70	0.00	0.88
Art	2.55	2.30	-0.25	no	0.64	0.73	0.00	0.64
Arts & Humanities – Other Topics	1.21	0.08	-1.13	no	0.00	0.00	-0.02	0.00
Asian Studies	1.22	0.50	-0.72	yes	0.19	0.24	-0.01	0.19
Astronomy & Astrophysics	1.04	0.66	-0.38	no	0.02	0.02	-0.01	0.02
Audiology & Speech-Language Pathology	1.07	0.32	-0.75	yes	0.20	0.27	-0.01	0.20
Automation & Control Systems	1.01	1.03	0.02	no	0.94	0.92	0.00	0.94
Behavioral Sciences	0.99	0.12	-0.87	no	0.00	0.00	-0.01	0.00
Biochemical Research Methods	1.07	0.87	-0.21	no	0.03	0.04	-0.01	0.03
Biochemistry & Molecular Biology	0.93	1.79	0.85	no	0.00	0.00	0.02	0.00
Biodiversity & Conservation	1.09	0.23	-0.86	no	0.00	0.00	-0.02	0.00
Biodiversity Conservation	1.09	0.23	-0.86	no	0.00	0.00	-0.02	0.00
Biology	0.78	1.98	1.20	no	0.00	0.00	0.05	0.00
Biomedical Social Sciences	1.06	0.37	-0.69	no	0.05	0.05	-0.01	0.05
Biophysics	0.97	0.00	-0.97	no	0.01	0.00	-0.01	0.01
Biotechnology & Applied Microbiology	1.16	0.28	-0.89	no	0.00	0.00	-0.03	0.00
Business	1.10	0.17	-0.92	no	0.00	0.00	-0.02	0.00
Business & Economics	1.03	0.14	-0.88	no	0.00	0.00	-0.01	0.00
Business, Finance	1.08	0.00	-1.08	yes	0.11	0.19	-0.01	0.11
Cardiac & Cardiovascular Systems	1.15	0.09	-1.06	no	0.00	0.00	-0.03	0.00
Cardiovascular System & Cardiology	1.12	0.10	-1.02	no	0.00	0.00	-0.03	0.00
Cell & Tissue Engineering	1.11	0.35	-0.76	no	0.01	0.01	-0.02	0.01

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Subject area	% among the 1% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Cell Biology	1.08	0.12	-0.96	no	0.00	0.00	-0.02	0.00
Chemistry	1.10	0.13	-0.96	no	0.00	0.00	-0.02	0.00
Chemistry, Analytical	1.10	0.92	-0.18	no	0.12	0.13	0.00	0.12
Chemistry, Applied	1.03	0.00	-1.03	no	0.00	0.00	-0.01	0.00
Chemistry, Inorganic & Nuclear	1.04	0.16	-0.88	no	0.03	0.03	-0.01	0.03
Chemistry, Medicinal	1.01	1.01	0.00	no	0.99	0.94	0.00	0.99
Chemistry, Multidisciplinary	1.12	0.01	-1.11	no	0.00	0.00	-0.02	0.00
Chemistry, Organic	1.07	0.38	-0.69	no	0.00	0.00	-0.01	0.00
Chemistry, Physical	1.10	0.06	-1.04	no	0.00	0.00	-0.01	0.00
Classics	2.26	2.70	0.43	no	0.59	0.59	0.01	0.59
Clinical Neurology	1.06	0.27	-0.79	no	0.00	0.00	-0.01	0.00
Communication	1.22	0.11	-1.11	no	0.00	0.00	-0.02	0.00
Computer Science	1.06	0.90	-0.16	no	0.14	0.16	0.00	0.14
Computer Science, Artificial Intelligence	1.10	0.95	-0.15	no	0.41	0.44	0.00	0.41
Computer Science, Cybernetics	1.16	0.00	-1.16	no	0.02	0.01	-0.02	0.02
Computer Science, Information Systems	1.02	0.15	-0.87	no	0.00	0.00	-0.02	0.00
Computer Science, Interdisciplinary Applications	1.05	3.83	2.78	no	0.00	0.00	0.03	0.00
Computer Science, Software Engineering	1.08	0.42	-0.66	no	0.03	0.02	-0.01	0.03
Computer Science, Theory & Methods	1.14	0.55	-0.59	no	0.13	0.16	-0.01	0.13
Construction & Building Technology	0.99	0.00	-0.99	no	0.00	0.00	-0.01	0.00
Critical Care Medicine	1.08	0.47	-0.61	no	0.00	0.00	-0.02	0.00
Crystallography	1.27	0.20	-1.07	no	0.00	0.00	-0.04	0.00
Demography	1.27	0.09	-1.18	no	0.00	0.00	-0.04	0.00
Dentistry, Oral Surgery & Medicine	1.02	0.27	-0.75	no	0.00	0.00	-0.02	0.00
Dermatology	1.11	0.18	-0.93	no	0.00	0.00	-0.02	0.00
Developmental Biology	1.06	0.00	-1.06	no	0.00	0.00	-0.02	0.00
Ecology	1.01	0.48	-0.53	no	0.00	0.00	-0.01	0.00
Economics	1.05	0.00	-1.05	no	0.00	0.00	-0.02	0.00
Education & Educational Research	1.05	0.44	-0.61	no	0.00	0.00	-0.01	0.00
Education, Scientific Disciplines	1.13	0.53	-0.60	no	0.00	0.00	-0.02	0.00
Electrochemistry	1.12	0.76	-0.36	no	0.00	0.00	-0.01	0.00

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Subject area	% among the 1% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Emergency Medicine	1.07	0.19	-0.88	no	0.00	0.00	-0.02	0.00
Endocrinology & Metabolism	1.08	0.15	-0.93	no	0.00	0.00	-0.02	0.00
Energy & Fuels	1.09	0.30	-0.79	no	0.00	0.00	-0.01	0.00
Engineering	1.05	0.58	-0.48	no	0.00	0.00	-0.01	0.00
Engineering, Aerospace	1.20	1.45	0.25	yes	0.85	0.57	0.00	0.85
Engineering, Biomedical	1.00	0.82	-0.18	no	0.13	0.15	0.00	0.13
Engineering, Chemical	1.09	0.16	-0.93	no	0.00	0.00	-0.01	0.00
Engineering, Civil	1.04	0.07	-0.97	no	0.00	0.00	-0.01	0.00
Engineering, Electrical & Electronic	1.08	0.60	-0.48	no	0.00	0.00	-0.01	0.00
Engineering, Environmental	1.09	0.00	-1.09	yes	0.07	0.08	-0.01	0.07
Engineering, Industrial	0.99	0.00	-0.99	yes	0.18	0.43	-0.01	0.18
Engineering, Manufacturing	0.91	10.56	9.65	yes	0.00	0.00	0.09	0.00
Engineering, Marine	1.32	0.00	-1.32	yes	0.03	0.02	-0.03	0.03
Engineering, Mechanical	1.10	0.17	-0.93	no	0.00	0.00	-0.01	0.00
Engineering, Multidisciplinary	1.08	0.66	-0.42	no	0.00	0.00	-0.01	0.00
Engineering, Petroleum	0.85	1.59	0.74	no	0.01	0.02	0.02	0.01
Entomology	0.83	0.06	-0.76	no	0.00	0.00	-0.02	0.00
Environmental Sciences	1.05	1.21	0.16	no	0.07	0.07	0.00	0.07
Environmental Sciences & Ecology	1.03	0.99	-0.05	no	0.49	0.53	0.00	0.49
Environmental Studies	1.04	0.16	-0.88	no	0.00	0.00	-0.02	0.00
Ethics	1.03	1.17	0.14	no	0.64	0.66	0.00	0.64
Evolutionary Biology	1.06	0.25	-0.81	no	0.00	0.00	-0.03	0.00
Family Studies	0.98	5.56	4.57	yes	0.00	0.00	0.05	0.00
Film, Radio & Television	1.64	0.19	-1.46	no	0.01	0.00	-0.02	0.01
Film, Radio, Television	1.64	0.19	-1.46	no	0.01	0.00	-0.02	0.01
Fisheries	1.00	0.50	-0.51	no	0.01	0.01	-0.01	0.01
Folklore	2.10	0.00	-2.10	no	0.00	0.00	-0.06	0.00
Food Science & Technology	1.00	0.04	-0.96	no	0.00	0.00	-0.02	0.00
Forestry	1.13	0.14	-0.99	no	0.00	0.00	-0.03	0.00
Gastroenterology & Hepatology	1.15	0.10	-1.05	no	0.00	0.00	-0.03	0.00
General & Internal Medicine	1.35	0.07	-1.28	no	0.00	0.00	-0.05	0.00

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Subject area	% among the 1% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Genetics & Heredity	1.13	0.38	-0.74	no	0.00	0.00	-0.03	0.00
Geochemistry & Geophysics	1.06	0.14	-0.92	no	0.00	0.00	-0.02	0.00
Geography	1.01	0.00	-1.01	no	0.00	0.00	-0.02	0.00
Geography, Physical	1.09	2.16	1.07	no	0.00	0.00	0.02	0.00
Geology	1.09	0.81	-0.28	no	0.00	0.00	-0.01	0.00
Geosciences, Multidisciplinary	1.10	0.86	-0.24	no	0.01	0.01	-0.01	0.01
Geriatrics & Gerontology	1.01	0.28	-0.73	no	0.00	0.00	-0.02	0.00
Gerontology	1.05	0.31	-0.74	no	0.03	0.02	-0.02	0.03
Government & Law	1.00	0.43	-0.57	no	0.01	0.01	-0.01	0.01
Health Care Sciences & Services	1.03	1.00	-0.04	no	0.74	0.78	0.00	0.74
Health Policy & Services	0.99	1.17	0.18	no	0.30	0.30	0.01	0.30
Hematology	1.06	0.29	-0.77	no	0.00	0.00	-0.01	0.00
History	1.39	0.29	-1.10	no	0.00	0.00	-0.02	0.00
History & Philosophy Of Science	1.28	0.00	-1.28	no	0.00	0.00	-0.03	0.00
Horticulture	1.11	0.04	-1.07	no	0.00	0.00	-0.03	0.00
Humanities, Multidisciplinary	1.22	0.07	-1.16	no	0.00	0.00	-0.02	0.00
Imaging Science & Photographic Technology	1.08	0.00	-1.08	no	0.02	0.01	-0.01	0.02
Immunology	1.06	0.42	-0.64	no	0.00	0.00	-0.02	0.00
Industrial Relations & Labor	0.94	1.64	0.70	no	0.06	0.09	0.02	0.06
Infectious Diseases	1.02	0.70	-0.32	no	0.00	0.00	-0.01	0.00
Information Science & Library Science	1.09	0.22	-0.87	no	0.00	0.00	-0.02	0.00
Instruments & Instrumentation	1.20	0.94	-0.26	no	0.05	0.05	-0.01	0.05
Integrative & Complementary Medicine	1.02	1.15	0.13	no	0.39	0.41	0.01	0.39
International Relations	1.03	0.00	-1.03	yes	0.06	0.05	-0.01	0.06
Language & Linguistics	1.11	0.98	-0.14	no	0.60	0.71	0.00	0.60
Law	1.11	0.91	-0.20	no	0.49	0.59	0.00	0.49
Life Sciences & Biomedicine – Other Topics	0.78	1.98	1.20	no	0.00	0.00	0.05	0.00
Limnology	1.10	0.00	-1.10	yes	0.03	0.02	-0.02	0.03
Linguistics	1.09	0.99	-0.10	no	0.67	0.81	0.00	0.67
Literary Theory & Criticism	1.08	0.58	-0.50	yes	0.53	1.00	-0.01	0.53
Literature	1.16	0.28	-0.88	no	0.00	0.00	-0.01	0.00

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Subject area	% among the 1% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Literature, Romance	2.93	1.78	-1.15	no	0.02	0.03	-0.02	0.02
Literature, Slavic	4.46	0.59	-3.87	no	0.01	0.01	-0.04	0.01
Logic	1.31	0.31	-1.00	no	0.03	0.02	-0.03	0.03
Management	1.05	0.20	-0.85	no	0.00	0.00	-0.02	0.00
Marine & Freshwater Biology	0.97	0.25	-0.72	no	0.00	0.00	-0.02	0.00
Materials Science	1.17	0.38	-0.79	no	0.00	0.00	-0.01	0.00
Materials Science, Biomaterials	1.07	0.58	-0.48	no	0.29	0.39	0.00	0.29
Materials Science, Ceramics	1.15	0.00	-1.15	no	0.00	0.00	-0.03	0.00
Materials Science, Multidisciplinary	1.18	0.43	-0.75	no	0.00	0.00	-0.01	0.00
Materials Science, Paper & Wood	1.23	0.61	-0.63	no	0.00	0.00	-0.02	0.00
Materials Science, Textiles	1.22	0.11	-1.12	no	0.00	0.00	-0.03	0.00
Mathematical & Computational Biology	1.31	0.47	-0.85	no	0.00	0.00	-0.04	0.00
Mathematical Methods In Social Sciences	1.04	0.00	-1.04	yes	0.38	1.00	-0.01	0.38
Mathematics	1.08	0.61	-0.47	no	0.00	0.00	-0.01	0.00
Mathematics, Applied	1.18	0.57	-0.61	no	0.00	0.00	-0.02	0.00
Mathematics, Interdisciplinary Applications	1.16	0.25	-0.90	no	0.00	0.00	-0.03	0.00
Mechanics	1.02	0.15	-0.87	no	0.00	0.00	-0.01	0.00
Medical Ethics	1.10	0.85	-0.24	no	0.48	0.62	-0.01	0.48
Medical Informatics	1.15	0.44	-0.72	no	0.00	0.00	-0.02	0.00
Medical Laboratory Technology	1.13	0.09	-1.04	no	0.00	0.00	-0.02	0.00
Medicine, General & Internal	1.42	0.04	-1.38	no	0.00	0.00	-0.06	0.00
Medicine, Research & Experimental	1.20	0.30	-0.90	no	0.00	0.00	-0.03	0.00
Medieval & Renaissance Studies	1.27	0.22	-1.05	no	0.05	0.04	-0.02	0.05
Metallurgy & Metallurgical Engineering	1.17	0.31	-0.86	no	0.00	0.00	-0.01	0.00
Meteorology & Atmospheric Sciences	1.00	1.30	0.30	no	0.00	0.00	0.01	0.00
Microbiology	0.95	0.96	0.01	no	0.89	0.87	0.00	0.89
Mineralogy	1.05	0.00	-1.05	yes	0.05	0.06	-0.01	0.05
Mining & Mineral Processing	0.98	0.00	-0.98	no	0.00	0.00	-0.02	0.00
Multidisciplinary Sciences	2.29	0.04	-2.25	no	0.00	0.00	-0.11	0.00
Music	2.35	0.00	-2.35	yes	0.11	0.19	-0.01	0.11
Mycology	0.91	6.24	5.32	no	0.00	0.00	0.08	0.00

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Subject area	% among the 1% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Nanoscience & Nanotechnology	1.25	0.09	-1.16	no	0.00	0.00	-0.02	0.00
Neuroimaging	1.07	0.55	-0.52	yes	0.34	0.60	-0.01	0.34
Neurosciences	1.05	0.18	-0.87	no	0.00	0.00	-0.02	0.00
Neurosciences & Neurology	1.06	0.22	-0.84	no	0.00	0.00	-0.02	0.00
Nuclear Science & Technology	1.13	2.07	0.94	no	0.03	0.04	0.01	0.03
Nursing	1.27	0.03	-1.24	no	0.00	0.00	-0.03	0.00
Nutrition & Dietetics	1.03	0.30	-0.73	no	0.00	0.00	-0.02	0.00
Obstetrics & Gynecology	1.00	0.28	-0.73	no	0.00	0.00	-0.01	0.00
Oceanography	1.00	0.44	-0.56	no	0.00	0.00	-0.01	0.00
Oncology	1.02	0.15	-0.88	no	0.00	0.00	-0.02	0.00
Operations Research & Management Science	1.01	0.00	-1.01	yes	0.32	1.00	0.00	0.32
Ophthalmology	1.09	0.15	-0.94	no	0.00	0.00	-0.03	0.00
Optics	0.90	1.97	1.07	no	0.00	0.00	0.04	0.00
Ornithology	1.13	0.74	-0.40	yes	0.66	1.00	0.00	0.66
Orthopedics	0.99	0.26	-0.73	no	0.00	0.00	-0.02	0.00
Otorhinolaryngology	0.96	0.29	-0.68	no	0.01	0.01	-0.01	0.01
Paleontology	1.10	0.61	-0.49	no	0.05	0.06	-0.01	0.05
Parasitology	0.92	1.09	0.17	no	0.07	0.07	0.01	0.07
Pathology	1.05	0.18	-0.88	no	0.00	0.00	-0.03	0.00
Pediatrics	1.08	0.13	-0.95	no	0.00	0.00	-0.02	0.00
Peripheral Vascular Disease	1.07	0.09	-0.98	no	0.00	0.00	-0.01	0.00
Pharmacology & Pharmacy	1.02	0.28	-0.75	no	0.00	0.00	-0.02	0.00
Philosophy	1.12	0.00	-1.12	no	0.00	0.00	-0.02	0.00
Physical Geography	1.09	2.16	1.07	no	0.00	0.00	0.02	0.00
Physics	1.23	0.61	-0.61	no	0.00	0.00	-0.01	0.00
Physics, Applied	1.30	0.72	-0.58	no	0.00	0.00	-0.01	0.00
Physics, Atomic, Molecular & Chemical	1.12	0.17	-0.96	no	0.00	0.00	-0.01	0.00
Physics, Condensed Matter	1.32	0.00	-1.32	no	0.00	0.00	-0.01	0.00
Physics, Mathematical	1.12	0.21	-0.90	no	0.00	0.00	-0.01	0.00
Physics, Multidisciplinary	1.28	0.41	-0.87	no	0.00	0.00	-0.02	0.00
Physics, Nuclear	1.34	1.49	0.15	no	0.53	0.54	0.00	0.53

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Subject area	% among the 1% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Physics, Particles & Fields	1.20	1.07	-0.13	no	0.47	0.53	0.00	0.47
Physiology	0.92	0.69	-0.23	no	0.05	0.06	-0.01	0.05
Plant Sciences	1.00	0.29	-0.71	no	0.00	0.00	-0.02	0.00
Political Science	1.01	0.00	-1.01	no	0.00	0.00	-0.01	0.00
Polymer Science	1.06	0.58	-0.48	no	0.02	0.02	-0.01	0.02
Primary Health Care	0.52	2.28	1.76	no	0.00	0.00	0.08	0.00
Psychiatry	1.03	0.19	-0.83	no	0.00	0.00	-0.02	0.00
Psychology	0.98	0.30	-0.68	no	0.00	0.00	-0.01	0.00
Psychology, Applied	1.06	0.00	-1.06	yes	0.06	0.09	-0.01	0.06
Psychology, Clinical	1.00	0.72	-0.28	no	0.45	0.57	0.00	0.45
Psychology, Educational	1.13	0.00	-1.13	yes	0.21	0.41	-0.01	0.21
Psychology, Experimental	1.04	0.00	-1.04	no	0.02	0.01	-0.01	0.02
Psychology, Multidisciplinary	0.95	0.32	-0.63	no	0.00	0.00	-0.02	0.00
Psychology, Social	1.01	3.03	2.02	yes	0.25	0.29	0.01	0.25
Public Administration	1.00	0.15	-0.84	no	0.03	0.02	-0.01	0.03
Public, Environmental & Occupational Health	1.00	1.14	0.14	no	0.01	0.01	0.01	0.01
Radiology, Nuclear Medicine & Medical Imaging	1.07	0.28	-0.79	no	0.00	0.00	-0.02	0.00
Rehabilitation	1.04	0.51	-0.54	no	0.00	0.00	-0.01	0.00
Religion	1.05	0.94	-0.11	no	0.57	0.62	0.00	0.57
Remote Sensing	1.07	0.27	-0.80	no	0.00	0.00	-0.02	0.00
Reproductive Biology	1.01	0.31	-0.70	no	0.00	0.00	-0.02	0.00
Research & Experimental Medicine	1.20	0.30	-0.90	no	0.00	0.00	-0.03	0.00
Respiratory System	1.10	0.27	-0.83	no	0.00	0.00	-0.01	0.00
Rheumatology	1.17	0.20	-0.97	no	0.00	0.00	-0.03	0.00
Robotics	1.10	0.00	-1.10	no	0.00	0.00	-0.03	0.00
Science & Technology – Other Topics	1.61	0.04	-1.57	no	0.00	0.00	-0.07	0.00
Social Issues	1.11	0.00	-1.11	no	0.00	0.00	-0.03	0.00
Social Sciences – Other Topics	1.00	1.49	0.49	no	0.00	0.00	0.01	0.00
Social Sciences, Biomedical	1.06	0.37	-0.69	no	0.05	0.05	-0.01	0.05
Social Sciences, Interdisciplinary	1.03	1.48	0.45	no	0.02	0.02	0.01	0.02
Social Sciences, Mathematical Methods	1.04	0.00	-1.04	yes	0.38	1.00	-0.01	0.38

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Subject area	% among the 1% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Social Work	0.98	1.81	0.83	no	0.07	0.10	0.01	0.07
Sociology	0.99	0.06	-0.93	no	0.00	0.00	-0.02	0.00
Soil Science	1.09	0.00	-1.09	no	0.00	0.00	-0.03	0.00
Spectroscopy	1.16	0.00	-1.16	yes	0.04	0.04	-0.01	0.04
Sport Sciences	1.04	0.08	-0.96	no	0.00	0.00	-0.02	0.00
Statistics & Probability	1.06	0.97	-0.09	no	0.62	0.72	0.00	0.62
Substance Abuse	1.09	0.35	-0.74	no	0.04	0.04	-0.01	0.04
Surgery	1.01	0.08	-0.93	no	0.00	0.00	-0.02	0.00
Telecommunications	1.01	0.49	-0.52	no	0.00	0.00	-0.01	0.00
Theater	1.88	1.79	-0.09	yes	0.96	1.00	0.00	0.96
Thermodynamics	1.13	0.22	-0.91	no	0.00	0.00	-0.02	0.00
Toxicology	0.75	2.84	2.10	no	0.00	0.00	0.06	0.00
Transportation	1.01	0.00	-1.01	yes	0.27	0.64	-0.01	0.27
Tropical Medicine	1.00	0.99	-0.02	no	0.90	0.95	0.00	0.90
Urban Studies	1.09	0.00	-1.09	yes	0.12	0.18	-0.01	0.12
Urology & Nephrology	1.07	0.02	-1.05	no	0.00	0.00	-0.02	0.00
Veterinary Sciences	1.07	0.22	-0.84	no	0.00	0.00	-0.04	0.00
Virology	0.85	2.27	1.41	no	0.00	0.00	0.05	0.00
Water Resources	1.10	0.97	-0.14	no	0.34	0.36	0.00	0.34
Women's Studies	1.12	0.00	-1.12	yes	0.76	1.00	0.00	0.76
Zoology	0.99	0.64	-0.35	no	0.00	0.00	-0.01	0.00

D.2. Results for articles published in 2014, for each of the subject areas

The same analysis as discussed in Addendum D.1 was conducted a second time, only considering the articles published in 2014 to control for the potential confounding effect of the variance between years. The table below presents the results for all subject areas in which any OA journal articles were published in 2014.

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Subject area	% among the 1% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Acoustics	1.09	0.00	-1.09	yes	0.09	0.11	-0.02	0.09
Agricultural Economics & Policy	1.25	0.00	-1.25	yes	0.19	0.36	-0.05	0.19
Agricultural Engineering	1.25	0.00	-1.25	yes	0.03	0.02	-0.04	0.03
Agriculture	1.19	0.04	-1.15	no	0.00	0.00	-0.04	0.00
Agriculture, Dairy & Animal Science	0.93	0.55	-0.38	no	0.25	0.34	-0.01	0.25
Agriculture, Multidisciplinary	1.33	0.06	-1.27	no	0.00	0.00	-0.05	0.00
Agronomy	1.22	0.06	-1.16	no	0.00	0.00	-0.04	0.00
Allergy	1.15	0.00	-1.15	yes	0.10	0.16	-0.03	0.10
Anatomy & Morphology	1.18	0.51	-0.67	yes	0.25	0.41	-0.02	0.25
Andrology	0.56	2.40	1.84	yes	0.08	0.11	0.08	0.08
Anesthesiology	1.10	0.32	-0.78	yes	0.19	0.37	-0.02	0.19
Anthropology	1.21	0.00	-1.21	yes	0.02	0.01	-0.04	0.02
Archaeology	1.07	0.00	-1.07	yes	0.27	0.63	-0.02	0.27
Architecture	2.19	0.00	-2.19	yes	0.20	0.40	-0.03	0.20
Area Studies	1.02	0.00	-1.02	yes	0.61	1.00	-0.01	0.61
Art	1.39	1.65	0.27	yes	0.81	0.69	0.00	0.81
Arts & Humanities – Other Topics	1.18	0.00	-1.18	yes	0.06	0.08	-0.03	0.06
Asian Studies	1.11	0.00	-1.11	yes	0.48	1.00	-0.02	0.48
Astronomy & Astrophysics	0.96	2.06	1.10	no	0.00	0.00	0.03	0.00
Audiology & Speech-Language Pathology	1.05	1.35	0.30	no	0.81	0.55	0.01	0.81
Automation & Control Systems	1.01	2.34	1.32	yes	0.06	0.07	0.02	0.06
Behavioral Sciences	1.11	0.00	-1.11	no	0.01	0.01	-0.03	0.01
Biochemical Research Methods	0.95	0.89	-0.06	no	0.81	0.88	0.00	0.81
Biochemistry & Molecular Biology	0.93	1.57	0.64	no	0.00	0.00	0.02	0.00
Biodiversity & Conservation	1.08	0.23	-0.85	yes	0.09	0.13	-0.02	0.09
Biodiversity Conservation	1.08	0.23	-0.85	yes	0.09	0.13	-0.02	0.09
Biology	0.67	2.05	1.37	no	0.00	0.00	0.06	0.00
Biomedical Social Sciences	1.08	0.00	-1.08	yes	0.18	0.41	-0.02	0.18
Biophysics	1.02	0.00	-1.02	yes	0.27	0.63	-0.01	0.27
Biotechnology & Applied Microbiology	1.23	0.21	-1.02	no	0.00	0.00	-0.04	0.00
Business	1.06	0.00	-1.06	yes	0.20	0.41	-0.02	0.20

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	% among the 1% most cited			*p*-value			Effect size	
Subject area	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Business & Economics	1.04	0.00	-1.04	no	0.01	0.00	-0.02	0.01
Business, Finance	1.25	0.00	-1.25	yes	0.67	1.00	-0.01	0.67
Cardiac & Cardiovascular Systems	1.17	0.04	-1.13	no	0.00	0.00	-0.04	0.00
Cardiovascular System & Cardiology	1.14	0.04	-1.11	no	0.00	0.00	-0.03	0.00
Cell & Tissue Engineering	1.15	0.43	-0.72	yes	0.16	0.22	-0.02	0.16
Cell Biology	1.14	0.19	-0.95	no	0.00	0.00	-0.03	0.00
Chemistry	1.07	0.18	-0.89	no	0.00	0.00	-0.02	0.00
Chemistry, Analytical	1.03	1.19	0.16	no	0.55	0.52	0.00	0.55
Chemistry, Applied	1.04	0.00	-1.04	yes	0.07	0.08	-0.02	0.07
Chemistry, Inorganic & Nuclear	1.03	0.00	-1.03	yes	0.30	0.63	-0.01	0.30
Chemistry, Medicinal	1.00	1.14	0.14	no	0.69	0.60	0.00	0.69
Chemistry, Multidisciplinary	1.08	0.03	-1.05	no	0.00	0.00	-0.02	0.00
Chemistry, Organic	1.06	0.37	-0.70	no	0.00	0.00	-0.02	0.00
Chemistry, Physical	1.07	0.00	-1.07	yes	0.04	0.04	-0.01	0.04
Classics	2.06	4.17	2.11	yes	0.33	0.28	0.03	0.33
Clinical Neurology	1.05	0.20	-0.85	no	0.00	0.00	-0.02	0.00
Communication	1.07	0.00	-1.07	yes	0.18	0.41	-0.02	0.18
Computer Science	1.02	0.86	-0.16	no	0.53	0.60	0.00	0.53
Computer Science, Artificial Intelligence	1.04	1.34	0.30	no	0.51	0.51	0.01	0.51
Computer Science, Cybernetics	1.13	0.00	-1.13	yes	0.34	1.00	-0.03	0.34
Computer Science, Information Systems	1.10	0.00	-1.10	no	0.00	0.00	-0.03	0.00
Computer Science, Interdisciplinary Applications	0.90	4.04	3.14	yes	0.00	0.00	0.04	0.00
Computer Science, Software Engineering	1.10	0.00	-1.10	yes	0.21	0.41	-0.01	0.21
Computer Science, Theory & Methods	1.00	0.00	-1.00	yes	0.36	1.00	-0.01	0.36
Construction & Building Technology	0.97	0.00	-0.97	yes	0.22	0.41	-0.01	0.22
Critical Care Medicine	1.13	0.21	-0.92	yes	0.06	0.09	-0.03	0.06
Crystallography	1.04	5.43	4.40	yes	0.00	0.00	0.05	0.00
Demography	1.23	0.00	-1.23	yes	0.14	0.22	-0.05	0.14
Dentistry, Oral Surgery & Medicine	0.95	0.16	-0.80	no	0.04	0.04	-0.02	0.04
Dermatology	1.09	0.00	-1.09	yes	0.03	0.02	-0.03	0.03
Developmental Biology	1.12	0.00	-1.12	yes	0.25	0.64	-0.02	0.25

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Subject area	% among the 1% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Ecology	1.07	0.50	-0.57	no	0.03	0.03	-0.02	0.03
Economics	1.06	0.00	-1.06	no	0.02	0.01	-0.02	0.02
Education & Educational Research	1.03	0.86	-0.17	no	0.59	0.76	0.00	0.59
Education, Scientific Disciplines	1.13	0.68	-0.46	no	0.32	0.39	-0.02	0.32
Electrochemistry	1.09	0.89	-0.20	no	0.42	0.47	-0.01	0.42
Emergency Medicine	1.04	0.00	-1.04	yes	0.06	0.07	-0.03	0.06
Endocrinology & Metabolism	1.08	0.39	-0.69	no	0.01	0.01	-0.02	0.01
Energy & Fuels	1.11	0.00	-1.11	no	0.00	0.00	-0.02	0.00
Engineering	1.09	0.30	-0.79	no	0.00	0.00	-0.02	0.00
Engineering, Aerospace	1.25	4.35	3.10	yes	0.19	0.26	0.02	0.19
Engineering, Biomedical	1.04	1.19	0.15	no	0.57	0.53	0.00	0.57
Engineering, Chemical	1.08	0.00	-1.08	no	0.01	0.00	-0.02	0.01
Engineering, Civil	1.06	0.00	-1.06	yes	0.08	0.08	-0.01	0.08
Engineering, Electrical & Electronic	1.13	0.38	-0.75	no	0.00	0.00	-0.02	0.00
Engineering, Environmental	1.08	0.00	-1.08	yes	0.20	0.41	-0.01	0.20
Engineering, Industrial	0.99	0.00	-0.99	yes	0.48	1.00	-0.01	0.48
Engineering, Manufacturing	0.84	17.24	16.40	yes	0.00	0.00	0.12	0.00
Engineering, Marine	1.39	0.00	-1.39	yes	0.21	0.37	-0.04	0.21
Engineering, Mechanical	1.10	0.31	-0.79	no	0.02	0.01	-0.02	0.02
Engineering, Multidisciplinary	1.31	0.18	-1.13	no	0.00	0.00	-0.05	0.00
Engineering, Petroleum	1.26	0.00	-1.26	yes	0.20	0.40	-0.03	0.20
Entomology	1.17	0.13	-1.05	no	0.01	0.00	-0.03	0.01
Environmental Sciences	1.08	0.42	-0.66	no	0.00	0.00	-0.02	0.00
Environmental Sciences & Ecology	1.07	0.43	-0.64	no	0.00	0.00	-0.02	0.00
Environmental Studies	1.12	0.13	-0.99	no	0.01	0.00	-0.03	0.01
Ethics	1.01	1.15	0.14	yes	0.83	0.74	0.00	0.83
Evolutionary Biology	1.15	0.37	-0.78	no	0.02	0.02	-0.03	0.02
Family Studies	0.98	12.50	11.52	yes	0.00	0.08	0.07	0.00
Film, Radio & Television	2.39	0.42	-1.97	no	0.05	0.06	-0.04	0.05
Film, Radio, Television	2.39	0.42	-1.97	no	0.05	0.06	-0.04	0.05
Fisheries	1.11	0.68	-0.43	yes	0.40	0.62	-0.01	0.40

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Subject area	% among the 1% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Folklore	2.13	0.00	-2.13	yes	0.24	0.60	-0.06	0.24
Food Science & Technology	1.03	0.00	-1.03	no	0.01	0.01	-0.02	0.01
Forestry	1.37	0.32	-1.06	no	0.01	0.00	-0.04	0.01
Gastroenterology & Hepatology	1.25	0.15	-1.10	no	0.00	0.00	-0.04	0.00
General & Internal Medicine	1.50	0.01	-1.49	no	0.00	0.00	-0.07	0.00
Genetics & Heredity	1.22	0.29	-0.93	no	0.00	0.00	-0.04	0.00
Geochemistry & Geophysics	1.13	0.70	-0.43	yes	0.40	0.63	-0.01	0.40
Geography	1.11	0.00	-1.11	yes	0.09	0.11	-0.03	0.09
Geography, Physical	1.09	1.93	0.85	yes	0.14	0.19	0.02	0.14
Geology	1.04	0.90	-0.15	no	0.46	0.55	0.00	0.46
Geosciences, Multidisciplinary	1.03	0.97	-0.06	no	0.77	0.83	0.00	0.77
Geriatrics & Gerontology	1.13	0.41	-0.72	no	0.04	0.04	-0.03	0.04
Gerontology	1.05	0.47	-0.58	yes	0.41	0.72	-0.02	0.41
Government & Law	1.03	0.00	-1.03	yes	0.08	0.13	-0.02	0.08
Health Care Sciences & Services	1.04	1.02	-0.02	no	0.94	0.99	0.00	0.94
Health Policy & Services	1.14	0.58	-0.56	no	0.18	0.24	-0.02	0.18
Hematology	1.07	0.00	-1.07	no	0.02	0.01	-0.02	0.02
History	2.06	0.35	-1.71	no	0.00	0.00	-0.03	0.00
History & Philosophy Of Science	1.15	0.00	-1.15	yes	0.16	0.25	-0.03	0.16
Horticulture	1.12	0.00	-1.12	yes	0.06	0.07	-0.03	0.06
Humanities, Multidisciplinary	1.14	0.00	-1.14	yes	0.15	0.26	-0.02	0.15
Imaging Science & Photographic Technology	1.06	0.00	-1.06	yes	0.38	1.00	-0.01	0.38
Immunology	1.12	0.62	-0.49	no	0.03	0.03	-0.01	0.03
Industrial Relations & Labor	1.12	0.00	-1.12	yes	0.34	1.00	-0.03	0.34
Infectious Diseases	1.11	0.75	-0.36	no	0.06	0.07	-0.02	0.06
Information Science & Library Science	0.92	0.39	-0.54	yes	0.37	0.73	-0.01	0.37
Instruments & Instrumentation	1.17	0.99	-0.19	no	0.52	0.60	-0.01	0.52
Integrative & Complementary Medicine	1.08	0.99	-0.09	no	0.80	0.87	0.00	0.80
International Relations	1.04	0.00	-1.04	yes	0.45	1.00	-0.01	0.45
Language & Linguistics	1.19	1.15	-0.03	yes	0.96	1.00	0.00	0.96
Law	1.14	0.00	-1.14	yes	0.14	0.27	-0.02	0.14

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Subject area	% among the 1% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Life Sciences & Biomedicine – Other Topics	0.67	2.05	1.37	no	0.00	0.00	0.06	0.00
Limnology	1.05	0.00	-1.05	yes	0.37	1.00	-0.02	0.37
Linguistics	1.01	1.03	0.03	yes	0.96	0.77	0.00	0.96
Literary Theory & Criticism	1.43	0.59	-0.84	yes	0.38	0.70	-0.03	0.38
Literature	1.05	0.24	-0.81	yes	0.11	0.13	-0.02	0.11
Literature, Romance	4.00	5.30	1.30	no	0.47	0.49	0.02	0.47
Literature, Slavic	4.52	0.59	-3.94	no	0.02	0.02	-0.10	0.02
Logic	1.08	2.06	0.98	yes	0.40	0.32	0.03	0.40
Management	1.04	0.00	-1.04	yes	0.21	0.41	-0.01	0.21
Marine & Freshwater Biology	1.04	0.55	-0.49	no	0.21	0.25	-0.01	0.21
Materials Science	1.09	0.30	-0.79	no	0.00	0.00	-0.02	0.00
Materials Science, Biomaterials	1.09	0.00	-1.09	yes	0.27	0.63	-0.01	0.27
Materials Science, Ceramics	1.26	0.00	-1.26	yes	0.03	0.03	-0.03	0.03
Materials Science, Multidisciplinary	1.09	0.30	-0.78	no	0.00	0.00	-0.02	0.00
Materials Science, Paper & Wood	1.59	0.00	-1.59	no	0.00	0.00	-0.07	0.00
Materials Science, Textiles	1.24	0.00	-1.24	yes	0.06	0.07	-0.04	0.06
Mathematical & Computational Biology	1.20	0.38	-0.81	no	0.00	0.00	-0.04	0.00
Mathematical Methods In Social Sciences	1.09	0.00	-1.09	yes	0.59	1.00	-0.01	0.59
Mathematics	1.15	0.36	-0.79	no	0.00	0.00	-0.03	0.00
Mathematics, Applied	1.27	0.34	-0.93	no	0.00	0.00	-0.03	0.00
Mathematics, Interdisciplinary Applications	1.30	0.13	-1.17	no	0.00	0.00	-0.05	0.00
Mechanics	1.07	0.57	-0.50	no	0.27	0.38	-0.01	0.27
Medical Ethics	1.01	1.25	0.24	yes	0.75	0.72	0.01	0.75
Medical Informatics	0.96	0.00	-0.96	yes	0.07	0.11	-0.03	0.07
Medical Laboratory Technology	1.09	0.69	-0.40	yes	0.65	1.00	-0.01	0.65
Medicine, General & Internal	1.64	0.00	-1.64	no	0.00	0.00	-0.08	0.00
Medicine, Research & Experimental	1.32	0.50	-0.82	no	0.00	0.00	-0.04	0.00
Medieval & Renaissance Studies	1.17	0.00	-1.17	yes	0.44	1.00	-0.03	0.44
Metallurgy & Metallurgical Engineering	1.09	0.24	-0.85	yes	0.09	0.14	-0.01	0.09
Meteorology & Atmospheric Sciences	1.06	0.85	-0.21	no	0.34	0.38	-0.01	0.34
Microbiology	1.03	0.80	-0.23	no	0.25	0.31	-0.01	0.25

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Subject area	% among the 1% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Mineralogy	1.05	0.00	-1.05	yes	0.36	1.00	-0.02	0.36
Mining & Mineral Processing	1.08	0.00	-1.08	yes	0.37	1.00	-0.02	0.37
Multidisciplinary Sciences	3.54	0.06	-3.48	no	0.00	0.00	-0.16	0.00
Music	1.87	0.00	-1.87	yes	0.63	1.00	-0.01	0.63
Mycology	0.79	5.49	4.70	yes	0.00	0.00	0.10	0.00
Nanoscience & Nanotechnology	1.12	0.13	-0.99	no	0.00	0.00	-0.03	0.00
Neuroimaging	1.05	1.07	0.02	yes	0.98	1.00	0.00	0.98
Neurosciences	1.12	0.31	-0.81	no	0.00	0.00	-0.03	0.00
Neurosciences & Neurology	1.11	0.30	-0.81	no	0.00	0.00	-0.03	0.00
Nuclear Science & Technology	1.29	0.76	-0.53	yes	0.59	1.00	-0.01	0.59
Nursing	1.13	0.00	-1.13	yes	0.04	0.03	-0.02	0.04
Nutrition & Dietetics	1.09	0.48	-0.62	no	0.03	0.03	-0.02	0.03
Obstetrics & Gynecology	1.02	0.35	-0.66	no	0.12	0.18	-0.01	0.12
Oceanography	1.09	1.16	0.07	no	0.88	0.84	0.00	0.88
Oncology	1.15	0.15	-1.00	no	0.00	0.00	-0.03	0.00
Operations Research & Management Science	0.97	0.00	-0.97	yes	0.69	1.00	0.00	0.69
Ophthalmology	1.25	0.00	-1.25	no	0.00	0.00	-0.04	0.00
Optics	0.88	1.52	0.64	no	0.00	0.00	0.03	0.00
Ornithology	1.03	0.00	-1.03	yes	0.68	1.00	-0.01	0.68
Orthopedics	0.97	0.31	-0.65	no	0.02	0.02	-0.02	0.02
Otorhinolaryngology	1.03	0.77	-0.26	yes	0.68	1.00	-0.01	0.68
Paleontology	1.15	0.00	-1.15	yes	0.10	0.17	-0.03	0.10
Parasitology	0.89	1.10	0.21	no	0.41	0.45	0.01	0.41
Pathology	1.18	0.37	-0.81	no	0.00	0.00	-0.03	0.00
Pediatrics	1.07	0.11	-0.96	no	0.01	0.00	-0.02	0.01
Peripheral Vascular Disease	1.06	0.00	-1.06	yes	0.09	0.12	-0.02	0.09
Pharmacology & Pharmacy	1.06	0.59	-0.47	no	0.01	0.01	-0.01	0.01
Philosophy	1.10	0.00	-1.10	yes	0.06	0.05	-0.02	0.06
Physical Geography	1.09	1.93	0.85	yes	0.14	0.19	0.02	0.14
Physics	1.12	0.72	-0.40	no	0.00	0.00	-0.01	0.00
Physics, Applied	1.17	0.29	-0.89	no	0.00	0.00	-0.02	0.00

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Subject area	% among the 1% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Physics, Atomic, Molecular & Chemical	1.06	0.00	-1.06	yes	0.07	0.08	-0.01	0.07
Physics, Condensed Matter	1.11	0.00	-1.11	no	0.02	0.01	-0.01	0.02
Physics, Mathematical	1.05	0.00	-1.05	yes	0.12	0.18	-0.02	0.12
Physics, Multidisciplinary	1.20	0.90	-0.30	no	0.11	0.12	-0.01	0.11
Physics, Nuclear	0.87	2.96	2.09	no	0.00	0.00	0.07	0.00
Physics, Particles & Fields	1.05	1.19	0.14	no	0.60	0.62	0.00	0.60
Physiology	0.98	1.26	0.28	no	0.31	0.33	0.01	0.31
Plant Sciences	1.07	0.59	-0.48	no	0.01	0.02	-0.02	0.01
Political Science	1.07	0.00	-1.07	yes	0.28	0.63	-0.01	0.28
Polymer Science	1.01	0.84	-0.17	yes	0.71	1.00	0.00	0.71
Primary Health Care	0.35	1.97	1.62	no	0.00	0.00	0.08	0.00
Psychiatry	1.08	0.28	-0.80	no	0.00	0.00	-0.02	0.00
Psychology	1.06	0.37	-0.69	no	0.00	0.00	-0.02	0.00
Psychology, Applied	1.29	0.00	-1.29	yes	0.40	1.00	-0.01	0.40
Psychology, Clinical	1.04	0.00	-1.04	yes	0.27	0.63	-0.01	0.27
Psychology, Educational	1.48	0.00	-1.48	yes	0.60	1.00	-0.01	0.60
Psychology, Experimental	1.06	0.00	-1.06	yes	0.30	0.63	-0.01	0.30
Psychology, Multidisciplinary	1.15	0.49	-0.66	no	0.01	0.01	-0.03	0.01
Public Administration	1.02	0.00	-1.02	yes	0.43	1.00	-0.01	0.43
Public, Environmental & Occupational Health	0.97	1.42	0.45	no	0.00	0.00	0.02	0.00
Radiology, Nuclear Medicine & Medical Imaging	1.07	0.33	-0.74	no	0.01	0.01	-0.02	0.01
Rehabilitation	1.01	1.08	0.07	no	0.84	0.86	0.00	0.84
Religion	1.14	1.13	-0.01	yes	0.98	1.00	0.00	0.98
Remote Sensing	1.15	0.13	-1.02	no	0.01	0.01	-0.04	0.01
Reproductive Biology	1.12	0.00	-1.12	yes	0.04	0.05	-0.03	0.04
Research & Experimental Medicine	1.32	0.50	-0.82	no	0.00	0.00	-0.04	0.00
Respiratory System	1.09	0.00	-1.09	no	0.02	0.01	-0.03	0.02
Rheumatology	1.25	0.11	-1.14	no	0.00	0.00	-0.04	0.00
Robotics	1.33	0.00	-1.33	yes	0.08	0.10	-0.04	0.08
Science & Technology– Other Topics	1.90	0.06	-1.85	no	0.00	0.00	-0.09	0.00
Social Issues	1.17	0.00	-1.17	yes	0.22	0.39	-0.03	0.22

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Subject area	% among the 1% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	p-value
Social Sciences– Other Topics	1.03	0.86	-0.17	no	0.64	0.86	0.00	0.64
Social Sciences, Biomedical	1.08	0.00	-1.08	yes	0.18	0.41	-0.02	0.18
Social Sciences, Interdisciplinary	1.03	1.09	0.06	no	0.90	0.82	0.00	0.90
Social Sciences, Mathematical Methods	1.09	0.00	-1.09	yes	0.59	1.00	-0.01	0.59
Social Work	1.04	0.99	-0.05	yes	0.96	1.00	0.00	0.96
Sociology	1.05	0.00	-1.05	yes	0.12	0.17	-0.02	0.12
Soil Science	1.13	0.00	-1.13	yes	0.04	0.03	-0.03	0.04
Spectroscopy	1.09	0.00	-1.09	yes	0.37	1.00	-0.01	0.37
Sport Sciences	1.06	0.20	-0.86	no	0.06	0.06	-0.02	0.06
Statistics & Probability	0.97	0.72	-0.25	no	0.56	0.82	-0.01	0.56
Substance Abuse	1.06	0.00	-1.06	yes	0.25	0.64	-0.02	0.25
Surgery	1.04	0.13	-0.91	no	0.00	0.00	-0.02	0.00
Telecommunications	1.14	0.00	-1.14	no	0.00	0.00	-0.03	0.00
Theater	1.90	0.00	-1.90	yes	0.64	1.00	-0.01	0.64
Thermodynamics	1.17	0.34	-0.83	no	0.02	0.02	-0.02	0.02
Toxicology	0.76	4.19	3.43	no	0.00	0.00	0.09	0.00
Transportation	1.05	0.00	-1.05	yes	0.55	1.00	-0.01	0.55
Tropical Medicine	0.90	1.12	0.22	no	0.51	0.62	0.01	0.51
Urban Studies	1.09	0.00	-1.09	yes	0.53	1.00	-0.01	0.53
Urology & Nephrology	1.10	0.11	-0.99	no	0.00	0.00	-0.03	0.00
Veterinary Sciences	1.07	0.45	-0.63	no	0.00	0.00	-0.03	0.00
Virology	0.85	1.92	1.07	no	0.00	0.00	0.04	0.00
Water Resources	1.05	0.83	-0.22	no	0.52	0.62	-0.01	0.52
Women's Studies	1.06	0.00	-1.06	yes	0.77	1.00	-0.01	0.77
Zoology	1.11	0.64	-0.47	no	0.08	0.10	-0.02	0.08

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ADDENDUM E:
Measure of citation advantage – percentage of articles among the 5% most frequently cited

E.1. Results for all years and all subject areas

Chapter 6 presents the results for the three measures of citation advantage for each of the subject areas for all articles published from 2005 to 2014. The third measure that was investigated was the percentage of OA and non-OA journal articles among the 1%, 5%, and 10% most frequently cited articles. These are referred to as 'percentile-based citation indicators'. The results of the second percentile-based citation indicator, 5%, are presented in this addendum. A three-fold method was applied to determine whether OA or non-OA journal articles in a subject area experienced a citation advantage, as elaborated upon in Chapter 4.

In Chapter 6 (sub-section 6.5.2), only those subject areas which experienced a citation advantage for their OA journal articles are named, and their results are reported in the chapter. The results for all the subject areas in which any OA journal articles were published in the ten years are listed in the table below.

	% among the 5% most cited			*p*-value			Effect size	
Subject area	**Non-OA**	**OA**	**Diff.**	**Expected value < 5**	**χ^2**	**Fisher's exact**	**ϕ**	***p*-value**
Acoustics	5.3	0.5	-4.7	no	0.00	0.00	-0.03	0.00
Agricultural Economics & Policy	6.5	0.8	-5.8	no	0.00	0.00	-0.07	0.00
Agricultural Engineering	5.7	0.0	-5.7	no	0.00	0.00	-0.06	0.00
Agriculture	5.8	0.5	-5.2	no	0.00	0.00	-0.09	0.00
Agriculture, Dairy & Animal Science	5.8	1.3	-4.6	no	0.00	0.00	-0.08	0.00

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Subject area	% among the 5% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Agriculture, Multidisciplinary	7.1	0.4	-6.7	no	0.00	0.00	-0.13	0.00
Agronomy	5.8	0.4	-5.4	no	0.00	0.00	-0.09	0.00
Allergy	5.8	0.5	-5.3	no	0.00	0.00	-0.06	0.00
Anatomy & Morphology	5.2	2.4	-2.7	no	0.00	0.00	-0.04	0.00
Andrology	4.6	5.1	0.5	no	0.48	0.50	0.01	0.48
Anesthesiology	5.0	4.5	-0.5	no	0.39	0.43	0.00	0.39
Anthropology	5.5	0.7	-4.8	no	0.00	0.00	-0.06	0.00
Archaeology	5.5	1.7	-3.8	no	0.00	0.00	-0.03	0.00
Architecture	44.4	37.8	-6.6	no	0.00	0.00	-0.03	0.00
Area Studies	5.1	5.8	0.7	no	0.71	0.71	0.00	0.71
Art	74.1	67.2	-6.9	no	0.00	0.00	-0.02	0.00
Arts & Humanities– Other Topics	6.3	2.2	-4.1	no	0.00	0.00	-0.04	0.00
Asian Studies	6.1	5.5	-0.6	no	0.60	0.66	-0.01	0.60
Astronomy & Astrophysics	5.3	3.1	-2.2	no	0.00	0.00	-0.02	0.00
Audiology & Speech-Language Pathology	5.1	2.5	-2.6	no	0.04	0.04	-0.02	0.04
Automation & Control Systems	5.0	4.9	-0.1	no	0.78	0.82	0.00	0.78
Behavioral Sciences	5.0	1.6	-3.4	no	0.00	0.00	-0.03	0.00
Biochemical Research Methods	5.1	5.5	0.3	no	0.12	0.12	0.00	0.12
Biochemistry & Molecular Biology	4.9	6.5	1.6	no	0.00	0.00	0.02	0.00
Biodiversity & Conservation	5.6	0.7	-5.0	no	0.00	0.00	-0.06	0.00
Biodiversity Conservation	5.6	0.7	-5.0	no	0.00	0.00	-0.06	0.00
Biology	4.6	7.5	2.9	no	0.00	0.00	0.05	0.00
Biomedical Social Sciences	5.2	1.5	-3.7	no	0.00	0.00	-0.03	0.00
Biophysics	4.9	0.4	-4.5	no	0.00	0.00	-0.02	0.00
Biotechnology & Applied Microbiology	5.6	2.2	-3.4	no	0.00	0.00	-0.06	0.00
Business	5.5	0.2	-5.3	no	0.00	0.00	-0.06	0.00
Business & Economics	5.2	0.7	-4.4	no	0.00	0.00	-0.03	0.00
Business, Finance	5.3	2.1	-3.2	no	0.03	0.03	-0.01	0.03
Cardiac & Cardiovascular Systems	5.6	1.0	-4.6	no	0.00	0.00	-0.06	0.00
Cardiovascular System & Cardiology	5.4	1.2	-4.2	no	0.00	0.00	-0.05	0.00
Cell & Tissue Engineering	5.6	1.5	-4.1	no	0.00	0.00	-0.04	0.00

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Subject area	% among the 5% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Cell Biology	5.3	1.4	-3.9	no	0.00	0.00	-0.04	0.00
Chemistry	5.4	1.0	-4.4	no	0.00	0.00	-0.04	0.00
Chemistry, Analytical	5.4	3.8	-1.7	no	0.00	0.00	-0.02	0.00
Chemistry, Applied	5.1	0.1	-5.0	no	0.00	0.00	-0.03	0.00
Chemistry, Inorganic & Nuclear	5.3	1.6	-3.6	no	0.00	0.00	-0.01	0.00
Chemistry, Medicinal	5.0	4.2	-0.8	no	0.03	0.03	-0.01	0.03
Chemistry, Multidisciplinary	5.6	0.2	-5.4	no	0.00	0.00	-0.05	0.00
Chemistry, Organic	5.3	2.0	-3.3	no	0.00	0.00	-0.03	0.00
Chemistry, Physical	5.4	0.5	-4.9	no	0.00	0.00	-0.01	0.00
Classics	13.1	22.9	9.8	no	0.00	0.00	0.06	0.00
Clinical Neurology	5.2	1.8	-3.5	no	0.00	0.00	-0.03	0.00
Communication	5.2	1.6	-3.6	no	0.00	0.00	-0.03	0.00
Computer Science	5.3	3.1	-2.1	no	0.00	0.00	-0.02	0.00
Computer Science, Artificial Intelligence	5.4	4.2	-1.2	no	0.00	0.00	-0.01	0.00
Computer Science, Cybernetics	5.7	0.0	-5.7	no	0.00	0.00	-0.05	0.00
Computer Science, Information Systems	5.2	1.0	-4.2	no	0.00	0.00	-0.04	0.00
Computer Science, Interdisciplinary Applications	5.2	9.8	4.6	no	0.00	0.00	0.02	0.00
Computer Science, Software Engineering	5.2	1.9	-3.3	no	0.00	0.00	-0.02	0.00
Computer Science, Theory & Methods	5.5	2.1	-3.4	no	0.00	0.00	-0.01	0.00
Construction & Building Technology	5.1	0.3	-4.8	no	0.00	0.00	-0.03	0.00
Critical Care Medicine	5.4	3.2	-2.2	no	0.00	0.00	-0.03	0.00
Crystallography	6.5	0.9	-5.6	no	0.00	0.00	-0.10	0.00
Demography	5.7	2.4	-3.4	no	0.00	0.00	-0.05	0.00
Dentistry, Oral Surgery & Medicine	5.5	1.3	-4.2	no	0.00	0.00	-0.04	0.00
Dermatology	5.4	1.1	-4.3	no	0.00	0.00	-0.04	0.00
Developmental Biology	5.0	0.6	-4.4	no	0.00	0.00	-0.03	0.00
Ecology	5.0	3.2	-1.9	no	0.00	0.00	-0.02	0.00
Economics	5.2	0.6	-4.6	no	0.00	0.00	-0.03	0.00
Education & Educational Research	5.1	4.0	-1.1	no	0.00	0.00	-0.01	0.00
Education, Scientific Disciplines	5.3	4.2	-1.1	no	0.01	0.01	-0.02	0.01
Electrochemistry	5.6	2.7	-2.9	no	0.00	0.00	-0.04	0.00

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Emergency Medicine	5.0	1.1	-3.9	no	0.00	0.00	-0.04	0.00
Endocrinology & Metabolism	5.3	1.3	-4.0	no	0.00	0.00	-0.04	0.00
Energy & Fuels	5.3	1.5	-3.7	no	0.00	0.00	-0.03	0.00
Engineering	5.2	2.5	-2.8	no	0.00	0.00	-0.02	0.00
Engineering, Aerospace	5.6	4.3	-1.2	yes	0.66	1.00	0.00	0.66
Engineering, Biomedical	5.2	3.7	-1.4	no	0.00	0.00	-0.02	0.00
Engineering, Chemical	5.3	0.8	-4.4	no	0.00	0.00	-0.03	0.00
Engineering, Civil	5.1	0.6	-4.5	no	0.00	0.00	-0.02	0.00
Engineering, Electrical & Electronic	5.4	3.3	-2.1	no	0.00	0.00	-0.02	0.00
Engineering, Environmental	5.4	0.0	-5.4	no	0.00	0.00	-0.01	0.00
Engineering, Industrial	5.0	0.0	-5.0	no	0.00	0.00	-0.02	0.00
Engineering, Manufacturing	4.9	20.7	15.7	no	0.00	0.00	0.07	0.00
Engineering, Marine	5.9	0.6	-5.4	no	0.00	0.00	-0.05	0.00
Engineering, Mechanical	5.3	0.7	-4.6	no	0.00	0.00	-0.03	0.00
Engineering, Multidisciplinary	5.5	1.7	-3.8	no	0.00	0.00	-0.06	0.00
Engineering, Petroleum	4.0	9.2	5.1	no	0.00	0.00	0.06	0.00
Entomology	5.0	0.8	-4.2	no	0.00	0.00	-0.06	0.00
Environmental Sciences	5.2	5.7	0.5	no	0.01	0.01	0.01	0.01
Environmental Sciences & Ecology	5.1	5.0	-0.2	no	0.22	0.22	0.00	0.22
Environmental Studies	5.1	1.9	-3.2	no	0.00	0.00	-0.03	0.00
Ethics	5.2	4.2	-1.0	no	0.12	0.14	-0.01	0.12
Evolutionary Biology	5.3	1.6	-3.6	no	0.00	0.00	-0.05	0.00
Family Studies	5.0	15.4	10.4	no	0.00	0.00	0.05	0.00
Film, Radio & Television	37.0	0.7	-36.3	no	0.00	0.00	-0.11	0.00
Film, Radio, Television	37.0	0.7	-36.3	no	0.00	0.00	-0.11	0.00
Fisheries	5.3	2.2	-3.1	no	0.00	0.00	-0.03	0.00
Folklore	11.3	4.7	-6.6	no	0.00	0.00	-0.08	0.00
Food Science & Technology	5.2	0.3	-4.9	no	0.00	0.00	-0.04	0.00
Forestry	5.7	1.2	-4.5	no	0.00	0.00	-0.07	0.00
Gastroenterology & Hepatology	5.5	1.1	-4.4	no	0.00	0.00	-0.06	0.00
General & Internal Medicine	6.3	1.1	-5.3	no	0.00	0.00	-0.10	0.00

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	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Genetics & Heredity	5.4	3.2	-2.1	no	0.00	0.00	-0.03	0.00
Geochemistry & Geophysics	5.4	0.8	-4.6	no	0.00	0.00	-0.04	0.00
Geography	5.2	0.1	-5.2	no	0.00	0.00	-0.05	0.00
Geography, Physical	5.3	7.2	1.9	no	0.00	0.00	0.02	0.00
Geology	5.2	4.7	-0.5	no	0.00	0.00	-0.01	0.00
Geosciences, Multidisciplinary	5.3	5.1	-0.2	no	0.25	0.26	0.00	0.25
Geriatrics & Gerontology	4.9	3.9	-1.0	no	0.02	0.02	-0.01	0.02
Gerontology	5.1	2.3	-2.8	no	0.00	0.00	-0.03	0.00
Government & Law	5.0	3.3	-1.7	no	0.00	0.00	-0.01	0.00
Health Care Sciences & Services	5.1	4.5	-0.6	no	0.01	0.01	-0.01	0.01
Health Policy & Services	5.0	4.5	-0.5	no	0.15	0.17	-0.01	0.15
Hematology	5.3	4.0	-1.3	no	0.00	0.00	-0.01	0.00
History	5.8	2.6	-3.2	no	0.00	0.00	-0.03	0.00
History & Philosophy Of Science	6.0	0.4	-5.6	no	0.00	0.00	-0.06	0.00
Horticulture	5.6	0.1	-5.4	no	0.00	0.00	-0.07	0.00
Humanities, Multidisciplinary	9.2	3.1	-6.1	no	0.00	0.00	-0.04	0.00
Imaging Science & Photographic Technology	5.3	0.2	-5.1	no	0.00	0.00	-0.03	0.00
Immunology	5.3	3.1	-2.2	no	0.00	0.00	-0.03	0.00
Industrial Relations & Labor	5.0	5.3	0.3	no	0.72	0.73	0.00	0.72
Infectious Diseases	5.0	4.2	-0.8	no	0.00	0.00	-0.01	0.00
Information Science & Library Science	5.4	1.7	-3.7	no	0.00	0.00	-0.04	0.00
Instruments & Instrumentation	5.7	4.5	-1.3	no	0.00	0.00	-0.01	0.00
Integrative & Complementary Medicine	5.1	6.3	1.3	no	0.00	0.00	0.02	0.00
International Relations	5.1	0.6	-4.5	no	0.00	0.00	-0.02	0.00
Language & Linguistics	5.4	2.4	-3.0	no	0.00	0.00	-0.03	0.00
Law	5.2	5.7	0.5	no	0.42	0.42	0.00	0.42
Life Sciences & Biomedicine – Other Topics	4.6	7.5	2.9	no	0.00	0.00	0.05	0.00
Limnology	5.5	1.2	-4.3	no	0.00	0.00	-0.03	0.00
Linguistics	5.1	3.1	-2.1	no	0.00	0.00	-0.02	0.00
Literary Theory & Criticism	5.5	2.3	-3.2	no	0.07	0.08	-0.02	0.07
Literature	6.4	2.9	-3.5	no	0.00	0.00	-0.02	0.00

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	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Literature, Romance	78.7	77.1	-1.7	no	0.18	0.18	-0.01	0.18
Literature, Slavic	89.8	100.0	10.2	no	0.00	0.00	0.07	0.00
Logic	5.6	1.5	-4.1	no	0.00	0.00	-0.05	0.00
Management	5.2	0.2	-5.0	no	0.00	0.00	-0.05	0.00
Marine & Freshwater Biology	5.2	1.1	-4.0	no	0.00	0.00	-0.04	0.00
Materials Science	5.7	1.6	-4.1	no	0.00	0.00	-0.03	0.00
Materials Science, Biomaterials	5.3	4.1	-1.2	no	0.23	0.28	-0.01	0.23
Materials Science, Ceramics	6.0	0.3	-5.7	no	0.00	0.00	-0.06	0.00
Materials Science, Multidisciplinary	5.8	1.7	-4.1	no	0.00	0.00	-0.03	0.00
Materials Science, Paper & Wood	5.6	4.3	-1.3	no	0.00	0.00	-0.02	0.00
Materials Science, Textiles	6.0	1.1	-4.9	no	0.00	0.00	-0.07	0.00
Mathematical & Computational Biology	5.9	3.5	-2.4	no	0.00	0.00	-0.05	0.00
Mathematical Methods In Social Sciences	5.2	1.4	-3.8	yes	0.14	0.19	-0.01	0.14
Mathematics	5.4	2.7	-2.7	no	0.00	0.00	-0.03	0.00
Mathematics, Applied	5.9	2.9	-3.0	no	0.00	0.00	-0.04	0.00
Mathematics, Interdisciplinary Applications	5.7	0.9	-4.8	no	0.00	0.00	-0.06	0.00
Mechanics	5.2	1.0	-4.1	no	0.00	0.00	-0.02	0.00
Medical Ethics	5.5	3.5	-2.0	no	0.01	0.01	-0.03	0.01
Medical Informatics	5.3	5.3	0.0	no	0.94	0.99	0.00	0.94
Medical Laboratory Technology	5.5	1.2	-4.2	no	0.00	0.00	-0.04	0.00
Medicine, General & Internal	6.7	0.9	-5.8	no	0.00	0.00	-0.12	0.00
Medicine, Research & Experimental	5.7	2.3	-3.4	no	0.00	0.00	-0.06	0.00
Medieval & Renaissance Studies	6.2	3.1	-3.0	no	0.01	0.01	-0.03	0.01
Metallurgy & Metallurgical Engineering	5.6	2.5	-3.1	no	0.00	0.00	-0.02	0.00
Meteorology & Atmospheric Sciences	4.9	6.6	1.6	no	0.00	0.00	0.03	0.00
Microbiology	4.8	5.8	1.0	no	0.00	0.00	0.01	0.00
Mineralogy	5.2	2.3	-2.9	no	0.02	0.02	-0.02	0.02
Mining & Mineral Processing	5.2	0.7	-4.5	no	0.00	0.00	-0.04	0.00
Multidisciplinary Sciences	10.6	0.8	-9.8	no	0.00	0.00	-0.22	0.00
Music	100.0	100.0	0.0	no				
Mycology	4.9	12.1	7.2	no	0.00	0.00	0.05	0.00

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Nanoscience & Nanotechnology	6.1	0.7	-5.4	no	0.00	0.00	-0.05	0.00
Neuroimaging	5.2	3.0	-2.2	no	0.06	0.08	-0.01	0.06
Neurosciences	5.2	2.0	-3.2	no	0.00	0.00	-0.04	0.00
Neurosciences & Neurology	5.2	2.1	-3.2	no	0.00	0.00	-0.03	0.00
Nuclear Science & Technology	5.5	4.8	-0.7	no	0.45	0.53	0.00	0.45
Nursing	5.7	0.4	-5.2	no	0.00	0.00	-0.06	0.00
Nutrition & Dietetics	5.1	1.9	-3.2	no	0.00	0.00	-0.04	0.00
Obstetrics & Gynecology	5.0	2.1	-2.9	no	0.00	0.00	-0.02	0.00
Oceanography	5.2	2.6	-2.6	no	0.00	0.00	-0.03	0.00
Oncology	5.1	1.6	-3.5	no	0.00	0.00	-0.04	0.00
Operations Research & Management Science	5.1	2.1	-3.0	yes	0.18	0.24	-0.01	0.18
Ophthalmology	5.6	1.3	-4.3	no	0.00	0.00	-0.06	0.00
Optics	4.5	9.9	5.4	no	0.00	0.00	0.09	0.00
Ornithology	6.3	2.2	-4.1	no	0.05	0.05	-0.02	0.05
Orthopedics	5.0	2.0	-3.0	no	0.00	0.00	-0.04	0.00
Otorhinolaryngology	5.0	3.2	-1.9	no	0.00	0.00	-0.01	0.00
Paleontology	5.3	3.3	-2.0	no	0.00	0.00	-0.02	0.00
Parasitology	4.3	6.0	1.7	no	0.00	0.00	0.04	0.00
Pathology	5.3	1.4	-3.9	no	0.00	0.00	-0.05	0.00
Pediatrics	5.3	1.6	-3.8	no	0.00	0.00	-0.03	0.00
Peripheral Vascular Disease	5.2	1.0	-4.2	no	0.00	0.00	-0.02	0.00
Pharmacology & Pharmacy	5.2	1.8	-3.4	no	0.00	0.00	-0.03	0.00
Philosophy	5.6	0.0	-5.6	no	0.00	0.00	-0.05	0.00
Physical Geography	5.3	7.2	1.9	no	0.00	0.00	0.02	0.00
Physics	6.0	3.7	-2.3	no	0.00	0.00	-0.02	0.00
Physics, Applied	6.2	4.9	-1.3	no	0.00	0.00	-0.01	0.00
Physics, Atomic, Molecular & Chemical	5.6	0.9	-4.6	no	0.00	0.00	-0.02	0.00
Physics, Condensed Matter	6.4	0.0	-6.4	no	0.00	0.00	-0.03	0.00
Physics, Mathematical	5.5	0.8	-4.8	no	0.00	0.00	-0.02	0.00
Physics, Multidisciplinary	6.3	3.0	-3.3	no	0.00	0.00	-0.04	0.00
Physics, Nuclear	6.3	5.9	-0.4	no	0.42	0.44	0.00	0.42

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Physics, Particles & Fields	6.0	4.2	-1.8	no	0.00	0.00	-0.01	0.00
Physiology	4.8	4.1	-0.7	no	0.01	0.01	-0.01	0.01
Plant Sciences	5.3	1.5	-3.8	no	0.00	0.00	-0.05	0.00
Political Science	4.9	0.2	-4.7	no	0.00	0.00	-0.03	0.00
Polymer Science	5.4	2.4	-3.0	no	0.00	0.00	-0.02	0.00
Primary Health Care	3.7	8.5	4.9	no	0.00	0.00	0.10	0.00
Psychiatry	5.1	1.4	-3.7	no	0.00	0.00	-0.04	0.00
Psychology	5.0	2.0	-3.1	no	0.00	0.00	-0.03	0.00
Psychology, Applied	5.1	0.0	-5.1	no	0.00	0.00	-0.02	0.00
Psychology, Clinical	5.1	2.0	-3.1	no	0.00	0.00	-0.02	0.00
Psychology, Educational	5.1	2.2	-2.9	no	0.12	0.17	-0.01	0.12
Psychology, Experimental	5.1	0.0	-5.1	no	0.00	0.00	-0.02	0.00
Psychology, Multidisciplinary	5.2	1.9	-3.3	no	0.00	0.00	-0.05	0.00
Psychology, Social	5.2	6.1	0.9	yes	0.82	0.69	0.00	0.82
Public Administration	5.0	0.2	-4.8	no	0.00	0.00	-0.03	0.00
Public, Environmental & Occupational Health	5.1	4.7	-0.4	no	0.00	0.00	-0.01	0.00
Radiology, Nuclear Medicine & Medical Imaging	5.3	2.2	-3.1	no	0.00	0.00	-0.03	0.00
Rehabilitation	5.1	3.1	-1.9	no	0.00	0.00	-0.02	0.00
Religion	5.5	4.2	-1.3	no	0.00	0.00	-0.02	0.00
Remote Sensing	5.2	3.3	-1.9	no	0.00	0.00	-0.02	0.00
Reproductive Biology	5.0	1.8	-3.1	no	0.00	0.00	-0.04	0.00
Research & Experimental Medicine	5.7	2.3	-3.4	no	0.00	0.00	-0.06	0.00
Respiratory System	5.3	2.4	-2.9	no	0.00	0.00	-0.02	0.00
Rheumatology	5.6	2.4	-3.2	no	0.00	0.00	-0.05	0.00
Robotics	5.3	0.1	-5.2	no	0.00	0.00	-0.07	0.00
Science & Technology – Other Topics	7.8	0.5	-7.3	no	0.00	0.00	-0.15	0.00
Social Issues	5.4	0.0	-5.4	no	0.00	0.00	-0.06	0.00
Social Sciences – Other Topics	5.0	4.1	-0.9	no	0.01	0.01	-0.01	0.01
Social Sciences, Biomedical	5.2	1.5	-3.7	no	0.00	0.00	-0.03	0.00
Social Sciences, Interdisciplinary	5.1	4.1	-0.9	no	0.02	0.02	-0.01	0.02
Social Sciences, Mathematical Methods	5.2	1.4	-3.8	yes	0.14	0.19	-0.01	0.14

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Subject area	% among the 5% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Social Work	5.1	4.0	-1.1	no	0.26	0.30	-0.01	0.26
Sociology	5.0	1.1	-4.0	no	0.00	0.00	-0.03	0.00
Soil Science	5.5	0.2	-5.3	no	0.00	0.00	-0.07	0.00
Spectroscopy	5.5	0.3	-5.2	no	0.00	0.00	-0.02	0.00
Sport Sciences	5.1	0.8	-4.4	no	0.00	0.00	-0.04	0.00
Statistics & Probability	5.2	3.8	-1.4	no	0.00	0.00	-0.01	0.00
Substance Abuse	5.2	2.1	-3.1	no	0.00	0.00	-0.02	0.00
Surgery	5.1	0.7	-4.4	no	0.00	0.00	-0.03	0.00
Telecommunications	4.9	4.2	-0.8	no	0.00	0.00	-0.01	0.00
Theater	35.4	21.4	-14.0	no	0.03	0.03	-0.02	0.03
Thermodynamics	5.5	0.7	-4.8	no	0.00	0.00	-0.04	0.00
Toxicology	4.3	11.5	7.2	no	0.00	0.00	0.09	0.00
Transportation	4.9	0.0	-4.9	no	0.01	0.00	-0.01	0.01
Tropical Medicine	5.1	5.2	0.2	no	0.56	0.56	0.00	0.56
Urban Studies	5.1	0.0	-5.1	no	0.00	0.00	-0.03	0.00
Urology & Nephrology	5.5	0.9	-4.6	no	0.00	0.00	-0.04	0.00
Veterinary Sciences	5.7	1.5	-4.2	no	0.00	0.00	-0.08	0.00
Virology	4.3	10.2	5.9	no	0.00	0.00	0.09	0.00
Water Resources	5.4	5.7	0.4	no	0.20	0.20	0.00	0.20
Women's Studies	5.2	0.0	-5.2	yes	0.51	1.00	-0.01	0.51
Zoology	5.0	2.8	-2.2	no	0.00	0.00	-0.03	0.00

E.2. Results for articles published in 2014, for each of the subject areas

The same analysis as discussed in AddendumE.1 was conducted a second time, only considering the articles published in 2014 to control for the potential confounding effect of the variance between years. The table below presents the results for all subject areas in which any OA journal articles were published in 2014.

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Subject area	% among the 5% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Acoustics	5.3	0.4	-4.9	no	0.00	0.00	-0.05	5.3
Agricultural Economics & Policy	6.2	0.0	-6.2	no	0.00	0.00	-0.11	6.2
Agricultural Engineering	5.8	0.0	-5.8	no	0.00	0.00	-0.08	5.8
Agriculture	5.7	0.7	-5.0	no	0.00	0.00	-0.08	5.7
Agriculture, Dairy & Animal Science	5.3	2.4	-2.9	no	0.00	0.00	-0.05	5.3
Agriculture, Multidisciplinary	7.1	0.6	-6.4	no	0.00	0.00	-0.12	7.1
Agronomy	5.8	0.6	-5.2	no	0.00	0.00	-0.09	5.8
Allergy	5.5	0.4	-5.1	no	0.00	0.00	-0.07	5.5
Anatomy & Morphology	5.4	4.9	-0.5	no	0.68	0.80	-0.01	5.4
Andrology	3.1	10.4	7.3	no	0.00	0.00	0.15	3.1
Anesthesiology	6.0	1.0	-5.1	no	0.00	0.00	-0.06	6.0
Anthropology	5.9	0.7	-5.2	no	0.00	0.00	-0.08	5.9
Archaeology	5.6	3.5	-2.1	no	0.33	0.41	-0.02	5.6
Architecture	8.1	8.0	-0.1	no	0.98	1.00	0.00	8.1
Area Studies	5.7	4.0	-1.7	yes	0.71	1.00	-0.01	5.7
Art	6.7	22.3	15.6	no	0.00	0.00	0.09	6.7
Arts & Humanities – Other Topics	5.5	0.7	-4.9	no	0.00	0.00	-0.05	5.5
Asian Studies	5.5	0.0	-5.5	yes	0.11	0.17	-0.05	5.5
Astronomy & Astrophysics	5.0	9.2	4.2	no	0.00	0.00	0.04	5.0
Audiology & Speech-Language Pathology	5.2	2.7	-2.5	yes	0.34	0.59	-0.02	5.2
Automation & Control Systems	5.2	3.7	-1.5	no	0.34	0.43	-0.01	5.2
Behavioral Sciences	5.3	2.2	-3.1	no	0.00	0.00	-0.04	5.3
Biochemical Research Methods	4.8	5.9	1.1	no	0.04	0.04	0.02	4.8
Biochemistry & Molecular Biology	4.9	6.0	1.1	no	0.00	0.00	0.02	4.9
Biodiversity & Conservation	5.5	0.2	-5.3	no	0.00	0.00	-0.07	5.5
Biodiversity Conservation	5.5	0.2	-5.3	no	0.00	0.00	-0.07	5.5
Biology	3.6	9.4	5.8	no	0.00	0.00	0.12	3.6
Biomedical Social Sciences	5.2	1.9	-3.4	no	0.06	0.06	-0.03	5.2
Biophysics	5.1	0.0	-5.1	no	0.01	0.00	-0.02	5.1
Biotechnology & Applied Microbiology	6.0	2.1	-3.8	no	0.00	0.00	-0.08	6.0
Business	5.2	0.0	-5.2	no	0.00	0.00	-0.04	5.2

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Subject area	% among the 5% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Business & Economics	5.1	0.9	-4.2	no	0.00	0.00	-0.03	5.1
Business, Finance	5.2	0.0	-5.2	yes	0.38	1.00	-0.01	5.2
Cardiac & Cardiovascular Systems	5.7	1.5	-4.2	no	0.00	0.00	-0.06	5.7
Cardiovascular System & Cardiology	5.4	1.7	-3.8	no	0.00	0.00	-0.05	5.4
Cell & Tissue Engineering	6.0	0.6	-5.3	no	0.00	0.00	-0.08	6.0
Cell Biology	5.5	1.9	-3.7	no	0.00	0.00	-0.06	5.5
Chemistry	5.4	1.4	-4.0	no	0.00	0.00	-0.04	5.4
Chemistry, Analytical	5.3	5.0	-0.2	no	0.69	0.76	0.00	5.3
Chemistry, Applied	5.1	0.0	-5.1	no	0.00	0.00	-0.03	5.1
Chemistry, Inorganic & Nuclear	5.2	0.0	-5.2	no	0.02	0.01	-0.02	5.2
Chemistry, Medicinal	5.1	3.4	-1.7	no	0.03	0.03	-0.02	5.1
Chemistry, Multidisciplinary	5.3	0.4	-5.0	no	0.00	0.00	-0.05	5.3
Chemistry, Organic	5.3	2.5	-2.8	no	0.00	0.00	-0.04	5.3
Chemistry, Physical	5.3	0.0	-5.3	no	0.00	0.00	-0.02	5.3
Classics	11.0	16.7	5.7	no	0.22	0.24	0.04	11.0
Clinical Neurology	5.2	1.8	-3.4	no	0.00	0.00	-0.04	5.2
Communication	4.9	3.6	-1.3	no	0.44	0.58	-0.01	4.9
Computer Science	5.2	2.1	-3.1	no	0.00	0.00	-0.03	5.2
Computer Science, Artificial Intelligence	5.2	2.7	-2.5	no	0.01	0.01	-0.02	5.2
Computer Science, Cybernetics	5.6	0.0	-5.6	yes	0.03	0.02	-0.06	5.6
Computer Science, Information Systems	5.5	0.5	-5.0	no	0.00	0.00	-0.05	5.5
Computer Science, Interdisciplinary Applications	4.8	9.1	4.3	no	0.01	0.01	0.02	4.8
Computer Science, Software Engineering	5.3	2.1	-3.2	no	0.09	0.13	-0.02	5.3
Computer Science, Theory & Methods	5.0	1.2	-3.8	yes	0.12	0.19	-0.02	5.0
Construction & Building Technology	5.1	0.6	-4.4	no	0.01	0.01	-0.03	5.1
Critical Care Medicine	5.3	3.8	-1.5	no	0.17	0.19	-0.02	5.3
Crystallography	5.6	13.0	7.5	no	0.00	0.01	0.04	5.6
Demography	6.0	0.6	-5.5	no	0.00	0.00	-0.09	6.0
Dentistry, Oral Surgery & Medicine	5.4	1.7	-3.6	no	0.00	0.00	-0.04	5.4
Dermatology	5.3	1.4	-3.8	no	0.00	0.00	-0.04	5.3
Developmental Biology	5.3	1.7	-3.6	no	0.09	0.09	-0.03	5.3

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Subject area	% among the 5% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Ecology	5.3	2.6	-2.7	no	0.00	0.00	-0.04	5.3
Economics	5.3	0.8	-4.6	no	0.00	0.00	-0.03	5.3
Education & Educational Research	5.1	4.6	-0.5	no	0.46	0.52	-0.01	5.1
Education, Scientific Disciplines	5.3	4.9	-0.4	no	0.67	0.76	-0.01	5.3
Electrochemistry	5.6	3.0	-2.6	no	0.00	0.00	-0.04	5.6
Emergency Medicine	5.1	1.2	-3.9	no	0.00	0.00	-0.05	5.1
Endocrinology & Metabolism	5.4	1.9	-3.5	no	0.00	0.00	-0.04	5.4
Energy & Fuels	5.4	0.3	-5.1	no	0.00	0.00	-0.04	5.4
Engineering	5.4	1.4	-3.9	no	0.00	0.00	-0.04	5.4
Engineering, Aerospace	6.2	8.7	2.5	yes	0.62	0.65	0.01	6.2
Engineering, Biomedical	5.4	4.9	-0.5	no	0.42	0.45	-0.01	5.4
Engineering, Chemical	5.2	0.4	-4.7	no	0.00	0.00	-0.03	5.2
Engineering, Civil	5.1	0.7	-4.4	no	0.00	0.00	-0.03	5.1
Engineering, Electrical & Electronic	5.6	2.0	-3.6	no	0.00	0.00	-0.04	5.6
Engineering, Environmental	5.2	0.0	-5.2	no	0.00	0.00	-0.03	5.2
Engineering, Industrial	5.2	0.0	-5.2	yes	0.10	0.18	-0.02	5.2
Engineering, Manufacturing	5.0	27.6	22.6	yes	0.00	0.00	0.07	5.0
Engineering, Marine	6.4	0.9	-5.5	no	0.02	0.01	-0.08	6.4
Engineering, Mechanical	5.4	0.5	-4.9	no	0.00	0.00	-0.05	5.4
Engineering, Multidisciplinary	6.6	0.7	-5.9	no	0.00	0.00	-0.11	6.6
Engineering, Petroleum	5.5	6.3	0.8	no	0.70	0.69	0.01	5.5
Entomology	5.9	0.1	-5.8	no	0.00	0.00	-0.09	5.9
Environmental Sciences	5.2	3.6	-1.5	no	0.00	0.00	-0.02	5.2
Environmental Sciences & Ecology	5.2	3.5	-1.7	no	0.00	0.00	-0.02	5.2
Environmental Studies	5.6	0.9	-4.7	no	0.00	0.00	-0.07	5.6
Ethics	5.2	4.6	-0.6	no	0.70	0.88	-0.01	5.2
Evolutionary Biology	5.6	2.6	-3.0	no	0.00	0.00	-0.05	5.6
Family Studies	5.3	37.5	32.2	yes	0.00	0.01	0.08	5.3
Film, Radio & Television	8.7	0.8	-7.9	no	0.00	0.00	-0.09	8.7
Film, Radio, Television	8.7	0.8	-7.9	no	0.00	0.00	-0.09	8.7
Fisheries	5.5	2.7	-2.7	no	0.01	0.01	-0.04	5.5

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Subject area	% among the 5% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Folklore	11.7	0.0	-11.7	no	0.00	0.00	-0.15	11.7
Food Science & Technology	5.2	0.3	-4.9	no	0.00	0.00	-0.04	5.2
Forestry	5.7	2.4	-3.3	no	0.00	0.00	-0.06	5.7
Gastroenterology & Hepatology	5.8	2.2	-3.6	no	0.00	0.00	-0.07	5.8
General & Internal Medicine	7.0	1.1	-5.9	no	0.00	0.00	-0.13	7.0
Genetics & Heredity	5.5	3.4	-2.1	no	0.00	0.00	-0.04	5.5
Geochemistry & Geophysics	5.2	2.1	-3.2	no	0.00	0.00	-0.03	5.2
Geography	5.3	0.0	-5.3	no	0.00	0.00	-0.06	5.3
Geography, Physical	5.0	8.0	3.0	no	0.01	0.02	0.03	5.0
Geology	5.0	5.9	0.9	no	0.04	0.05	0.01	5.0
Geosciences, Multidisciplinary	5.1	6.4	1.2	no	0.01	0.01	0.02	5.1
Geriatrics & Gerontology	5.0	5.8	0.9	no	0.26	0.27	0.01	5.0
Gerontology	5.3	5.6	0.3	no	0.83	0.75	0.00	5.3
Government & Law	5.1	2.7	-2.4	no	0.07	0.08	-0.02	5.1
Health Care Sciences & Services	5.1	4.8	-0.2	no	0.68	0.72	0.00	5.1
Health Policy & Services	5.2	4.8	-0.4	no	0.66	0.71	-0.01	5.2
Hematology	5.3	3.5	-1.8	no	0.08	0.09	-0.02	5.3
History	5.2	3.8	-1.4	no	0.14	0.17	-0.02	5.2
History & Philosophy Of Science	6.3	0.0	-6.3	no	0.00	0.00	-0.07	6.3
Horticulture	5.6	0.0	-5.6	no	0.00	0.00	-0.07	5.6
Humanities, Multidisciplinary	6.0	0.0	-6.0	no	0.00	0.00	-0.05	6.0
Imaging Science & Photographic Technology	5.1	1.4	-3.8	yes	0.15	0.27	-0.02	5.1
Immunology	5.5	3.5	-2.0	no	0.00	0.00	-0.03	5.5
Industrial Relations & Labor	5.0	4.9	-0.1	yes	0.97	1.00	0.00	5.0
Infectious Diseases	5.4	4.1	-1.3	no	0.00	0.00	-0.03	5.4
Information Science & Library Science	5.1	1.5	-3.6	no	0.01	0.01	-0.04	5.1
Instruments & Instrumentation	5.9	5.1	-0.8	no	0.23	0.25	-0.01	5.9
Integrative & Complementary Medicine	5.0	5.5	0.5	no	0.50	0.53	0.01	5.0
International Relations	5.2	0.0	-5.2	yes	0.08	0.11	-0.03	5.2
Language & Linguistics	5.3	2.7	-2.6	no	0.06	0.06	-0.03	5.3
Law	5.4	7.0	1.6	no	0.35	0.32	0.01	5.4

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Subject area	% among the 5% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Life Sciences & Biomedicine – Other Topics	3.6	9.4	5.8	no	0.00	0.00	0.12	3.6
Limnology	5.2	5.4	0.2	yes	0.93	0.79	0.00	5.2
Linguistics	5.2	3.1	-2.1	no	0.12	0.13	-0.02	5.2
Literary Theory & Criticism	6.5	2.4	-4.1	no	0.04	0.04	-0.07	6.5
Literature	7.2	4.4	-2.8	no	0.03	0.03	-0.02	7.2
Literature, Romance	5.3	7.6	2.2	no	0.28	0.32	0.03	5.3
Literature, Slavic	100.0	100.0	0.0	no				100.0
Logic	5.2	3.1	-2.1	yes	0.37	0.47	-0.03	5.2
Management	5.2	0.0	-5.2	no	0.00	0.00	-0.03	5.2
Marine & Freshwater Biology	5.3	2.6	-2.7	no	0.00	0.00	-0.03	5.3
Materials Science	5.4	1.5	-4.0	no	0.00	0.00	-0.04	5.4
Materials Science, Biomaterials	5.4	1.8	-3.6	no	0.10	0.13	-0.02	5.4
Materials Science, Ceramics	5.8	0.3	-5.5	no	0.00	0.00	-0.06	5.8
Materials Science, Multidisciplinary	5.4	1.7	-3.7	no	0.00	0.00	-0.04	5.4
Materials Science, Paper & Wood	6.6	2.0	-4.6	yes	0.00	0.00	-0.10	6.6
Materials Science, Textiles	6.0	0.4	-5.7	no	0.00	0.00	-0.08	6.0
Mathematical & Computational Biology	5.3	3.5	-1.7	no	0.00	0.00	-0.04	5.3
Mathematical Methods In Social Sciences	5.2	0.0	-5.2	no	0.23	0.40	-0.02	5.2
Mathematics	5.5	1.7	-3.9	no	0.00	0.00	-0.06	5.5
Mathematics, Applied	5.8	1.9	-3.9	no	0.00	0.00	-0.07	5.8
Mathematics, Interdisciplinary Applications	6.5	0.5	-6.0	no	0.00	0.00	-0.12	6.5
Mechanics	5.4	1.1	-4.2	no	0.00	0.00	-0.03	5.4
Medical Ethics	5.3	4.6	-0.7	no	0.65	0.74	-0.01	5.3
Medical Informatics	4.4	6.8	2.4	no	0.05	0.06	0.03	4.4
Medical Laboratory Technology	5.1	3.5	-1.7	no	0.37	0.56	-0.02	5.1
Medicine, General & Internal	7.6	0.9	-6.7	no	0.00	0.00	-0.15	7.6
Medicine, Research & Experimental	6.0	3.0	-3.0	no	0.00	0.00	-0.07	6.0
Medieval & Renaissance Studies	5.3	4.0	-1.3	yes	0.68	1.00	-0.01	5.3
Metallurgy & Metallurgical Engineering	5.4	2.8	-2.6	no	0.02	0.03	-0.02	5.4
Meteorology & Atmospheric Sciences	4.8	6.5	1.7	no	0.00	0.00	0.03	4.8
Microbiology	4.8	5.6	0.8	no	0.06	0.07	0.01	4.8

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Subject area	% among the 5% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Mineralogy	5.1	7.6	2.5	yes	0.33	0.30	0.02	5.1
Mining & Mineral Processing	5.4	8.1	2.7	yes	0.31	0.29	0.02	5.4
Multidisciplinary Sciences	15.7	1.1	-14.6	no	0.00	0.00	-0.30	15.7
Music	100.0	100.0	0.0	no				100.0
Mycology	4.7	12.1	7.4	yes	0.00	0.00	0.07	4.7
Nanoscience & Nanotechnology	5.6	0.8	-4.7	no	0.00	0.00	-0.06	5.6
Neuroimaging	5.2	2.7	-2.5	no	0.13	0.16	-0.03	5.2
Neurosciences	5.4	2.9	-2.5	no	0.00	0.00	-0.04	5.4
Neurosciences & Neurology	5.3	2.8	-2.5	no	0.00	0.00	-0.04	5.3
Nuclear Science & Technology	6.3	3.8	-2.5	no	0.24	0.28	-0.01	6.3
Nursing	5.2	0.3	-4.9	no	0.00	0.00	-0.05	5.2
Nutrition & Dietetics	5.7	2.0	-3.7	no	0.00	0.00	-0.05	5.7
Obstetrics & Gynecology	5.1	3.0	-2.2	no	0.02	0.02	-0.02	5.1
Oceanography	5.2	4.3	-0.9	no	0.36	0.44	-0.01	5.2
Oncology	5.5	2.1	-3.4	no	0.00	0.00	-0.05	5.5
Operations Research & Management Science	5.2	0.0	-5.2	yes	0.35	1.00	-0.01	5.2
Ophthalmology	6.2	0.8	-5.4	no	0.00	0.00	-0.08	6.2
Optics	4.4	7.6	3.2	no	0.00	0.00	0.06	4.4
Ornithology	5.8	0.0	-5.8	yes	0.32	1.00	-0.03	5.8
Orthopedics	5.1	2.0	-3.1	no	0.00	0.00	-0.05	5.1
Otorhinolaryngology	5.4	3.5	-1.9	no	0.18	0.20	-0.02	5.4
Paleontology	5.2	3.8	-1.4	no	0.34	0.44	-0.02	5.2
Parasitology	4.9	5.3	0.4	no	0.48	0.49	0.01	4.9
Pathology	5.7	2.1	-3.6	no	0.00	0.00	-0.07	5.7
Pediatrics	5.3	2.5	-2.8	no	0.00	0.00	-0.03	5.3
Peripheral Vascular Disease	5.4	0.0	-5.4	no	0.00	0.00	-0.04	5.4
Pharmacology & Pharmacy	5.2	2.5	-2.7	no	0.00	0.00	-0.03	5.2
Philosophy	5.3	0.0	-5.3	no	0.00	0.00	-0.05	5.3
Physical Geography	5.0	8.0	3.0	no	0.01	0.02	0.03	5.0
Physics	5.6	4.0	-1.6	no	0.00	0.00	-0.02	5.6
Physics, Applied	5.8	2.6	-3.3	no	0.00	0.00	-0.04	5.8

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Subject area	% among the 5% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Physics, Atomic, Molecular & Chemical	5.3	0.0	-5.3	no	0.00	0.00	-0.03	5.3
Physics, Condensed Matter	5.6	0.0	-5.6	no	0.00	0.00	-0.03	5.6
Physics, Mathematical	5.3	0.0	-5.3	no	0.00	0.00	-0.04	5.3
Physics, Multidisciplinary	5.8	5.6	-0.2	no	0.66	0.70	0.00	5.8
Physics, Nuclear	4.9	9.9	5.0	no	0.00	0.00	0.07	4.9
Physics, Particles & Fields	5.2	6.0	0.8	no	0.16	0.16	0.01	5.2
Physiology	4.8	6.6	1.7	no	0.00	0.01	0.03	4.8
Plant Sciences	5.8	3.2	-2.6	no	0.00	0.00	-0.04	5.8
Political Science	5.1	0.0	-5.1	no	0.02	0.01	-0.03	5.1
Polymer Science	5.1	3.0	-2.1	no	0.04	0.04	-0.02	5.1
Primary Health Care	4.2	8.2	4.0	no	0.00	0.00	0.08	4.2
Psychiatry	5.2	2.6	-2.7	no	0.00	0.00	-0.03	5.2
Psychology	5.3	2.2	-3.1	no	0.00	0.00	-0.04	5.3
Psychology, Applied	5.1	0.0	-5.1	yes	0.09	0.11	-0.03	5.1
Psychology, Clinical	5.2	0.8	-4.3	no	0.03	0.03	-0.02	5.2
Psychology, Educational	5.1	0.0	-5.1	yes	0.32	1.00	-0.02	5.1
Psychology, Experimental	5.1	0.0	-5.1	no	0.02	0.01	-0.03	5.1
Psychology, Multidisciplinary	5.8	2.6	-3.2	no	0.00	0.00	-0.06	5.8
Public Administration	5.1	0.0	-5.1	yes	0.07	0.07	-0.03	5.1
Public, Environmental & Occupational Health	5.1	5.1	0.0	no	0.89	0.90	0.00	5.1
Radiology, Nuclear Medicine & Medical Imaging	5.3	2.5	-2.9	no	0.00	0.00	-0.03	5.3
Rehabilitation	5.1	4.6	-0.5	no	0.52	0.58	-0.01	5.1
Religion	5.6	4.5	-1.0	no	0.42	0.46	-0.01	5.6
Remote Sensing	5.7	2.8	-2.9	no	0.00	0.00	-0.05	5.7
Reproductive Biology	5.4	1.9	-3.4	no	0.00	0.00	-0.04	5.4
Research & Experimental Medicine	6.0	3.0	-3.0	no	0.00	0.00	-0.07	6.0
Respiratory System	5.1	3.1	-2.0	no	0.05	0.05	-0.02	5.1
Rheumatology	5.7	2.5	-3.2	no	0.00	0.00	-0.06	5.7
Robotics	6.2	0.0	-6.2	no	0.00	0.00	-0.10	6.2
Science & Technology – Other Topics	9.3	0.7	-8.6	no	0.00	0.00	-0.19	9.3
Social Issues	5.4	0.0	-5.4	no	0.01	0.00	-0.06	5.4

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	% among the 5% most cited			*p*-value			Effect size	
Subject area	**Non-OA**	**OA**	**Diff.**	**Expected value < 5**	**χ^2**	**Fisher's exact**	**ϕ**	***p*-value**
Social Sciences – Other Topics	5.2	3.4	-1.7	no	0.03	0.03	-0.02	5.2
Social Sciences, Biomedical	5.2	1.9	-3.4	no	0.06	0.06	-0.03	5.2
Social Sciences, Interdisciplinary	5.4	2.9	-2.5	no	0.01	0.01	-0.03	5.4
Social Sciences, Mathematical Methods	5.2	0.0	-5.2	no	0.23	0.40	-0.02	5.2
Social Work	5.4	1.0	-4.4	no	0.05	0.06	-0.04	5.4
Sociology	5.4	0.5	-4.9	no	0.00	0.00	-0.04	5.4
Soil Science	5.7	0.0	-5.7	no	0.00	0.00	-0.07	5.7
Spectroscopy	5.6	0.0	-5.6	yes	0.04	0.03	-0.02	5.6
Sport Sciences	5.2	0.8	-4.4	no	0.00	0.00	-0.05	5.2
Statistics & Probability	5.2	3.2	-2.0	no	0.04	0.04	-0.02	5.2
Substance Abuse	5.2	1.6	-3.6	no	0.08	0.09	-0.03	5.2
Surgery	5.5	1.1	-4.4	no	0.00	0.00	-0.04	5.5
Telecommunications	5.6	0.4	-5.2	no	0.00	0.00	-0.07	5.6
Theater	7.9	9.1	1.2	yes	0.88	0.60	0.00	7.9
Thermodynamics	5.6	0.7	-4.9	no	0.00	0.00	-0.06	5.6
Toxicology	4.4	12.2	7.8	no	0.00	0.00	0.10	4.4
Transportation	5.2	0.0	-5.2	yes	0.18	0.42	-0.02	5.2
Tropical Medicine	4.1	5.8	1.6	no	0.03	0.03	0.04	4.1
Urban Studies	5.2	0.0	-5.2	yes	0.16	0.26	-0.03	5.2
Urology & Nephrology	5.8	1.3	-4.4	no	0.00	0.00	-0.05	5.8
Veterinary Sciences	5.4	2.8	-2.6	no	0.00	0.00	-0.05	5.4
Virology	4.1	8.7	4.6	no	0.00	0.00	0.08	4.1
Water Resources	5.0	6.9	1.9	no	0.01	0.01	0.02	5.0
Women's Studies	5.5	0.0	-5.5	yes	0.49	1.00	-0.02	5.5
Zoology	5.1	4.0	-1.1	no	0.05	0.06	-0.02	5.1

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ADDENDUM F:
Measure of citation advantage – percentage of articles among the 10% most frequently cited

F.1. Results for all years and all subject areas

Chapter 6 presents the results for the three measures of citation advantage for each of the subject areas for all articles published from 2005 to 2014. The third measure that was investigated was the percentage of OA and non-OA journal articles among the 1%, 5%, and 10% most frequently cited articles. These are referred to as 'percentile-based citation indicators'. The results of the third percentile-based citation indicator, 10%, are presented in this addendum. A three-fold method was applied to determine whether OA or non-OA journal articles in a subject area experienced a citation advantage, as elaborated upon in Chapter 4.

In Chapter 6 (sub-section 6.5.3), only those subject areas which experienced a citation advantage for their OA journal articles are named, and their results are reported in the chapter. The results for all the subject areas in which any OA journal articles were published in the ten years are listed in the table below.

	% among the 10% most cited			***p*-value**			**Effect size**	
Subject area	**Non-OA**	**OA**	**Diff.**	**Expected value < 5**	**χ^2**	**Fisher's exact**	**ϕ**	***p*-value**
Acoustics	10.6	1.4	-9.2	no	0.00	-0.05	0.00	10.6
Agricultural Economics & Policy	12.3	1.3	-11.0	no	0.00	-0.10	0.00	12.3
Agricultural Engineering	11.2	0.1	-11.2	no	0.00	-0.08	0.00	11.2
Agriculture	11.6	1.3	-10.3	no	0.00	-0.12	0.00	11.6
Agriculture, Dairy & Animal Science	12.6	2.8	-9.8	no	0.00	-0.12	0.00	12.6

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Subject area	% among the 10% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Agriculture, Multidisciplinary	14.4	1.1	-13.3	no	0.00	-0.19	0.00	14.4
Agronomy	11.7	1.2	-10.5	no	0.00	-0.13	0.00	11.7
Allergy	11.5	1.5	-10.0	no	0.00	-0.08	0.00	11.5
Anatomy & Morphology	10.2	4.3	-5.9	no	0.00	-0.06	0.00	10.2
Andrology	8.5	10.5	2.0	no	0.06	0.03	0.05	8.5
Anesthesiology	10.5	8.9	-1.5	no	0.08	-0.01	0.08	10.5
Anthropology	10.9	1.7	-9.2	no	0.00	-0.08	0.00	10.9
Archaeology	10.8	3.2	-7.7	no	0.00	-0.05	0.00	10.8
Architecture	83.1	79.8	-3.3	no	0.01	-0.02	0.01	83.1
Area Studies	10.3	15.5	5.2	no	0.04	0.02	0.03	10.3
Art	100.0	100.0	0.0	no				100.0
Arts & Humanities – Other Topics	11.4	5.3	-6.1	no	0.00	-0.04	0.00	11.4
Asian Studies	11.3	7.2	-4.1	no	0.01	-0.03	0.01	11.3
Astronomy & Astrophysics	10.7	5.3	-5.5	no	0.00	-0.03	0.00	10.7
Audiology & Speech-Language Pathology	10.0	8.6	-1.5	no	0.45	-0.01	0.39	10.0
Automation & Control Systems	10.0	8.7	-1.3	no	0.07	-0.01	0.07	10.0
Behavioral Sciences	10.0	3.7	-6.3	no	0.00	-0.04	0.00	10.0
Biochemical Research Methods	10.1	11.4	1.3	no	0.00	0.01	0.00	10.1
Biochemistry & Molecular Biology	9.9	11.9	1.9	no	0.00	0.02	0.00	9.9
Biodiversity & Conservation	11.2	1.4	-9.8	no	0.00	-0.09	0.00	11.2
Biodiversity Conservation	11.2	1.4	-9.8	no	0.00	-0.09	0.00	11.2
Biology	9.7	12.1	2.4	no	0.00	0.03	0.00	9.7
Biomedical Social Sciences	10.4	4.4	-6.0	no	0.00	-0.04	0.00	10.4
Biophysics	9.9	1.4	-8.6	no	0.00	-0.02	0.00	9.9
Biotechnology & Applied Microbiology	10.9	5.5	-5.4	no	0.00	-0.07	0.00	10.9
Business	11.1	0.6	-10.5	no	0.00	-0.09	0.00	11.1
Business & Economics	10.3	2.0	-8.3	no	0.00	-0.05	0.00	10.3
Business, Finance	10.6	4.2	-6.4	no	0.00	-0.02	0.00	10.6
Cardiac & Cardiovascular Systems	11.1	2.9	-8.2	no	0.00	-0.08	0.00	11.1
Cardiovascular System & Cardiology	10.7	3.0	-7.7	no	0.00	-0.07	0.00	10.7
Cell & Tissue Engineering	10.8	3.6	-7.2	no	0.00	-0.05	0.00	10.8

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Subject area	% among the 10% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Cell Biology	10.5	3.8	-6.7	no	0.00	-0.05	0.00	10.5
Chemistry	10.8	2.3	-8.4	no	0.00	-0.05	0.00	10.8
Chemistry, Analytical	10.7	7.0	-3.6	no	0.00	-0.02	0.00	10.7
Chemistry, Applied	10.3	0.2	-10.0	no	0.00	-0.04	0.00	10.3
Chemistry, Inorganic & Nuclear	10.7	4.7	-6.0	no	0.00	-0.01	0.00	10.7
Chemistry, Medicinal	10.1	7.9	-2.3	no	0.00	-0.01	0.00	10.1
Chemistry, Multidisciplinary	11.2	0.8	-10.5	no	0.00	-0.08	0.00	11.2
Chemistry, Organic	10.7	4.6	-6.1	no	0.00	-0.04	0.00	10.7
Chemistry, Physical	10.7	2.1	-8.6	no	0.00	-0.02	0.00	10.7
Classics	13.1	22.9	9.8	no	0.00	0.06	0.00	13.1
Clinical Neurology	10.4	4.1	-6.3	no	0.00	-0.04	0.00	10.4
Communication	10.5	4.6	-5.9	no	0.00	-0.04	0.00	10.5
Computer Science	10.5	5.5	-4.9	no	0.00	-0.03	0.00	10.5
Computer Science, Artificial Intelligence	10.6	7.4	-3.2	no	0.00	-0.02	0.00	10.6
Computer Science, Cybernetics	11.0	1.3	-9.8	no	0.00	-0.06	0.00	11.0
Computer Science, Information Systems	10.5	2.4	-8.1	no	0.00	-0.05	0.00	10.5
Computer Science, Interdisciplinary Applications	10.3	15.4	5.1	no	0.00	0.02	0.00	10.3
Computer Science, Software Engineering	10.2	4.3	-6.0	no	0.00	-0.03	0.00	10.2
Computer Science, Theory & Methods	10.8	3.4	-7.4	no	0.00	-0.02	0.00	10.8
Construction & Building Technology	10.4	0.8	-9.5	no	0.00	-0.05	0.00	10.4
Critical Care Medicine	10.4	8.0	-2.5	no	0.00	-0.02	0.00	10.4
Crystallography	12.8	2.2	-10.6	no	0.00	-0.13	0.00	12.8
Demography	11.3	6.4	-4.9	no	0.00	-0.06	0.00	11.3
Dentistry, Oral Surgery & Medicine	11.1	4.2	-6.9	no	0.00	-0.05	0.00	11.1
Dermatology	11.0	3.3	-7.7	no	0.00	-0.06	0.00	11.0
Developmental Biology	10.0	1.6	-8.5	no	0.00	-0.05	0.00	10.0
Ecology	10.2	6.4	-3.8	no	0.00	-0.03	0.00	10.2
Economics	10.4	2.1	-8.2	no	0.00	-0.04	0.00	10.4
Education & Educational Research	10.1	9.5	-0.6	no	0.14	0.00	0.13	10.1
Education, Scientific Disciplines	10.2	10.7	0.5	no	0.35	0.01	0.34	10.2
Electrochemistry	11.2	5.1	-6.1	no	0.00	-0.06	0.00	11.2

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Subject area	% among the 10% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Emergency Medicine	10.2	2.4	-7.8	no	0.00	-0.06	0.00	10.2
Endocrinology & Metabolism	10.4	3.2	-7.2	no	0.00	-0.05	0.00	10.4
Energy & Fuels	10.4	3.5	-6.9	no	0.00	-0.04	0.00	10.4
Engineering	10.5	4.8	-5.7	no	0.00	-0.03	0.00	10.5
Engineering, Aerospace	11.9	7.2	-4.6	no	0.35	-0.01	0.24	11.9
Engineering, Biomedical	10.4	7.3	-3.1	no	0.00	-0.03	0.00	10.4
Engineering, Chemical	10.3	1.9	-8.4	no	0.00	-0.04	0.00	10.3
Engineering, Civil	10.1	1.1	-9.0	no	0.00	-0.03	0.00	10.1
Engineering, Electrical & Electronic	10.7	7.1	-3.6	no	0.00	-0.02	0.00	10.7
Engineering, Environmental	10.6	0.0	-10.6	no	0.00	-0.02	0.00	10.6
Engineering, Industrial	10.1	0.0	-10.1	no	0.00	-0.02	0.00	10.1
Engineering, Manufacturing	10.2	26.8	16.5	no	0.00	0.05	0.00	10.2
Engineering, Marine	11.3	3.3	-7.9	no	0.00	-0.05	0.00	11.3
Engineering, Mechanical	10.6	1.6	-9.0	no	0.00	-0.04	0.00	10.6
Engineering, Multidisciplinary	10.9	3.3	-7.6	no	0.00	-0.08	0.00	10.9
Engineering, Petroleum	8.9	17.4	8.6	no	0.00	0.07	0.00	8.9
Entomology	10.5	2.7	-7.8	no	0.00	-0.07	0.00	10.5
Environmental Sciences	10.4	10.5	0.1	no	0.67	0.00	0.67	10.4
Environmental Sciences & Ecology	10.3	9.3	-1.0	no	0.00	-0.01	0.00	10.3
Environmental Studies	10.2	4.6	-5.6	no	0.00	-0.04	0.00	10.2
Ethics	10.2	9.9	-0.4	no	0.73	0.00	0.70	10.2
Evolutionary Biology	10.5	4.0	-6.5	no	0.00	-0.07	0.00	10.5
Family Studies	9.9	25.2	15.3	no	0.00	0.06	0.00	9.9
Film, Radio & Television	100.0	100.0	0.0	no				100.0
Film, Radio, Television	100.0	100.0	0.0	no				100.0
Fisheries	10.9	4.7	-6.2	no	0.00	-0.05	0.00	10.9
Folklore	71.2	65.4	-5.7	no	0.01	-0.05	0.01	71.2
Food Science & Technology	10.4	0.9	-9.6	no	0.00	-0.05	0.00	10.4
Forestry	11.6	2.4	-9.1	no	0.00	-0.10	0.00	11.6
Gastroenterology & Hepatology	10.9	3.0	-7.9	no	0.00	-0.08	0.00	10.9
General & Internal Medicine	12.3	3.3	-9.0	no	0.00	-0.13	0.00	12.3

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Subject area	% among the 10% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Genetics & Heredity	10.4	8.0	-2.5	no	0.00	-0.03	0.00	10.4
Geochemistry & Geophysics	10.9	2.2	-8.7	no	0.00	-0.05	0.00	10.9
Geography	10.5	0.3	-10.2	no	0.00	-0.07	0.00	10.5
Geography, Physical	10.7	12.8	2.1	no	0.01	0.01	0.01	10.7
Geology	10.5	9.5	-1.0	no	0.00	-0.01	0.00	10.5
Geosciences, Multidisciplinary	10.5	10.3	-0.2	no	0.45	0.00	0.45	10.5
Geriatrics & Gerontology	9.9	8.0	-1.9	no	0.00	-0.02	0.00	9.9
Gerontology	10.0	4.7	-5.4	no	0.00	-0.04	0.00	10.0
Government & Law	10.1	7.1	-3.0	no	0.00	-0.01	0.00	10.1
Health Care Sciences & Services	10.1	9.6	-0.5	no	0.10	-0.01	0.10	10.1
Health Policy & Services	10.1	10.2	0.1	no	0.84	0.00	0.85	10.1
Hematology	10.4	9.2	-1.2	no	0.01	-0.01	0.01	10.4
History	14.6	5.9	-8.7	no	0.00	-0.05	0.00	14.6
History & Philosophy Of Science	11.6	1.5	-10.2	no	0.00	-0.08	0.00	11.6
Horticulture	11.1	0.5	-10.6	no	0.00	-0.10	0.00	11.1
Humanities, Multidisciplinary	26.0	13.5	-12.6	no	0.00	-0.06	0.00	26.0
Imaging Science & Photographic Technology	10.4	0.9	-9.5	no	0.00	-0.04	0.00	10.4
Immunology	10.6	7.1	-3.6	no	0.00	-0.03	0.00	10.6
Industrial Relations & Labor	10.2	11.0	0.8	no	0.50	0.01	0.51	10.2
Infectious Diseases	10.1	8.7	-1.4	no	0.00	-0.02	0.00	10.1
Information Science & Library Science	10.8	4.0	-6.7	no	0.00	-0.06	0.00	10.8
Instruments & Instrumentation	11.3	8.7	-2.5	no	0.00	-0.02	0.00	11.3
Integrative & Complementary Medicine	10.2	12.0	1.9	no	0.00	0.02	0.00	10.2
International Relations	10.1	0.9	-9.2	no	0.00	-0.03	0.00	10.1
Language & Linguistics	11.1	5.0	-6.1	no	0.00	-0.04	0.00	11.1
Law	10.7	12.6	1.8	no	0.04	0.01	0.03	10.7
Life Sciences & Biomedicine – Other Topics	9.7	12.1	2.4	no	0.00	0.03	0.00	9.7
Limnology	10.7	4.1	-6.6	no	0.00	-0.03	0.00	10.7
Linguistics	10.4	5.9	-4.5	no	0.00	-0.03	0.00	10.4
Literary Theory & Criticism	11.0	2.3	-8.7	no	0.00	-0.04	0.00	11.0
Literature	90.3	86.8	-3.5	no	0.00	-0.02	0.00	90.3

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	% among the 10% most cited			*p*-value			Effect size	
Subject area	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Literature, Romance	100.0	100.0	0.0	no				100.0
Literature, Slavic	100.0	100.0	0.0	no				100.0
Logic	11.3	3.1	-8.2	no	0.00	-0.07	0.00	11.3
Management	10.5	0.5	-10.1	no	0.00	-0.07	0.00	10.5
Marine & Freshwater Biology	10.4	2.8	-7.6	no	0.00	-0.05	0.00	10.4
Materials Science	11.2	3.5	-7.8	no	0.00	-0.05	0.00	11.2
Materials Science, Biomaterials	10.6	6.8	-3.8	no	0.01	-0.01	0.01	10.6
Materials Science, Ceramics	12.0	1.0	-11.0	no	0.00	-0.09	0.00	12.0
Materials Science, Multidisciplinary	11.3	3.4	-7.9	no	0.00	-0.05	0.00	11.3
Materials Science, Paper & Wood	11.2	10.1	-1.1	no	0.10	-0.01	0.09	11.2
Materials Science, Textiles	11.8	3.3	-8.5	no	0.00	-0.09	0.00	11.8
Mathematical & Computational Biology	11.2	8.6	-2.6	no	0.00	-0.04	0.00	11.2
Mathematical Methods In Social Sciences	10.3	5.5	-4.8	no	0.24	-0.01	0.18	10.3
Mathematics	10.9	5.4	-5.5	no	0.00	-0.05	0.00	10.9
Mathematics, Applied	11.3	5.5	-5.8	no	0.00	-0.06	0.00	11.3
Mathematics, Interdisciplinary Applications	11.3	2.3	-9.0	no	0.00	-0.09	0.00	11.3
Mechanics	10.4	2.3	-8.1	no	0.00	-0.03	0.00	10.4
Medical Ethics	10.8	7.0	-3.8	no	0.00	-0.04	0.00	10.8
Medical Informatics	10.3	10.8	0.5	no	0.53	0.00	0.51	10.3
Medical Laboratory Technology	10.9	2.1	-8.8	no	0.00	-0.05	0.00	10.9
Medicine, General & Internal	12.7	3.3	-9.4	no	0.00	-0.14	0.00	12.7
Medicine, Research & Experimental	11.2	5.2	-6.0	no	0.00	-0.07	0.00	11.2
Medieval & Renaissance Studies	14.7	6.5	-8.2	no	0.00	-0.06	0.00	14.7
Metallurgy & Metallurgical Engineering	11.1	5.1	-6.0	no	0.00	-0.03	0.00	11.1
Meteorology & Atmospheric Sciences	10.0	13.3	3.3	no	0.00	0.04	0.00	10.0
Microbiology	9.6	11.6	2.0	no	0.00	0.02	0.00	9.6
Mineralogy	10.4	4.6	-5.8	no	0.00	-0.02	0.00	10.4
Mining & Mineral Processing	10.2	1.7	-8.5	no	0.00	-0.06	0.00	10.2
Multidisciplinary Sciences	19.6	3.3	-16.2	no	0.00	-0.26	0.00	19.6
Music	100.0	100.0	0.0	no				100.0
Mycology	10.0	15.1	5.1	no	0.00	0.03	0.00	10.0

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Subject area	% among the 10% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Nanoscience & Nanotechnology	12.1	1.8	-10.3	no	0.00	-0.07	0.00	12.1
Neuroimaging	10.5	6.6	-3.8	no	0.02	-0.02	0.02	10.5
Neurosciences	10.4	5.0	-5.3	no	0.00	-0.04	0.00	10.4
Neurosciences & Neurology	10.4	5.0	-5.4	no	0.00	-0.04	0.00	10.4
Nuclear Science & Technology	10.4	8.6	-1.8	no	0.17	0.00	0.15	10.4
Nursing	11.9	2.3	-9.7	no	0.00	-0.08	0.00	11.9
Nutrition & Dietetics	10.2	3.8	-6.4	no	0.00	-0.06	0.00	10.2
Obstetrics & Gynecology	10.3	5.5	-4.8	no	0.00	-0.02	0.00	10.3
Oceanography	10.4	4.7	-5.7	no	0.00	-0.05	0.00	10.4
Oncology	10.3	4.2	-6.2	no	0.00	-0.05	0.00	10.3
Operations Research & Management Science	10.3	3.2	-7.1	no	0.02	-0.01	0.02	10.3
Ophthalmology	11.9	3.8	-8.1	no	0.00	-0.08	0.00	11.9
Optics	9.1	18.3	9.1	no	0.00	0.11	0.00	9.1
Ornithology	11.3	3.7	-7.7	no	0.00	-0.03	0.00	11.3
Orthopedics	10.1	4.4	-5.7	no	0.00	-0.05	0.00	10.1
Otorhinolaryngology	10.1	6.6	-3.4	no	0.00	-0.02	0.00	10.1
Paleontology	10.4	7.2	-3.2	no	0.00	-0.03	0.00	10.4
Parasitology	8.3	12.5	4.2	no	0.00	0.07	0.00	8.3
Pathology	10.7	3.6	-7.1	no	0.00	-0.07	0.00	10.7
Pediatrics	10.5	4.1	-6.3	no	0.00	-0.04	0.00	10.5
Peripheral Vascular Disease	10.3	2.5	-7.8	no	0.00	-0.03	0.00	10.3
Pharmacology & Pharmacy	10.4	3.6	-6.8	no	0.00	-0.05	0.00	10.4
Philosophy	11.0	0.0	-11.0	no	0.00	-0.07	0.00	11.0
Physical Geography	10.7	12.8	2.1	no	0.01	0.01	0.01	10.7
Physics	11.8	7.5	-4.3	no	0.00	-0.03	0.00	11.8
Physics, Applied	12.1	10.2	-1.9	no	0.00	-0.01	0.00	12.1
Physics, Atomic, Molecular & Chemical	11.3	2.1	-9.2	no	0.00	-0.03	0.00	11.3
Physics, Condensed Matter	12.5	0.2	-12.3	no	0.00	-0.05	0.00	12.5
Physics, Mathematical	11.1	1.9	-9.2	no	0.00	-0.03	0.00	11.1
Physics, Multidisciplinary	12.3	7.1	-5.1	no	0.00	-0.05	0.00	12.3
Physics, Nuclear	12.2	11.0	-1.2	no	0.08	-0.01	0.08	12.2

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	% among the 10% most cited			*p*-value			Effect size	
Subject area	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Physics, Particles & Fields	12.0	8.1	-3.9	no	0.00	-0.02	0.00	12.0
Physiology	9.9	8.1	-1.8	no	0.00	-0.02	0.00	9.9
Plant Sciences	10.6	3.6	-7.0	no	0.00	-0.07	0.00	10.6
Political Science	10.0	0.6	-9.5	no	0.00	-0.04	0.00	10.0
Polymer Science	10.5	4.4	-6.2	no	0.00	-0.02	0.00	10.5
Primary Health Care	8.5	15.5	6.9	no	0.00	0.11	0.00	8.5
Psychiatry	10.2	3.3	-6.9	no	0.00	-0.05	0.00	10.2
Psychology	10.1	4.9	-5.2	no	0.00	-0.03	0.00	10.1
Psychology, Applied	10.2	0.6	-9.5	no	0.00	-0.03	0.00	10.2
Psychology, Clinical	9.9	3.0	-6.9	no	0.00	-0.03	0.00	9.9
Psychology, Educational	10.2	6.6	-3.6	no	0.20	-0.01	0.17	10.2
Psychology, Experimental	10.3	0.9	-9.3	no	0.00	-0.03	0.00	10.3
Psychology, Multidisciplinary	10.5	4.3	-6.3	no	0.00	-0.07	0.00	10.5
Psychology, Social	10.4	12.1	1.8	yes	0.77	0.00	0.74	10.4
Public Administration	10.1	0.3	-9.8	no	0.00	-0.04	0.00	10.1
Public, Environmental & Occupational Health	10.6	9.0	-1.6	no	0.00	-0.02	0.00	10.6
Radiology, Nuclear Medicine & Medical Imaging	10.4	5.2	-5.3	no	0.00	-0.04	0.00	10.4
Rehabilitation	10.2	6.8	-3.4	no	0.00	-0.03	0.00	10.2
Religion	13.3	9.7	-3.5	no	0.00	-0.03	0.00	13.3
Remote Sensing	10.4	7.4	-3.0	no	0.00	-0.03	0.00	10.4
Reproductive Biology	10.0	4.7	-5.4	no	0.00	-0.04	0.00	10.0
Research & Experimental Medicine	11.2	5.2	-6.0	no	0.00	-0.07	0.00	11.2
Respiratory System	10.4	5.9	-4.6	no	0.00	-0.03	0.00	10.4
Rheumatology	11.2	6.1	-5.1	no	0.00	-0.06	0.00	11.2
Robotics	10.5	0.4	-10.1	no	0.00	-0.10	0.00	10.5
Science & Technology – Other Topics	15.0	2.0	-13.1	no	0.00	-0.20	0.00	15.0
Social Issues	10.7	0.3	-10.5	no	0.00	-0.09	0.00	10.7
Social Sciences – Other Topics	10.2	7.1	-3.1	no	0.00	-0.02	0.00	10.2
Social Sciences, Biomedical	10.4	4.4	-6.0	no	0.00	-0.04	0.00	10.4
Social Sciences, Interdisciplinary	10.5	6.2	-4.2	no	0.00	-0.04	0.00	10.5
Social Sciences, Mathematical Methods	10.3	5.5	-4.8	no	0.24	-0.01	0.18	10.3

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Subject area	% among the 10% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Social Work	10.8	7.8	-2.9	no	0.04	-0.02	0.04	10.8
Sociology	10.0	1.8	-8.3	no	0.00	-0.05	0.00	10.0
Soil Science	11.6	1.0	-10.5	no	0.00	-0.09	0.00	11.6
Spectroscopy	10.8	0.9	-10.0	no	0.00	-0.02	0.00	10.8
Sport Sciences	10.3	1.6	-8.7	no	0.00	-0.06	0.00	10.3
Statistics & Probability	10.5	8.2	-2.3	no	0.00	-0.02	0.00	10.5
Substance Abuse	10.4	4.2	-6.2	no	0.00	-0.04	0.00	10.4
Surgery	10.1	1.9	-8.2	no	0.00	-0.05	0.00	10.1
Telecommunications	10.0	9.1	-0.9	no	0.01	-0.01	0.01	10.0
Theater	90.5	89.3	-1.2	no	0.65	0.00	0.75	90.5
Thermodynamics	10.8	1.2	-9.6	no	0.00	-0.06	0.00	10.8
Toxicology	9.2	18.3	9.1	no	0.00	0.08	0.00	9.2
Transportation	9.9	0.0	-9.9	no	0.00	-0.02	0.00	9.9
Tropical Medicine	10.1	11.0	0.8	no	0.03	0.01	0.03	10.1
Urban Studies	10.1	0.0	-10.1	no	0.00	-0.04	0.00	10.1
Urology & Nephrology	10.9	2.8	-8.1	no	0.00	-0.06	0.00	10.9
Veterinary Sciences	11.6	3.4	-8.2	no	0.00	-0.11	0.00	11.6
Virology	8.7	19.5	10.8	no	0.00	0.12	0.00	8.7
Water Resources	10.7	10.9	0.2	no	0.59	0.00	0.59	10.7
Women's Studies	10.2	0.0	-10.2	yes	1.00	-0.01	0.34	10.2
Zoology	10.3	5.9	-4.4	no	0.00	-0.04	0.00	10.3

F.2. Results for articles published in 2014, for each of the subject areas

The same analysis as discussed in Addendum F.1 was conducted a second time, only considering the articles published in 2014 to control for the potential confounding effect of the variance between years. The table below presents the results for all subject areas in which any OA journal articles were published in 2014.

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Subject area	% among the 10% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Acoustics	10.9	1.6	-9.3	no	0.00	0.00	-0.07	0.00
Agricultural Economics & Policy	12.1	0.7	-11.4	no	0.00	0.00	-0.14	0.00
Agricultural Engineering	11.4	0.0	-11.4	no	0.00	0.00	-0.12	0.00
Agriculture	11.6	1.3	-10.3	no	0.00	0.00	-0.12	0.00
Agriculture, Dairy & Animal Science	12.5	5.0	-7.4	no	0.00	0.00	-0.08	0.00
Agriculture, Multidisciplinary	13.0	1.4	-11.6	no	0.00	0.00	-0.16	0.00
Agronomy	11.6	0.9	-10.7	no	0.00	0.00	-0.13	0.00
Allergy	11.6	1.8	-9.8	no	0.00	0.00	-0.09	0.00
Anatomy & Morphology	10.7	8.7	-1.9	no	0.26	0.27	-0.02	0.26
Andrology	8.2	18.4	10.2	no	0.00	0.00	0.14	0.00
Anesthesiology	11.2	3.8	-7.4	no	0.00	0.00	-0.07	0.00
Anthropology	11.8	0.9	-10.9	no	0.00	0.00	-0.12	0.00
Archaeology	11.0	7.0	-4.0	no	0.18	0.22	-0.03	0.18
Architecture	10.3	8.0	-2.3	no	0.52	0.70	-0.02	0.52
Area Studies	10.2	4.0	-6.2	yes	0.31	0.51	-0.02	0.31
Art	100.0	100.0	0.0	no				
Arts & Humanities – Other Topics	13.3	3.8	-9.5	no	0.00	0.00	-0.07	0.00
Asian Studies	12.2	2.3	-10.0	no	0.04	0.05	-0.06	0.04
Astronomy & Astrophysics	10.1	13.5	3.3	no	0.00	0.00	0.03	0.00
Audiology & Speech-Language Pathology	10.1	10.8	0.7	no	0.83	0.84	0.00	0.83
Automation & Control Systems	10.4	5.6	-4.8	no	0.02	0.02	-0.02	0.02
Behavioral Sciences	10.7	5.5	-5.2	no	0.00	0.00	-0.05	0.00
Biochemical Research Methods	9.7	11.9	2.2	no	0.00	0.00	0.02	0.00
Biochemistry & Molecular Biology	9.9	11.1	1.2	no	0.00	0.00	0.01	0.00
Biodiversity & Conservation	11.1	0.7	-10.5	no	0.00	0.00	-0.10	0.00
Biodiversity Conservation	11.1	0.7	-10.5	no	0.00	0.00	-0.10	0.00
Biology	8.3	15.3	7.0	no	0.00	0.00	0.10	0.00
Biomedical Social Sciences	10.3	6.2	-4.2	no	0.09	0.11	-0.03	0.09
Biophysics	10.1	1.7	-8.4	no	0.00	0.00	-0.03	0.00
Biotechnology & Applied Microbiology	11.3	5.3	-6.0	no	0.00	0.00	-0.09	0.00
Business	10.5	0.6	-9.8	no	0.00	0.00	-0.05	0.00

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Subject area	% among the 10% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Business & Economics	10.3	3.7	-6.6	no	0.00	0.00	-0.03	0.00
Business, Finance	11.4	7.1	-4.3	yes	0.62	1.00	-0.01	0.62
Cardiac & Cardiovascular Systems	11.0	3.6	-7.4	no	0.00	0.00	-0.08	0.00
Cardiovascular System & Cardiology	10.8	3.6	-7.2	no	0.00	0.00	-0.07	0.00
Cell & Tissue Engineering	11.6	3.7	-7.9	no	0.00	0.00	-0.09	0.00
Cell Biology	10.8	5.5	-5.4	no	0.00	0.00	-0.06	0.00
Chemistry	10.6	3.2	-7.4	no	0.00	0.00	-0.05	0.00
Chemistry, Analytical	10.4	8.8	-1.6	no	0.05	0.06	-0.01	0.05
Chemistry, Applied	10.6	0.0	-10.6	no	0.00	0.00	-0.05	0.00
Chemistry, Inorganic & Nuclear	11.0	1.0	-10.1	no	0.00	0.00	-0.03	0.00
Chemistry, Medicinal	10.5	8.1	-2.5	no	0.02	0.02	-0.02	0.02
Chemistry, Multidisciplinary	10.7	1.3	-9.3	no	0.00	0.00	-0.07	0.00
Chemistry, Organic	10.5	5.4	-5.1	no	0.00	0.00	-0.05	0.00
Chemistry, Physical	10.6	0.0	-10.6	no	0.00	0.00	-0.03	0.00
Classics	11.0	16.7	5.7	no	0.22	0.24	0.04	0.22
Clinical Neurology	10.3	4.7	-5.6	no	0.00	0.00	-0.04	0.00
Communication	10.2	8.4	-1.8	no	0.45	0.51	-0.01	0.45
Computer Science	10.3	3.5	-6.8	no	0.00	0.00	-0.04	0.00
Computer Science, Artificial Intelligence	10.5	4.2	-6.3	no	0.00	0.00	-0.04	0.00
Computer Science, Cybernetics	11.3	0.0	-11.3	no	0.00	0.00	-0.09	0.00
Computer Science, Information Systems	10.8	1.7	-9.2	no	0.00	0.00	-0.07	0.00
Computer Science, Interdisciplinary Applications	9.9	11.6	1.7	no	0.43	0.41	0.01	0.43
Computer Science, Software Engineering	10.5	4.9	-5.6	no	0.03	0.03	-0.02	0.03
Computer Science, Theory & Methods	10.1	1.2	-8.9	no	0.01	0.00	-0.03	0.01
Construction & Building Technology	10.5	1.3	-9.2	no	0.00	0.00	-0.04	0.00
Critical Care Medicine	10.3	9.1	-1.1	no	0.44	0.47	-0.01	0.44
Crystallography	10.8	17.4	6.6	no	0.04	0.06	0.02	0.04
Demography	11.6	2.9	-8.7	no	0.00	0.00	-0.11	0.00
Dentistry, Oral Surgery & Medicine	10.0	4.6	-5.4	no	0.00	0.00	-0.05	0.00
Dermatology	10.5	3.4	-7.2	no	0.00	0.00	-0.06	0.00
Developmental Biology	10.2	3.4	-6.8	no	0.02	0.01	-0.04	0.02

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Subject area	% among the 10% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Ecology	10.7	6.0	-4.7	no	0.00	0.00	-0.04	0.00
Economics	10.5	2.1	-8.3	no	0.00	0.00	-0.05	0.00
Education & Educational Research	10.4	12.0	1.5	no	0.10	0.10	0.01	0.10
Education, Scientific Disciplines	9.5	12.8	3.3	no	0.01	0.02	0.04	0.01
Electrochemistry	11.3	5.0	-6.4	no	0.00	0.00	-0.07	0.00
Emergency Medicine	10.4	3.0	-7.4	no	0.00	0.00	-0.07	0.00
Endocrinology & Metabolism	10.6	4.4	-6.1	no	0.00	0.00	-0.06	0.00
Energy & Fuels	10.6	1.5	-9.0	no	0.00	0.00	-0.06	0.00
Engineering	10.7	2.8	-7.9	no	0.00	0.00	-0.06	0.00
Engineering, Aerospace	12.7	8.7	-4.0	yes	0.57	0.76	-0.01	0.57
Engineering, Biomedical	10.7	8.6	-2.0	no	0.01	0.01	-0.02	0.01
Engineering, Chemical	10.3	1.3	-9.0	no	0.00	0.00	-0.04	0.00
Engineering, Civil	10.4	2.8	-7.6	no	0.00	0.00	-0.03	0.00
Engineering, Electrical & Electronic	10.9	4.5	-6.4	no	0.00	0.00	-0.05	0.00
Engineering, Environmental	10.3	0.0	-10.3	no	0.00	0.00	-0.04	0.00
Engineering, Industrial	10.3	0.0	-10.3	no	0.02	0.01	-0.03	0.02
Engineering, Manufacturing	10.1	58.6	48.5	yes	0.00	0.00	0.11	0.00
Engineering, Marine	12.9	2.7	-10.2	no	0.00	0.00	-0.11	0.00
Engineering, Mechanical	10.7	1.2	-9.5	no	0.00	0.00	-0.07	0.00
Engineering, Multidisciplinary	12.8	1.7	-11.1	no	0.00	0.00	-0.15	0.00
Engineering, Petroleum	11.6	10.2	-1.4	no	0.63	0.77	-0.01	0.63
Entomology	11.3	1.6	-9.6	no	0.00	0.00	-0.11	0.00
Environmental Sciences	10.4	7.0	-3.4	no	0.00	0.00	-0.03	0.00
Environmental Sciences & Ecology	10.3	6.9	-3.5	no	0.00	0.00	-0.03	0.00
Environmental Studies	10.7	3.6	-7.2	no	0.00	0.00	-0.07	0.00
Ethics	9.6	13.8	4.2	no	0.03	0.04	0.04	0.03
Evolutionary Biology	11.0	5.7	-5.3	no	0.00	0.00	-0.07	0.00
Family Studies	10.0	37.5	27.5	yes	0.01	0.04	0.05	0.01
Film, Radio & Television	100.0	100.0	0.0	no				
Film, Radio, Television	100.0	100.0	0.0	no				
Fisheries	11.4	5.2	-6.2	no	0.00	0.00	-0.06	0.00

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	% among the 10% most cited			p-value			Effect size	
Subject area	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	p-value
Folklore	100.0	100.0	0.0	no				
Food Science & Technology	10.4	0.5	-9.9	no	0.00	0.00	-0.05	0.00
Forestry	12.2	5.4	-6.8	no	0.00	0.00	-0.09	0.00
Gastroenterology & Hepatology	11.4	5.2	-6.2	no	0.00	0.00	-0.08	0.00
General & Internal Medicine	13.4	3.9	-9.4	no	0.00	0.00	-0.15	0.00
Genetics & Heredity	10.6	7.8	-2.8	no	0.00	0.00	-0.04	0.00
Geochemistry & Geophysics	10.3	4.2	-6.2	no	0.00	0.00	-0.04	0.00
Geography	10.9	1.2	-9.7	no	0.00	0.00	-0.07	0.00
Geography, Physical	10.6	14.6	4.1	no	0.02	0.02	0.03	0.02
Geology	10.0	11.7	1.7	no	0.01	0.01	0.02	0.01
Geosciences, Multidisciplinary	9.9	12.6	2.8	no	0.00	0.00	0.03	0.00
Geriatrics & Gerontology	9.8	12.6	2.7	no	0.01	0.01	0.03	0.01
Gerontology	10.1	9.9	-0.2	no	0.93	1.00	0.00	0.93
Government & Law	10.4	10.1	-0.3	no	0.88	0.99	0.00	0.88
Health Care Sciences & Services	10.0	10.3	0.4	no	0.65	0.64	0.00	0.65
Health Policy & Services	10.2	9.3	-0.9	no	0.48	0.50	-0.01	0.48
Hematology	10.3	8.0	-2.3	no	0.09	0.10	-0.02	0.09
History	15.7	8.8	-6.9	no	0.00	0.00	-0.05	0.00
History & Philosophy Of Science	11.2	0.6	-10.6	no	0.00	0.00	-0.09	0.00
Horticulture	11.0	0.6	-10.4	no	0.00	0.00	-0.10	0.00
Humanities, Multidisciplinary	12.8	4.4	-8.4	no	0.00	0.00	-0.05	0.00
Imaging Science & Photographic Technology	10.3	4.2	-6.1	no	0.09	0.11	-0.03	0.09
Immunology	10.8	8.4	-2.4	no	0.00	0.00	-0.02	0.00
Industrial Relations & Labor	9.7	19.8	10.0	no	0.00	0.01	0.09	0.00
Infectious Diseases	10.3	9.2	-1.1	no	0.05	0.05	-0.02	0.05
Information Science & Library Science	10.6	1.5	-9.0	no	0.00	0.00	-0.07	0.00
Instruments & Instrumentation	11.4	9.4	-2.1	no	0.02	0.02	-0.02	0.02
Integrative & Complementary Medicine	10.4	11.0	0.7	no	0.54	0.53	0.01	0.54
International Relations	10.3	0.0	-10.3	no	0.01	0.01	-0.04	0.01
Language & Linguistics	11.2	3.5	-7.7	no	0.00	0.00	-0.06	0.00
Law	10.9	19.8	8.9	no	0.00	0.00	0.06	0.00

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Subject area	% among the 10% most cited			*p*-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Life Sciences & Biomedicine – Other Topics	8.3	15.3	7.0	no	0.00	0.00	0.10	0.00
Limnology	10.5	6.8	-3.7	no	0.30	0.43	-0.02	0.30
Linguistics	10.9	6.6	-4.3	no	0.02	0.02	-0.03	0.02
Literary Theory & Criticism	12.5	2.4	-10.1	no	0.00	0.00	-0.13	0.00
Literature	100.0	100.0	0.0	no				
Literature, Romance	100.0	100.0	0.0	no				
Literature, Slavic	100.0	100.0	0.0	no				
Logic	10.7	4.1	-6.6	no	0.04	0.05	-0.07	0.04
Management	10.3	0.0	-10.3	no	0.00	0.00	-0.04	0.00
Marine & Freshwater Biology	10.6	4.3	-6.3	no	0.00	0.00	-0.05	0.00
Materials Science	10.9	2.8	-8.0	no	0.00	0.00	-0.06	0.00
Materials Science, Biomaterials	10.6	4.6	-6.0	no	0.04	0.04	-0.02	0.04
Materials Science, Ceramics	11.2	0.6	-10.6	no	0.00	0.00	-0.08	0.00
Materials Science, Multidisciplinary	10.8	2.8	-8.0	no	0.00	0.00	-0.06	0.00
Materials Science, Paper & Wood	13.2	5.2	-8.0	no	0.00	0.00	-0.12	0.00
Materials Science, Textiles	11.6	1.5	-10.1	no	0.00	0.00	-0.10	0.00
Mathematical & Computational Biology	10.7	9.0	-1.7	no	0.04	0.04	-0.03	0.04
Mathematical Methods In Social Sciences	10.3	0.0	-10.3	yes	0.08	0.10	-0.04	0.08
Mathematics	12.2	3.6	-8.6	no	0.00	0.00	-0.10	0.00
Mathematics, Applied	11.5	4.0	-7.4	no	0.00	0.00	-0.10	0.00
Mathematics, Interdisciplinary Applications	13.0	0.9	-12.1	no	0.00	0.00	-0.17	0.00
Mechanics	10.7	2.5	-8.2	no	0.00	0.00	-0.04	0.00
Medical Ethics	10.4	10.4	0.1	no	0.98	1.00	0.00	0.98
Medical Informatics	9.0	11.2	2.1	no	0.20	0.20	0.02	0.20
Medical Laboratory Technology	10.5	4.9	-5.6	no	0.03	0.02	-0.04	0.03
Medicine, General & Internal	13.7	4.1	-9.6	no	0.00	0.00	-0.15	0.00
Medicine, Research & Experimental	12.0	5.9	-6.1	no	0.00	0.00	-0.10	0.00
Medieval & Renaissance Studies	16.0	6.0	-10.0	no	0.06	0.07	-0.07	0.06
Metallurgy & Metallurgical Engineering	10.9	5.5	-5.4	no	0.00	0.00	-0.03	0.00
Meteorology & Atmospheric Sciences	9.8	14.8	5.0	no	0.00	0.00	0.07	0.00
Microbiology	9.7	11.8	2.1	no	0.00	0.00	0.03	0.00

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Subject area	% among the 10% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Mineralogy	11.2	11.4	0.2	no	0.96	1.00	0.00	0.96
Mining & Mineral Processing	10.8	13.5	2.7	no	0.46	0.45	0.01	0.46
Multidisciplinary Sciences	28.0	4.1	-24.0	no	0.00	0.00	-0.35	0.00
Music	100.0	100.0	0.0	no				
Mycology	10.3	12.1	1.8	no	0.59	0.60	0.01	0.59
Nanoscience & Nanotechnology	11.2	1.8	-9.4	no	0.00	0.00	-0.09	0.00
Neuroimaging	10.9	7.0	-3.9	no	0.09	0.11	-0.03	0.09
Neurosciences	10.5	7.1	-3.4	no	0.00	0.00	-0.04	0.00
Neurosciences & Neurology	10.4	6.8	-3.6	no	0.00	0.00	-0.04	0.00
Nuclear Science & Technology	10.8	4.5	-6.2	no	0.02	0.02	-0.02	0.02
Nursing	10.7	1.1	-9.7	no	0.00	0.00	-0.07	0.00
Nutrition & Dietetics	10.7	4.6	-6.1	no	0.00	0.00	-0.07	0.00
Obstetrics & Gynecology	10.2	7.7	-2.5	no	0.05	0.06	-0.02	0.05
Oceanography	10.4	7.9	-2.5	no	0.05	0.06	-0.02	0.05
Oncology	10.9	4.8	-6.0	no	0.00	0.00	-0.07	0.00
Operations Research & Management Science	10.2	0.0	-10.2	yes	0.18	0.40	-0.01	0.18
Ophthalmology	13.4	2.6	-10.8	no	0.00	0.00	-0.12	0.00
Optics	9.0	15.1	6.1	no	0.00	0.00	0.08	0.00
Ornithology	13.2	0.0	-13.2	yes	0.12	0.25	-0.05	0.12
Orthopedics	10.3	3.9	-6.4	no	0.00	0.00	-0.07	0.00
Otorhinolaryngology	10.4	6.9	-3.5	no	0.07	0.07	-0.02	0.07
Paleontology	10.4	6.4	-4.0	no	0.05	0.05	-0.04	0.05
Parasitology	8.5	11.4	2.8	no	0.00	0.00	0.05	0.00
Pathology	11.2	5.1	-6.0	no	0.00	0.00	-0.08	0.00
Pediatrics	10.3	7.0	-3.3	no	0.00	0.00	-0.02	0.00
Peripheral Vascular Disease	10.6	0.4	-10.2	no	0.00	0.00	-0.05	0.00
Pharmacology & Pharmacy	10.4	5.3	-5.2	no	0.00	0.00	-0.05	0.00
Philosophy	10.7	0.3	-10.4	no	0.00	0.00	-0.07	0.00
Physical Geography	10.6	14.6	4.1	no	0.02	0.02	0.03	0.02
Physics	11.1	7.8	-3.2	no	0.00	0.00	-0.03	0.00
Physics, Applied	11.4	6.2	-5.1	no	0.00	0.00	-0.04	0.00

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Subject area	% among the 10% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Physics, Atomic, Molecular & Chemical	11.4	0.9	-10.4	no	0.00	0.00	-0.04	0.00
Physics, Condensed Matter	11.2	0.0	-11.2	no	0.00	0.00	-0.05	0.00
Physics, Mathematical	10.4	1.3	-9.1	no	0.00	0.00	-0.04	0.00
Physics, Multidisciplinary	11.1	11.4	0.3	no	0.61	0.62	0.00	0.61
Physics, Nuclear	10.3	17.3	7.0	no	0.00	0.00	0.08	0.00
Physics, Particles & Fields	10.4	11.3	0.9	no	0.26	0.27	0.01	0.26
Physiology	9.8	13.5	3.7	no	0.00	0.00	0.04	0.00
Plant Sciences	10.5	6.5	-4.0	no	0.00	0.00	-0.05	0.00
Political Science	10.3	0.0	-10.3	no	0.00	0.00	-0.04	0.00
Polymer Science	10.1	4.4	-5.7	no	0.00	0.00	-0.03	0.00
Primary Health Care	7.9	12.9	5.0	no	0.00	0.00	0.08	0.00
Psychiatry	10.3	6.7	-3.7	no	0.00	0.00	-0.03	0.00
Psychology	10.3	6.0	-4.3	no	0.00	0.00	-0.04	0.00
Psychology, Applied	10.6	0.0	-10.6	no	0.01	0.01	-0.04	0.01
Psychology, Clinical	10.1	3.4	-6.7	no	0.02	0.01	-0.03	0.02
Psychology, Educational	10.2	5.6	-4.6	yes	0.52	1.00	-0.01	0.52
Psychology, Experimental	10.4	0.0	-10.4	no	0.00	0.00	-0.04	0.00
Psychology, Multidisciplinary	11.4	5.8	-5.7	no	0.00	0.00	-0.08	0.00
Public Administration	10.1	0.0	-10.1	no	0.01	0.00	-0.04	0.01
Public, Environmental & Occupational Health	11.1	9.5	-1.5	no	0.00	0.00	-0.02	0.00
Radiology, Nuclear Medicine & Medical Imaging	10.4	5.7	-4.7	no	0.00	0.00	-0.04	0.00
Rehabilitation	9.9	10.8	0.9	no	0.41	0.42	0.01	0.41
Religion	12.0	7.1	-4.9	no	0.01	0.00	-0.05	0.01
Remote Sensing	10.6	8.2	-2.4	no	0.04	0.05	-0.03	0.04
Reproductive Biology	10.4	7.0	-3.5	no	0.04	0.04	-0.03	0.04
Research & Experimental Medicine	12.0	5.9	-6.1	no	0.00	0.00	-0.10	0.00
Respiratory System	10.3	5.9	-4.4	no	0.00	0.00	-0.03	0.00
Rheumatology	11.3	5.4	-5.9	no	0.00	0.00	-0.08	0.00
Robotics	11.6	0.9	-10.7	no	0.00	0.00	-0.12	0.00
Science & Technology – Other Topics	17.5	2.2	-15.4	no	0.00	0.00	-0.25	0.00
Social Issues	10.7	0.8	-9.9	no	0.00	0.00	-0.09	0.00

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Subject area	% among the 10% most cited			p-value			Effect size	
	Non-OA	OA	Diff.	Expected value < 5	χ^2	Fisher's exact	ϕ	*p*-value
Social Sciences – Other Topics	10.5	5.5	-4.9	no	0.00	0.00	-0.04	0.00
Social Sciences, Biomedical	10.3	6.2	-4.2	no	0.09	0.11	-0.03	0.09
Social Sciences, Interdisciplinary	10.8	3.6	-7.2	no	0.00	0.00	-0.07	0.00
Social Sciences, Mathematical Methods	10.3	0.0	-10.3	yes	0.08	0.10	-0.04	0.08
Social Work	11.7	2.0	-9.7	no	0.00	0.00	-0.06	0.00
Sociology	10.4	0.9	-9.5	no	0.00	0.00	-0.06	0.00
Soil Science	11.1	0.8	-10.3	no	0.00	0.00	-0.10	0.00
Spectroscopy	11.2	0.0	-11.2	no	0.00	0.00	-0.03	0.00
Sport Sciences	10.5	2.2	-8.3	no	0.00	0.00	-0.06	0.00
Statistics & Probability	10.4	6.5	-3.9	no	0.00	0.00	-0.03	0.00
Substance Abuse	10.3	4.1	-6.2	no	0.02	0.02	-0.04	0.02
Surgery	10.4	2.7	-7.6	no	0.00	0.00	-0.05	0.00
Telecommunications	11.8	1.5	-10.3	no	0.00	0.00	-0.10	0.00
Theater	100.0	100.0	0.0	no				
Thermodynamics	11.1	1.0	-10.0	no	0.00	0.00	-0.09	0.00
Toxicology	9.3	17.9	8.6	no	0.00	0.00	0.08	0.00
Transportation	10.4	0.0	-10.4	yes	0.05	0.04	-0.03	0.05
Tropical Medicine	6.6	13.2	6.6	no	0.00	0.00	0.11	0.00
Urban Studies	10.4	0.0	-10.4	yes	0.04	0.05	-0.04	0.04
Urology & Nephrology	10.7	3.2	-7.5	no	0.00	0.00	-0.07	0.00
Veterinary Sciences	11.0	5.2	-5.8	no	0.00	0.00	-0.08	0.00
Virology	8.2	18.2	10.1	no	0.00	0.00	0.13	0.00
Water Resources	10.1	12.9	2.8	no	0.01	0.01	0.02	0.01
Women's Studies	10.2	0.0	-10.2	yes	0.34	1.00	-0.02	0.34
Zoology	11.7	9.4	-2.3	no	0.01	0.01	-0.02	0.01

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ADDENDUM G: Comparison with Dorta-González *et al.* (2017) in terms of percentage of open access journal articles

The results of this study for the percentage of articles published in 2014, which were OA journal articles were compared with the results obtained by Dorta-González *et al.* (2017). Their study, which made use of the OA journal tag of WoS, investigated only article type documents published in the years 2009 and 2014, and they investigated 249 subject areas. The current study also made use of the WoS OA journal tag present in the microdata, investigated articles and reviews published from 2005 to 2014, and investigated all subject areas present for those years (274).

	% OA journal articles for 2014		
Subject area	**Dorta-González *et al.* (2017)**	**Current study**	**% difference**
Acoustics	5.5	5.6	1.9
Agricultural Economics & Policy	16.6	17.6	5.9
Agricultural Engineering	11.0	10.8	1.4
Agriculture, Dairy & Animal Science	12.9	13.6	5.5
Agriculture, Multidisciplinary	24.4	24.2	0.8
Agronomy	18.0	16.8	6.5
Allergy	10.1	9.5	6.2
Anatomy & Morphology	17.5	17.9	2.5
Andrology	18.6	26.1	40.3
Anesthesiology	8.8	8.3	5.7
Anthropology	13.0	13.0	0.2
Archaeology	4.4	4.0	8.2
Architecture	4.1	4.0	1.5
Area Studies	0.9	1.1	22.4
Art	5.0	2.5	49.6
Asian Studies	3.8	3.6	4.5
Astronomy & Astrophysics	2.0	6.0	202.3
Automation & Control Systems	2.7	2.4	9.8
Behavioral Sciences	8.3	8.2	0.9
Biochemical Research Methods	11.2	10.3	8.3
Biochemistry & Molecular Biology	9.6	10.1	5.4
Biodiversity Conservation	9.8	8.9	9.3
Biology	27.5	26.5	3.8
Biophysics	0.9	0.8	8.0
Biotechnology & Applied Microbiology	23.0	24.5	6.3
Business	1.6	2.6	65.1

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Subject area	% OA journal articles for 2014: Dorta-González *et al.* (2017)	Current study	% difference
Business, Finance	0.3	0.3	7.4
Cardiac & Cardiovascular Systems	13.9	12.5	10.3
Cell & Tissue Engineering	18.7	12.9	31.0
Cell Biology	15.1	14.2	6.2
Chemistry, Analytical	6.3	6.7	5.7
Chemistry, Applied	2.2	2.3	2.9
Chemistry, Inorganic & Nuclear	0.8	0.8	2.9
Chemistry, Medicinal	6.0	6.1	1.2
Chemistry, Multidisciplinary	5.3	5.8	8.8
Chemistry, Organic	8.4	9.0	7.0
Chemistry, Physical	0.6	0.6	4.0
Classics	6.1	5.2	14.7
Clinical Neurology	5.4	5.8	7.3
Communication	5.7	5.3	7.4
Computer Science, Artificial Intelligence	4.4	4.1	5.9
Computer Science, Cybernetics	5.9	5.7	2.6
Computer Science, Information Systems	6.6	6.1	6.8
Computer Science, Interdisciplinary Applications	1.5	1.4	8.0
Computer Science, Software Engineering	1.8	1.7	7.5
Computer Science, Theory & Methods	1.1	0.9	19.6
Construction & Building Technology	2.2	2.2	1.3
Critical Care Medicine	1.8	9.8	444.7
Crystallography	1.2	1.4	13.8
Demography	17.7	17.6	0.8
Dentistry, Oral Surgery & Medicine	6.7	6.9	2.3
Dermatology	8.0	5.9	26.6
Developmental Biology	3.2	2.8	11.4
Ecology	9.4	9.0	3.9
Economics	2.9	2.9	1.5
Education & Educational Research	9.1	8.0	12.0
Education, Scientific Disciplines	16.9	16.5	2.5
Electrochemistry	12.3	12.9	5.0
Emergency Medicine	9.1	8.0	12.6
Endocrinology & Metabolism	8.5	8.3	2.1
Energy & Fuels	3.7	3.7	0.8
Engineering, Aerospace	0.7	0.7	1.7
Engineering, Biomedical	3.6	12.3	240.3
Engineering, Chemical	2.1	2.3	9.2
Engineering, Civil	2.2	1.8	19.2
Engineering, Electrical & Electronic	3.9	6.0	54.3
Engineering, Environmental	1.3	1.2	8.4
Engineering, Industrial	1.0	1.0	0.3
Engineering, Manufacturing	0.5	0.5	3.2
Engineering, Marine	13.4	13.3	1.1
Engineering, Mechanical	5.3	5.3	0.7
Engineering, Multidisciplinary	23.3	23.2	0.5
Engineering, Petroleum	5.5	6.1	10.3
Entomology	13.3	12.9	2.7

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Subject area	% OA journal articles for 2014		% difference
	Dorta-González *et al.* (2017)	Current study	
Environmental Sciences	6.7	6.8	1.3
Environmental Studies	11.1	10.6	4.3
Ethics	7.5	11.6	55.3
Evolutionary Biology	12.6	17.7	40.6
Family Studies	0.4	0.3	15.1
Film, Radio, Television	13.9	9.7	30.3
Fisheries	8.9	8.9	0.0
Folklore	21.1	18.3	13.5
Food Science & Technology	2.5	2.8	11.3
Forestry	19.0	18.7	1.8
Gastroenterology & Hepatology	21.0	20.5	2.3
Genetics & Heredity	22.2	20.8	6.2
Geochemistry & Geophysics	4.1	4.0	3.6
Geography	5.7	5.8	1.9
Geography, Physical	5.2	6.4	22.2
Geology	16.9	11.9	29.6
Geosciences, Multidisciplinary	11.7	11.8	0.8
Geriatrics & Gerontology	17.0	15.8	7.0
Gerontology	7.7	7.7	0.5
Health Care Sciences & Services	18.2	16.5	9.4
Health Policy & Services	12.3	11.7	4.7
Hematology	4.7	4.8	2.7
History	7.2	7.8	8.5
History of Social Sciences	7.3	0.0	N/A
Horticulture	9.0	8.9	1.1
Humanities, Multidisciplinary	5.4	4.6	14.1
Imaging Science & Photographic Technology	1.7	1.6	4.4
Immunology	9.6	10.8	12.6
Industrial Relations & Labor	8.6	8.3	3.4
Infectious Diseases	27.4	26.5	3.2
Information Science & Library Science	6.8	6.2	8.6
Instruments & Instrumentation	9.4	9.6	2.5
Integrative & Complementary Medicine	33.7	31.8	5.6
International Relations	1.5	1.6	6.9
Language & Linguistics	6.2	5.9	4.6
Law	2.0	4.0	100.5
Limnology	3.7	3.8	1.4
Linguistics	5.3	4.6	12.4
Literature	3.4	4.1	19.7
Literature, Romance	7.2	7.1	1.3
Management	1.7	1.7	1.0
Marine & Freshwater Biology	6.0	6.0	0.3
Materials Science, Biomaterials	1.8	1.4	22.4
Materials Science, Ceramics	6.1	6.2	1.2
Materials Science, Multidisciplinary	6.0	6.0	0.8
Materials Science, Paper & Wood	31.6	31.3	1.0
Materials Science, Textiles	11.3	11.1	1.4
Mathematical & Computational Biology	32.8	31.7	3.4

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Subject area	% OA journal articles for 2014		% difference
	Dorta-González *et al.* (2017)	Current study	
Mathematics	12.2	14.6	19.5
Mathematics, Applied	13.8	18.5	34.3
Mathematics, Interdisciplinary Applications	24.5	24.2	1.2
Mechanics	2.7	2.6	3.7
Medical Ethics	16.6	25.7	54.6
Medical Informatics	10.9	10.1	7.1
Medical Laboratory Technology	4.6	4.3	6.6
Medicine, General & Internal	41.5	37.4	9.9
Medicine, Research & Experimental	33.2	33.5	0.9
Medieval & Renaissance Studies	7.4	6.1	17.5
Metallurgy & Metallurgical Engineering	3.2	2.6	19.0
Meteorology & Atmospheric Sciences	21.9	21.8	0.6
Microbiology	14.4	15.0	4.3
Mineralogy	2.1	2.9	37.1
Mining & Mineral Processing	6.0	2.7	55.2
Multidisciplinary Sciences	73.8	72.7	1.5
Music	0.4	0.3	35.6
Mycology	0.7	4.6	557.2
Nanoscience & Nanotechnology	9.6	9.3	2.7
Neuroimaging	6.5	6.6	0.8
Neurosciences	12.9	13.3	3.3
Nuclear Science & Technology	1.4	1.4	1.8
Nursing	5.2	5.0	3.3
Nutrition & Dietetics	12.9	12.4	3.5
Obstetrics & Gynecology	5.3	4.9	7.3
Oceanography	9.2	8.8	3.8
Oncology	13.8	13.3	3.3
Operations Research & Management Science	0.2	0.2	6.4
Ophthalmology	15.5	14.9	3.9
Optics	17.9	20.3	13.5
Ornithology	1.5	1.5	2.1
Orthopedics	11.0	10.8	1.9
Otorhinolaryngology	4.6	4.7	2.9
Paleontology	9.2	8.6	6.9
Parasitology	52.2	52.0	0.4
Pathology	22.1	19.4	12.2
Pediatrics	5.8	5.5	4.4
Peripheral Vascular Disease	2.6	2.6	1.3
Pharmacology & Pharmacy	8.5	8.0	5.9
Philosophy	5.3	4.9	7.5
Physics, Applied	4.4	6.6	49.4
Physics, Atomic, Molecular & Chemical	1.8	1.9	3.6
Physics, Condensed Matter	2.0	1.7	14.4
Physics, Mathematical	2.2	2.2	1.5
Physics, Multidisciplinary	17.5	16.8	4.1
Physics, Nuclear	4.2	13.1	212.9
Physics, Particles & Fields	6.2	13.7	120.7
Physiology	12.9	14.6	13.3

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Subject area	% OA journal articles for 2014		% difference
	Dorta-González *et al.* (2017)	Current study	
Plant Sciences	13.3	13.9	4.2
Political Science	1.6	1.7	5.5
Polymer Science	2.5	2.5	0.2
Primary Health Care	44.9	43.3	3.5
Psychiatry	8.1	7.9	3.1
Psychology	13.3	7.9	40.9
Psychology, Applied	1.5	1.5	0.9
Psychology, Clinical	1.6	1.6	0.1
Psychology, Educational	0.9	0.9	5.5
Psychology, Experimental	1.5	1.4	5.3
Psychology, Multidisciplinary	20.2	21.0	3.8
Public Administration	3.6	1.3	64.9
Public, Environmental & Occupational Health	20.7	23.3	12.7
Radiology, Nuclear Medicine & Medical Imaging	7.4	7.8	4.8
Rehabilitation	11.8	11.6	1.5
Religion	10.4	10.4	0.3
Remote Sensing	14.5	16.1	10.7
Reproductive Biology	7.8	7.9	1.1
Respiratory System	5.8	5.9	1.3
Rheumatology	14.0	18.3	30.5
Robotics	14.1	14.0	0.4
Social Issues	5.6	7.2	28.9
Social Sciences, Biomedical	4.8	5.2	8.3
Social Sciences, Interdisciplinary	11.0	10.0	8.8
Social Sciences, Mathematical Methods	0.7	1.1	60.2
Social Work	4.6	4.6	1.1
Sociology	4.2	4.1	1.3
Soil Science	8.5	8.8	3.7
Spectroscopy	0.8	0.8	1.7
Sport Sciences	6.0	5.7	5.3
Statistics & Probability	5.6	5.9	6.2
Substance Abuse	3.1	3.4	9.1
Surgery	4.4	4.4	0.1
Telecommunications	10.2	9.8	3.9
Theater	1.5	1.0	31.1
Thermodynamics	8.7	7.4	15.0
Toxicology	7.5	8.3	10.3
Transportation	1.0	0.6	37.7
Tropical Medicine	52.8	52.9	0.2
Urban Studies	1.7	1.5	12.5
Urology & Nephrology	8.5	8.5	0.3
Veterinary Sciences	21.6	21.5	0.3
Virology	19.2	19.7	2.5
Water Resources	7.7	7.2	6.2
Zoology	13.8	12.9	6.5

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ADDENDUM H:
Subject areas with citation advantage for non-open access journal articles

H.1. Articles published during the entire time frame

While this study investigated the OA journal citation advantage, the process of examining this through tests of statistically significant (independent samples t-test and chi-square test of independence) and measures of effect size (ϕ and r_{pb}), as detailed in Chapter 4 section 4.2.3, also answered the question whether a subject area experienced a non-OA journal citation advantage for the measure in question. In Chapter 6, these subject areas are briefly referred to as well as in the conclusion section of this study (see section 7.3).

The table below presents the subject areas in which the difference of between the measures for OA and non-OA journal articles favoured non-OA journal articles, in which the differences were statistically significant, and in which the association had an effect size of ≥ 0.1 for at least one of the measures of citation advantage for all publications published from 2005 to 2014 and indexed in WoS.

Subject area	MNCS	Cited	1%	5%	10%	Number of measures with non-OA citation advantage
Multidisciplinary Sciences	Yes		Yes	Yes	Yes	4
Agriculture, Multidisciplinary	Yes	Yes		Yes	Yes	4
Medicine, General & Internal	Yes			Yes	Yes	3
Agriculture	Yes	Yes			Yes	3
Agriculture, Dairy & Animal Science	Yes	Yes			Yes	3
Agronomy	Yes	Yes			Yes	3
Horticulture	Yes	Yes			Yes	3
Robotics	Yes	Yes			Yes	3
Veterinary Sciences	Yes	Yes			Yes	3
Crystallography		Yes			Yes	2
General & Internal Medicine				Yes	Yes	2
Science & Technology – Other Topics	Yes			Yes		2
Materials Science, Ceramics	Yes	Yes				2
Plant Sciences	Yes	Yes				2
Nursing	Yes	Yes				2
Agricultural Economics & Policy	Yes	Yes				2
Agricultural Engineering	Yes	Yes				2
Anatomy & Morphology	Yes	Yes				2

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Anthropology	Yes	Yes				2
Biodiversity & Conservation	Yes	Yes				2
Biodiversity Conservation	Yes	Yes				2
Business	Yes	Yes				2
Forestry	Yes	Yes				2
Geography	Yes	Yes				2
History & Philosophy of Science	Yes	Yes				2
Management	Yes	Yes				2
Mining & Mineral Processing	Yes	Yes				2
Social Issues	Yes	Yes				2
Soil Science	Yes	Yes				2
Science & Technology – Other Topics					Yes	1
Film, Radio & Television				Yes		1
Film, Radio, Television				Yes		1
Allergy	Yes					1
Medical Laboratory Technology		Yes				1
Engineering, Multidisciplinary		Yes				1
Emergency Medicine		Yes				1
Mathematics, Interdisciplinary Applications		Yes				1
Social Sciences, Interdisciplinary		Yes				1
Archaeology		Yes				1
Pharmacology & Pharmacy		Yes				1
Mathematics, Applied		Yes				1
Philosophy		Yes				1
Thermodynamics		Yes				1
Business & Economics		Yes				1
Gerontology		Yes				1
Demography		Yes				1
Logic		Yes				1
Entomology		Yes				1
Marine & Freshwater Biology		Yes				1
Food Science & Technology		Yes				1
Chemistry, Multidisciplinary		Yes				1
Medical Ethics		Yes				1
Physics, Condensed Matter		Yes				1
Computer Science, Cybernetics		Yes				1
Psychiatry		Yes				1
Geochemistry & Geophysics		Yes				1
Social Sciences – Other Topics		Yes				1
Dermatology		Yes				1
Sport Sciences		Yes				1
Biomedical Social Sciences		Yes				1
Social Sciences, Biomedical		Yes				1
Information Science & Library Science		Yes				1
Sociology		Yes				1
Oceanography		Yes				1
Public Administration		Yes				1
Number of subject areas	**28**	**57**	**1**	**7**	**12**	

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H.2. Articles published in 2014

Similar to Addendum H.1, the table below presents the results when only those articles published in 2014 are investigated. This analysis was conducted to examine the potential confounding effect of the variable 'year of publication' on the relationship between access status and the measures of citation advantage. There are six subject areas in which the association showed a moderate effect size ($0.3 \leq \phi < 0.5$), as indicated in the table below.

Subject area	MNCS	Cited	1%	5%	10%	Number of measures with non-OA citation advantage
Multidisciplinary Sciences	Yes		Yes	Yes	Yes*	4
Agricultural Economics & Policy	Yes	Yes*		Yes	Yes	4
Engineering, Multidisciplinary	Yes	Yes*		Yes	Yes	4
Mathematics, Interdisciplinary Applications	Yes	Yes*		Yes	Yes	4
Agriculture, Multidisciplinary	Yes	Yes		Yes	Yes	4
Medicine, General & Internal	Yes			Yes	Yes	3
Science & Technology – Other Topics	Yes			Yes	Yes	3
Agricultural Engineering	Yes	Yes*			Yes	3
Anthropology	Yes	Yes*			Yes	3
Agronomy	Yes	Yes			Yes	3
Agriculture	Yes	Yes			Yes	3
Robotics	Yes	Yes			Yes	3
Literary Theory & Criticism	Yes	Yes			Yes	3
Folklore	Yes	Yes		Yes		3
Entomology	Yes	Yes			Yes	3
Engineering, Marine	Yes	Yes			Yes	3
Ophthalmology	Yes	Yes			Yes	3
Demography	Yes	Yes			Yes	3
Materials Science, Textiles		Yes			Yes	2
General & Internal Medicine				Yes	Yes	2
Geography	Yes	Yes				2
Thermodynamics	Yes	Yes				2
Social Issues	Yes	Yes				2
Computer Science, Cybernetics	Yes	Yes				2
Soil Science	Yes	Yes				2
Materials Science, Ceramics	Yes	Yes				2
Horticulture	Yes	Yes				2
Mathematics, Applied	Yes	Yes				2
Veterinary Sciences	Yes	Yes				2
Forestry	Yes	Yes				2
Biodiversity & Conservation	Yes	Yes				2
Biodiversity Conservation	Yes	Yes				2
Acoustics	Yes	Yes				2
Agriculture, Dairy & Animal Science	Yes	Yes				2
Materials Science, Paper & Wood					Yes	1
Social Sciences, Interdisciplinary		Yes				1

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Subject area	MNCS	Cited	1%	5%	10%	Number of measures with non-OA citation advantage
Business		Yes				1
Electrochemistry		Yes				1
Geochemistry & Geophysics		Yes				1
Allergy	Yes					1
Nutrition & Dietetics	Yes					1
Integrative & Complementary Medicine		Yes				1
Social Sciences – Other Topics		Yes				1
Nursing		Yes				1
Dermatology		Yes				1
Sociology		Yes				1
Marine & Freshwater Biology		Yes				1
Chemistry, Applied		Yes				1
Computer Science, Theory & Methods		Yes				1
Physics, Atomic, Molecular & Chemical		Yes				1
Public Administration		Yes				1
Engineering, Industrial		Yes				1
Computer Science, Information Systems		Yes				1
Logic		Yes				1
Biomedical Social Sciences		Yes				1
Social Sciences, Biomedical		Yes				1
Archaeology		Yes				1
Physics, Condensed Matter		Yes				1
Anatomy & Morphology		Yes				1
Information Science & Library Science		Yes				1
History & Philosophy of Science		Yes				1
Philosophy		Yes				1
Engineering		Yes				1
Engineering, Mechanical		Yes				1
Mathematics		Yes				1
Management		Yes				1
Emergency Medicine		Yes				1
Medical Laboratory Technology		Yes				1
Telecommunications		Yes				1
Number of subject areas	**34**	**62**	**1**	**9**	**20**	

*Moderate effect size ($0.3 \leq \phi < 0.5$).