

WEB INDICATORS FOR RESEARCH EVALUATION. PART 1: CITATIONS AND LINKS TO ACADEMIC ARTICLES FROM THE WEB

Indicadores web para evaluación de la investigación. Parte 1: Citas y enlaces a artículos académicos desde la Web

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Abstract

The extensive use of the web by many sectors of society has created the potential for new wider impact indicators. This article reviews research about *Google Scholar* and *Google Patents*, both of which can be used as sources of impact indicators for academic articles. It also briefly reviews methods to extract types of links and citations from the web as a whole, although the indicators that these generate are now probably too broad and too dominated by automatically generated websites, such as library and publisher catalogues, to be useful in practice. More valuable web-based indicators can be derived from specific types of web pages that cite academic research, such as online presentations, course syllabi, and science blogs. These provide evidence that is easier to understand and use and less likely to be affected by unwanted types of automatically generated content, although they are susceptible to gaming.

Keywords

Webometrics; Altmetrics; Alternative metrics; Alternative indicators; Citation analysis; Web indicators; Scientometrics; *Google Scholar*.

Resumen

El gran uso de la web por parte de muchos sectores de la sociedad ha creado el potencial para nuevos indicadores de impacto más amplios. Este artículo revisa la investigación sobre *Google Scholar* y *Google Patents*, servicios que pueden ser utilizados como fuente de indicadores de impacto de artículos académicos. También se examinan brevemente los métodos para extraer tipos de enlaces y citas de la Web en su conjunto, aunque para que sean útiles en la práctica los indicadores que éstos generan ahora son probablemente demasiado amplios y demasiado dominados por sitios web generados automáticamente, como catálogos de biblioteca y de editoriales. Indicadores basados en la web más valiosos se pueden derivar

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de determinados tipos de páginas web que citan investigaciones académicas, tales como presentaciones online, programas de cursos y blogs científicos. Éstos proporcionan evidencia más fácil de entender y de usar, y son menos propensos a ser afectados por los tipos indeseados de contenido generados de forma automática, aunque son susceptibles de ser falseados.

Palabras clave

Webmetría; Altmétricas; Indicadores alternativos; Métricas alternativas; Análisis de citas; Indicadores Web; Cienciometría; *Google Académico*.

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1. Introduction

The need to evaluate the contributions of researchers, research groups, departments or collections of papers occurs in many situations, including job applications, promotion decisions, research assessment exercises, research funding programme assessments, and grant applications. Although peer judgements are commonly used in such cases, quantitative indicators may sometimes aid the decision making: "to inform, but not to determine, judgements of research quality" (Warner, 2000, p. 453). These quantitative indicators have mainly been based on citations in traditional citation indexes, such as the *Web of Science (WoS)* and *Scopus*. Although controversial and frequently misused, judicious use of quantitative indicators can speed and improve some types of research evaluation (Wouters *et al.* 2015).

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Despite agreement that traditional citation databases are the best sources of data for indicators to help peer review for research evaluation, some aspects of intellectual impact are not well reflected in conventional citation indexes. For example, citation indexes are not comprehensive and are mainly restricted to English language refereed journal articles, with weaker coverage of books and conference papers. Another problem is that publications may be used during the research process or for other academic-related activities, such as teaching, without being formally cited. More generally, citation databases are unlikely to be useful to track the wider impacts of research, such as on business, government and society. Hence, research that has important societal or cultural impacts may be systematically undervalued if assessed with the aid of citation-based indicators. Thus, it is clear that other data sources are needed if quantitative indicators can be used to aid the evaluation of the wider impacts of academic research.

Peer review seems to be more reliable than citation counting for research evaluation and hence is the first choice in most cases, although subjective perceptions of research

quality may cause many different types of bias (Lee; Sugimoto; Zhang; Cronin, 2013) and finding expert reviewers can also be difficult (Weller, 2001). Expert judgments can also be time-consuming and expensive, especially for large research assessment exercises. For instance, in the 2008 UK *Research Assessment Exercise (RAE)* for Biological Sciences each of the subject specialist evaluators (mostly senior professors) assessed about 1,000 papers "within a few months" (Eyre-Walker; Stoletzki, 2013, p. 7) and some Social Sciences and Humanities evaluators had to evaluate about 100 books within the same timeframe (Kousha; Thelwall; Rezaie, 2011). Thus, even for important evaluations that drive major funding decisions, such as this one, there may be too much research to allow in depth reading (Taylor; Walker, 2009; see also: Weller, 2001). Moreover, expert evaluations are expensive and complex to organise: the 2001-2003 Italian national research assessment exercise recruited 6,600 experts (about 22% from overseas) at a cost of about 3.5 million Euros (Franceschet; Costantini, 2011, p. 275). Similarly, the operating expenditure for the 2008 UK *RAE* was about £12 million (p. 45):

<http://www.rae.ac.uk/pubs/2009/manager/manager.pdf>

Hence, any quantitative indicators that could make research evaluations cheaper could be extremely valuable.

More than a decade ago, the development of new ways for scholars to write, communicate and publish (e.g., Kling; McKim, 1999, 2000) led to calls for novel indicators for electronic scholarly communication (Ingwersen, 1998; Cronin, 2001; Borgman; Furner, 2002). These *alternative metrics* include *web citations* in digitised scholarly documents (e.g., eprints, books, science blogs or clinical guidelines) or, more recently, *altmetrics* (Priem; Taraborelli; Groth; Neylon, 2010) derived from social media (e.g., social bookmarks, comments, ratings, tweets). In theory, alternative metrics may be helpful when evaluators, funders or even national research assessment need to know about "social, economic and cultural benefits and impacts beyond academia" (REF, 2011, p. 4) as well as non-standard impacts inside academia.

This is the first of a three part literature review of web indicators helpful for research assessment of academics articles. This part starts with *Google Scholar*. Although primarily a free search engine for academic articles, it includes citation counts for these articles and so functions as a citation index that can be used for research impact indicators. *Google Patents*, in contrast, does not provide citation counts for the academic

articles cited by the patents that it indexes but can nevertheless be used indirectly to identify citations from patents. Web links are the earliest source of web impact indicators used, and this article discusses methods to identify different types of links to academic articles and indicators of overall web impact derived from them. More specific types of impact indicators can also be derived from the web by restricting the focus to a specific type of academic-related website, or even file type, and this paper finished by reviewing the evidence that indicators from links or mentions in online syllabi, science blogs or presentations can be useful.

In most cases, the main evidence for the value of an indicator is a statistically significant and positive correlation with citation counts. Although this is a logical first step to assess any new quantitative indicator it is almost paradoxical in that a perfect correlation would indicate that two indicators were essentially identical, whereas the claim for most new indicators is that they reflect something different from that of citation counts. Nevertheless, a positive correlation between a new indicator and citation counts is empirical evidence that the new indicator reflects something related to academic communication, rather than being purely spam or random, and the strength of the correlation can suggest the extent to which the two are similar (Sud; Thelwall, 2014b). The correlation strength should be evaluated in the context of the range of ages of the articles assessed and the breadth of fields covered in the test because both of these can substantially affect correlation coefficients (Thelwall; Fairclough, 2015). Disciplinary differences in the correlation magnitude are also to be expected because of the substantial differences in the way in which academic fields are organised (e.g., Whitley, 2000).

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2. Limitations of traditional citation databases: A brief overview

The citation-based indicators used for research evaluation are imperfect and have many limitations that should be considered when they are used (see MacRoberts; MacRoberts, 1989, 1996; Moed, 2005a). Currently (July, 2015), Thomson Reuters claims that its citation indexes cover about 12,000 core journals, 160,000 conference proceedings and 50,000 editorially selected books:

http://wokinfo.com/products_tools/multidisciplinary/webofscience

The growth rate of its *Science Citation Index (SCI)*, however, seems to be smaller than that of other comparable databases, suggesting that it may be covering a decreasing proportion of the scientific literature, especially in the Social Sciences (Larsen; Von Ins, 2010).

Using traditional citation databases for research evaluation in the Social Sciences, Arts and Humanities is more problematic than in Science and Medicine. This is because scholars in these areas are more likely to author types of publications, and in languages other than English, that are under-represented in, or absent from, traditional citation indexes (Moed, 2005a; Nederhof, 2006; Huang; Chang, 2008). For example, less than 10% of Australian universities' academic publications 1999–2001 were in Thomson Scientific's citation indexes in some areas (Butler, 2008) and under 30% of the (selective) outputs of some Arts and Humanities fields in the 2001 UK *Research Assessment Exercise (RAE)* were in the *Web of Science (WoS)* (Mahdi; D'Este; Neely, 2008). Just under half (48%) of 4,600 publications by researchers from three UK business schools over the period 2001–2007 in Business and Management were in *WoS*, whereas *Google Scholar* searches found 66% of these publications, including 90% of the journal articles (Mingers; Lipitakis, 2010). Furthermore, no significant correlations have been found in 9 out of 28 subject areas for the 2001 UK *RAE* between *WoS* citations and *RAE* peer review scores in Social Sciences and Humanities fields (e.g., Education, Sociology, History, Politics, International Studies), whereas in most science fields moderate to high correlations have been found (Mahdi; D'Este; Neely, 2008, p. 16). One of the reasons for the low *WoS* coverage of Humanities *RAE* submissions is that about 16.5% of all submissions to the 2008 UK *RAE* were books (monographs, edited books and book chapters), with books being more prevalent in the Social sciences and Humanities (31%) than in Science (1%) (Kousha; Thelwall; Rezaie, 2011). These studies, combined with other evidence (e.g., Hicks, 1999; Archambault; Vignola-Gagné; Côté; Larivière; Gingras, 2006; Nederhof, 2006; Huang; Chang, 2008), suggest that the coverage of *WoS* and *Scopus* for both articles and books could be insufficient for bibliometric analyses of Social Sciences and Humanities research, despite the recent inclusion of some books and monographs in both databases.

It is important to be clear that even in Science and Medicine citation counts are only research impact indicators and do not directly measure the quality of an article. The clearest evidence for this is that duplicate articles published in high impact journals seem to attract twice as many citations as identical versions published in lower impact journals, suggesting that citations may partly reflect the prestige of the publishing journal (Larivière; Gingras, 2010), or that the audience for an article may partly reflect the publication venue. Journal impact factors are particularly controversial and are not recommended for research evaluation purposes because of their many limitations, such as variability over time and the unfairness of comparing between different types of journals and between journals in different fields (Seglen, 1997; Sombatsompop; Markpin, 2005). Citation indicators also cannot be used for recently published papers because they need time to accrue enough citations for a reasonable assessment and in some subject areas, such as the Social Sciences, research takes longer to be cited (Glänzel; Schoepflin, 1995; Glänzel; Schlemmer; Thijs, 2003). Hence, citation indicators should not be used to compare articles in different fields (unless field normalised), published in di-

fferent years (unless time normalised) or of different types. More extensive reviews of citation-based indicators, normalisation issues and applications are available elsewhere (Moed, 2005a; Wouters *et al.*, 2015).

3. Web-based scholarly databases

The Web contains free general scholarly databases, such as *Google Scholar* and *Microsoft Academic Search* (although the latter seemed to have virtually stopped indexing new documents by 2014: Orduña-Malea; Ayllón; Martín-Martín; Delgado-López-Cózar, 2014), as well as institutional and subject repositories (e.g., *ADS*, *AgEcon*, *arXiv*, *CiteSeerX*, *Dryad*, *PhilPapers*, *PubMed*, *RePEc*, *SSRN* – see also <http://www.openoar.org>) some of which report citation or usage data. These inherit many of the strengths and limitations of traditional bibliometric databases, but with important differences.

3.1. Google Scholar

Google Scholar (*GS*) is a free online academic search engine that uses automated software to extract citations from online digital publications and combines it with data provided by some publishers. Many researchers use it to search for academic publications (Nicholas; Clark; Rowlands; Jamali, 2009; Herrera, 2011), as well as to promote their publications or impact by generating *Google Scholar Citation* (*GSC*) profiles (Ortega; Aguillo, 2012). For instance, a survey of 220 Science and Engineering scientists at one American university showed that *GS* was second (64.5%) to *WoS* (66.8%) for routine literature searches out of eighteen databases (Hightower; Caldwell, 2010). Similarly, a survey of over 3,000 university faculty in the United States found that *Google* and *Google Scholar* were the third most “often” or “occasionally” used (about 70%) to find academic publications (Schonfeld; Housewright, 2010).

Although *GS* was not primarily developed to rival conventional citation indexes, many studies have compared it against them for research assessment (see Appendix A). *GS* covers a wider range of academic journals and millions of other scholarly-related publications in different languages and countries, making it particularly worth investigating for impact assessment in areas that are not well covered by *WoS* or *Scopus*.

Google does not allow routine automatic gathering data from *GS* but has apparently made an exception for the *Publish or Perish* software:

<http://www.harzing.com/pophelp/faq.htm#Q1010>

developed to compute research impact indicators (e.g., the h-index) from *GS* data (Harzing; Van der Wal, 2008). The superior coverage of *GS* in *Computer Science and Informatics* in the UK *Research Excellence Framework* (*REF*, a successor to the *RAE*) has led to it being recognised as helpful to assist peer review when *Scopus*-indexed citations are inadequate (*REF*, 2012). A team of scientometricians has also recommended *GS* citations for the individual assessment of researchers in the EU (after checking for false matches), when evaluators, research committees and funders need complementary or wider impact indicators (*Acumen portfolio*, 2014).

3.1.1. Google Scholar coverage vs. conventional citation indexes

Unfortunately, it is not possible to accurately estimate the coverage of *GS* (Orduña-Malea; Ayllón; Martín-Martín; Delgado-López-Cózar, 2015), but it appears to cover about 88% (100 out of 114 million) of the English-language scholarly documents accessible on the web (Khabisa; Giles, 2014) which seems to be about double the size of *WoS* (about 51 million records, including conference proceedings by September 2014¹). *GS* also seems to have comparable coverage of high impact scientific journals. A 2006 study, for instance, found that *GS* covers an overwhelming majority of the journals in the *Thomson-Reuters Science* (86%), *Social Sciences* (88%) and *Arts and Humanities* (81%) *Citation Indexes* (Mayr; Walter, 2007). Since then, the current and retroactive coverage of *GS* appears to have expanded in many Science fields (e.g., Chen, 2010; Harzing, 2014, 2013; De Winter; Zadpoor; Doudou, 2014; Orduña-Malea; Delgado-López-Cózar, 2014). Many studies have confirmed that *GS* has greater coverage of international and non-traditional publications (see Appendix A), suggesting that it could be useful for assessing citation impact outside that covered by conventional citation indexes (e.g., Meho; Yang, 2007; Bar-Ilan, 2008; Kulkarni; Aziz; Shams; Busse, 2009; Franceschet, 2010; Kousha; Thelwall; Rezaie, 2011; De Groote; Raszewski, 2012; Minasny; Hartemink; McBratney; Jang, 2013).

The wide coverage of *GS* is not universal, however, and its coverage of publishers and other sources varies across fields. For instance, in Chemistry the median citation counts of accepted papers derived from *WoS*, *Scopus* and *Chemical Abstracts* (23, 23 and 25, respectively) were much higher than the *GS* citation counts (median 1) in one study (Bornmann *et al.*, 2009) and more *WoS* unique citations were found than *GS* citations (450 vs. 61, respectively) for 276 Chemistry articles in another (Kousha; Thelwall, 2008b). These results may have been affected by subsequent agreements between *Google Scholar* and publishers, however. In contrast, a comparison of the h-index for 5,283 computer scientists derived from *GS* and *WoS* showed that the mean h-index from *GS* (3.54) was higher than the mean h-index from *WoS* (2.19), but the reverse was true for 1,354 physicists (*GS* h-index mean 6.7 and *WoS* h-index mean 7.15) (Henzinger; Suñol; Weber, 2009). A comparison of citations to 1,000 books submitted to the 2008 UK *Research Assessment Exercise* (*RAE*) across seven book-based disciplines also found that both the numbers and medians of *GS* citations to books were three times higher than the comparable *Scopus* citations (Kousha; Thelwall; Rezaie, 2011). This suggests that, in addition to Computer Science, *GS* may be more useful for Arts and Humanities research than is *WoS*. The same may be true for Business because a study of the publications of Canadian business school faculty members found that the mean number of publications (22), citations (271), and the h-index (4.6) derived from *GS* were much higher than from *WoS* (5, 51 and 1.9, respectively) (Amara; Landry, 2012) and the *GS* mean citations per paper were almost double those of *WoS* for the research outputs of three UK busi-

ness and management schools (**Mingers; Lipitakis, 2010**). Nevertheless, the coverage of *GS* may have expanded since some or all of these studies were completed.

The value of *Google Scholar* citation counts in research evaluation can be best assessed by comparing them with peer review judgments of academic articles. A study of articles submitted for the *Research Excellence Framework (REF) 2014* correlated *Google Scholar* citations with peer judgements by 36 panels of disciplinary experts grading on a five point scale (0, 1*, 2*, 3*, 4*; although most were 3* or 4*) (**Hefce, 2015**). The articles form artificially high quality samples due to their selection criteria, reducing the correlation strengths. For articles published in 2008, the oldest year covered, the correlations varied from 0.600 (Clinical Medicine, n=2070) to -0.163 (Theology, n=45). The correlations tended to be strong and positive in the Life and Physical Sciences as well as in Economics. They were small and both negative and positive in the Arts and Humanities. The correlations were at least 0.2 in all Life and Natural sciences and most Social Sciences and Engineering. The main exception was the low correlation of 0.151 (n=300) for Architecture, Built Environment and Planning, although this includes an element of the Humanities.

“*Google Scholar* data should not be used without extra checking for evaluations of individuals (e.g., with citation counts or the h-index) or for any other formal research evaluations for a number of reasons”

The same 2008 UK data (**Hefce, 2015**) makes possible, for the first time, systematic comparisons between *Google Scholar* and *Scopus* for citation indicators in all areas of research. *Google Scholar* citation counts seem to be less useful than *Scopus* citations in Health and Natural Sciences because for all of these, *Scopus* citation tended to correlate a little more strongly with peer judgements than did *Google Scholar* citations (mean difference: 0.061). Similarly, *Scopus* citations tended to correlate more strongly with peer judgements than did *Google Scholar* citations in the five Engineering subjects (mean difference: 0.032), although Electrical and Electronic Engineering, Metallurgy and Materials is an exception. For Computer Science, in which *Google Scholar* has particularly good coverage, the correlation with both sources was identical (0.484, n=1035). In the Arts and Humanities (*REF* units 27-36, approximately) the reverse was true, confirming the discussion above. More specifically, *Google Scholar* citations tended to correlate more strongly with peer judgements than did *Scopus* citations in the ten Arts and Humanities subjects (mean difference: 0.024), although both History and Music, Drama, Dance and Performing Arts are exceptions. In the ten Social Sciences (*REF* units 17-26, approximately), the situation is more mixed, with *Scopus* citations having a stronger correlation with peer review in six subjects and *Google Scholar* citations having the stronger correlation in 4 (mean difference: 0.006). These findings about differences should not be extrapolated

outside of the UK, however, except perhaps to other major English-speaking nations. Presumably correlations with peer judgements would be relatively lower for *Scopus* citations for these countries due to lower coverage of the national literature but it is not clear that *Google Scholar* coverage would also be similarly lower because this depends on the extent to which the national literature is online and indexed by *Google*.

3.1.2. Problems with *Google Scholar* for research evaluation

Despite the substantial, albeit occasionally patchy, *Google Scholar* coverage of publications and citations in comparison with conventional citation indexes, *GS* data should not be used without extra checking for evaluations of individuals (e.g., with citation counts or the h-index) or for any other formal research evaluations for a number of reasons. First, *GS* does not provide transparent information about its indexed sources and its coverage may change substantially over time without warning or notice. Most importantly, *GS* has no clear quality control over its indexed publications. Thus, manipulation of citation counts, automatically generated or deliberately faked documents and references as well as misidentification of authors, publication titles and years are serious concerns for those wishing to use raw statistics from *GS* for evaluative purposes (e.g., **Norris; Oppenheim, 2007; Falagas; Pitsouni, Malietzis; Pappas, 2008; Jacsó, 2006, 2008a, 2010 and 2011; Beel; Gipp, 2010a; Beel; Gipp, 2010b; Labbé; Labbé, 2013; Delgado-López-Cózar; Robinson-García; Torres-Salinas, 2014**). This seems to be particularly problematic for assessments of individual academics (**Jacsó, 2008b, 2008c**) or articles.

The evidence shows that *Google Scholar* could be helpful for the construction of citation impact indicators when evaluators need a database with wider coverage than that of *WoS* or *Scopus*, Business, Arts and Humanities and perhaps many more, although *GS* does not seem to provide improved coverage in some fields (this may have changed since the research reviewed above). *GS* also seems likely to be useful when for assessments including a substantial amount of non-English documents and perhaps also when recently published or in press publications must be assessed. However, due to a lack of quality control over its indexing of web publications, *GS* raw data is susceptible to spamming to an extent that it should not be used unfiltered for serious research evaluation purposes. *Google Scholar Citations (GSC)* might be useful for the citation statistics in authors' profiles (**Ortega; Aguillo, 2014**), but not all authors have profiles, and there are problems with citation manipulation and errors in citation attributions.

3.2. Patents and *Google Patents*

A patent is a set of legal rights to an invention within a particular country or set of countries that is usually registered in patent offices for a period of time. Patents contain citations and, intuitively, a citation from a patent indicates that the cited document may have some commercial value or may have helped to generate commercial value. There are differences and similarities between patent and paper citations (for reviews see **Meyer, 2000a; Oppenheim, 2000**). For patents, both authors and examiners decide which publica-

tions should be cited. In fact, patent examiners may add or remove applicant citations based upon judgements of relevance. Thus, patent citations could reflect the citation motivations of both examiners and applicants (Meyer, 2000a). Assuming that citations from patents can be used as evidence of the commercial impacts of research, such as influence on emerging technologies and innovations (Meyer, 2000b, 2001, 2002) or the effectiveness of research investment (Shelton; Fadel; Foland, 2015), patent databases could be used for research monitoring.

Correlations between patent citation counts from the *World Intellectual Property Organization (WIPO)* and peer review judgements for UK REF 2014 articles from 2008 (see the GS section above) found a maximum value of 0.229 (Clinical Medicine, n=2070), with the highest values occurring amongst engineering, life and Natural Sciences (Hefce, 2015). Nevertheless, most areas of research had too few *WIPO* patent citations to calculate a correlation coefficient, confirming that patents are highly subject-specific in usefulness.

3.2.1. Impact evidence from Google Patents

Google Patents (GP) claims to cover the full text of patents and patent applications originating from the *United States Patent and Trademark Office (Uspto)* from 1790 and the *European Patent Office (EPO)* from 1978:

<https://support.google.com/faqs/answer/2539193>

“The value of patent citations is far from universal because patents are not used in many areas of industry, so the lack of a citation from a patent is not evidence that an article has had no direct commercial value”

Hence, whilst not internationally comprehensive, it covers two important sources. The *GP* full-text search capability makes it possible to locate citations to academic publications within a large number of digitised patents. For instance, a conference paper “*Viz3D: Effective exploratory visualization of large multidimensional data sets*” by Artero *et al.* had not received any citations in *WoS* citation indexes (including conferences) by July 2015. At this date, however, it had been formally cited in at least 14 patents indexed by *GP*, suggesting that it may be a type of research that is more useful for inventors than for academics. A semi-automatic method has been developed to extract patent citations from *Google* via *Bing* API searches and evaluated with 322,192 Science and Engineering *Scopus* articles from every second year during 1996-2012 with sufficient accuracy and coverage for patent citation analysis. Low but statistically significant correlations between the *Google Patents* citations and *Scopus* citations are consistent with patent citations partially reflecting the commercial or technological value of scientific articles (Kousha; Thelwall, in press). The number of citations to publications from patents has been previously recommended as one way for academics to demonstrate evidence of the commercial relevance of their research (*Acumen portfolio*, p. 42).

Google Patents citation searches may help to identify some types of commercially relevant research. Nevertheless, the value of patent citations is far from universal because patents are not used in many areas of industry, so the lack of a citation from a patent is not evidence that an article has had no direct commercial value.

3.3. Usage indicators from scholarly databases

Digital readership information is now routinely collected by publishers for the electronic versions of their articles. Several early studies have shown that more cited journals tended to be more read (e.g., Stankus; Rice, 1982; Tsay, 1998) and so readership may reflect a similar type of impact to that of citations. Statistics about downloads or views of electronic articles can, in theory, also be extracted for research evaluation purposes from local library log files, digital libraries, aggregator services and scientific publishers. In addition, partial usage statistics can be obtained from some social bookmarking tools (Haustein; Siebenlist, 2011). Indicators from this data are based on the assumption that a view or download of a scholarly source indicates someone with a degree of interest or need for it (Kurtz; Bollen, 2010).

Although an early study found no connection between online views and citations for journals (Darmoni *et al.*, 2000), later investigations have found positive associations between citations and downloads, suggesting that the two tend to reflect overlapping types of impact (e.g., Kurtz *et al.*, 2005; Brody *et al.*, 2006; Duy; Vaughan, 2006). A detailed study of Astrophysics articles found a strong association between the number of electronic accesses of and the number of citations to online articles based on data from the *NASA Astrophysics Data System*. Although citation counts could predict electronic accesses and vice versa, their combination is better than each individual one (Kurtz *et al.*, 2005). A significant positive Spearman correlation (but very low: 0.22) has also been found between download rates and citation counts to 1,190 articles published in the journal *Tetrahedron letters*, during the two years after publication (Moed, 2005b). This correlation increased for downloads made after 3 months from the publication date (0.35). Similar correlations have also been found for articles deposited to *arXiv.org* subject categories (Brody; Harnad; Carr, 2006).

Local usage data (e.g., institutional) can also be used for download indicators and one study found them to correlate significantly ($r=0.935, 0.624$ and 0.681) with the local citation data of researchers for three publishers and one Canadian university. Nevertheless, there was no association between the Journal Impact Factor and journal usage data, suggesting that local citations better reflect journal use than do global impact factors (Duy; Vaughan, 2006). Significant correlations have also been found between local online journal use provided by publishers and local journal citations for 639 journals at the *California Institute of Technology* (McDonald, 2007). This association was stronger than the correlations between local print use and local citations for a set of 458 journals, indicating that online journal data captures more usage than does its print counterpart. Chu and Krichel (2007) examined the relationships between ci-

tation indicators (*Social Science Citation Index* and *GS*) and download rates for the 200 most downloaded papers from the *RePEc* e-print archive in economics, finding moderate statistically significant correlations between download rates for papers with citations from *Social Science Citation Index* citations (0.54) and *Google Scholar* (0.61). Another study also found significant positive correlations between different total impact factor and journal usage factor indicators in Computer Science, Economics and Finance, Oncology and Arts and Humanities (except for Psychology), although there were some disciplinary differences in the relationships between the citation and download indicators (**Gorraiz; Gumpenberger; Schlögl**, 2013).

It is possible to some extent to guess at the audience of an article from the IP addresses of its downloaders. For example, if the IP addresses are all associated with universities then the audience is presumably academic but if a substantial fraction comes from commercial sector organisations then this suggests a wider audience. Although it is technically possible to make such breakdowns and the wider impact evidence that they might generate would be useful for research evaluation, it is difficult to make them robust in practice. Hence, with a few exceptions (e.g., **Duin; King; Van den Besselaar**, 2012), this approach has not been used for evaluations.

A range of usage-oriented metrics have been proposed that are analogous to classical journal citation indicators such as the “usage impact factor” (**Bollen; Van de Sompel**, 2008), “usage immediacy index” or “download immediacy index” (**Rowlands; Nicholas**, 2007; **Wan; Hua; Rousseau; Sun**, 2010) and “usage half-life” (**Rowlands; Nicholas**, 2007; **Schloegl; Gorraiz**, 2010). There have also been important initiatives to develop platforms to collect and process usage data from publishers, including *Mesur* (**Bollen; Van de Sompel; Rodriguez**, 2008) and *Serum* (**Gorraiz; Gumpenberger**, 2010), in addition to the *Counter* initiative to standardise counting across publishers:

<http://www.projectcounter.org>

Nevertheless, usage statistics are not generally available for research assessment yet and they seem to be relatively easy to spam to some extent. Perhaps most tellingly, download statistics correlate substantially more weakly with peer review judgements about the quality of academic articles than do citation counts (*Hefce*, 2015).

4. Citations and links from the general Web

It is possible to extract information from the Web in order to identify citations to publications, hence using the web as a huge and uncontrolled de-facto citation database. This data collection can be automated, such as through the *Bing Applications Programming Interface* (API), making the web a practical, albeit somewhat tricky, source of this type of citation data. The free software *Webometric Analyst*: (<http://lexiurl.wlv.ac.uk>) can run automatic searches through the *Bing* API for this purpose. Commercial search engines should not be used for longitudinal comparisons, however, because changes in indexing strategies can affect the results (**Van den Bosch; Bogers; De Kunder**, 2015).

4.1. Link analysis

Over a decade ago webometric researchers attempted to assess online impact by counting web hyperlinks on the basis that, like citations, they were inter-document connections that may tend to confer authority on their targets (**Almind; Ingwersen**, 1997; **Rousseau**, 1997). This is also the idea behind *Google's PageRank* algorithm and so is intuitively credible. It led to the “Web Impact Factor” (**Ingwersen**, 1998), which was similar to the Journal Impact Factor but based on hyperlinks and applicable to any collection of websites. Online mentions of academics’ names (**Aguinis; Suárez-González; Lannelongue; Joo**, 2012; **Cronin; Snyder; Rosenbaum; Martinson; Callahan**, 1998) have also been proposed as a method to identify the wider impacts or fame of academics. These initiatives all examined whether web extracted metrics could provide data for impact assessment that could extend traditional citation indicators (**Cronin**, 2001). Many other early investigations also exploited analogies between web links and citations to develop indicators for the impact of journal web sites or online articles (**Harter; Ford**, 2000; **Smith**, 1999; **Vaughan; Hysen**, 2002; **Vaughan; Thelwall**, 2003). On a larger scale, studies of sets of university web sites revealed that link counts correlated with the amount of research produced by universities, as measured by the *RAE* or similar exercises (e.g., **Thelwall**, 2001; **Smith; Thelwall**, 2002; **Thelwall; Harries**, 2003). Nevertheless, the removal of hyperlink search facilities from all major commercial search engines has undermined the use of link data for the web impact assessment of research, although alternative methods have been suggested that can be collected from commercial search engines, including *URL citations* (**Kousha; Thelwall**, 2006) as well as *title mentions* and *linked title mentions* (**Sud; Thelwall**, 2014a), as discussed below.

Although early studies found that counts of web hyperlinks to online articles, journal websites and university websites correlated with traditional citation metrics or other indicators of research productivity or impact, link-based metrics have not been used to assess the research of individuals. The number of links to a university website (external inlinks) is one of the indicators used for measuring the visibility of academic institutions (**Aguillo; Granadino; Ortega; Prieto**, 2006) in the *Webometrics Ranking of World Universities*, however. Hyperlink counts are now less easy to obtain and are probably not useful for assessing the impact of individual papers, academics or even research groups but may be helpful as a visibility indicator at the entire institution level, although link spam is widespread and hyperlinks can be generated automatically in large numbers for legitimate reasons, such as to connect related online databases or wikis.

4.2. Web and URL citations

Vaughan and Shaw (2003, 2005) coined the term *Web citation* to refer to a mention of an exact article title in a web page, proposing counts of these as a new impact indicator and showing that they tended to correlate with traditional citation-based indicators. Web citations, in this sense, can easily be identified by searches for article titles in commercial search engines. These web citation searches may return matches in the reference lists or text of any type of docu-

ment on the Web. In contrast, an *URL citation* is a mention the URL of an online scholarly work (e.g., an open access article) in a web page. Both web and URL citations can be gathered manually from the online interfaces of commercial search engines or automatically by submitting queries to *Bing* through its free API, although more than 5,000 queries per month will need to be paid for.

URL citation counts have been used as an alternative to web citation counts with similarly promising evidence that they correlate with traditional citation counts (Kousha; Thelwall, 2006, 2007a). URL citations have the advantage that, unlike article titles, they are normally unique and hence unambiguous, but the disadvantage that many citations of online publications omit the paper's URL or use a DOI (digital object identifier) as an indirect pointer. Moreover, previous studies have shown that general Web or URL citation searches with commercial search engines gives results that need extensive manual checking to identify online citations in formal research publications because most web or URL citations seem to be created for non-scientific reasons, such as (arguably) library reading lists and online copies of journal tables of contents. For instance, out of 854 web citations to 46 library and information science journals, only 30% were citations from other publications (Vaughan; Shaw, 2003) and only a quarter of online citations to journal articles in Biology, Physics, Chemistry, and Computing represent citation impact from references in other web documents (Kousha; Thelwall, 2007b). URL citations are probably less useful now than when they were originally conceived because of the use of complex URLs in some modern publishers' websites and the rise of DOIs as an alternative method for pointing to online documents.

Since web or URL citations to publications can be located by commercial search engines (*Google* manually and *Bing* automatically) and there is evidence (although not recent) that they can be indicators of research impact, they could be used for indicators of the scholarly impact of research if they are filtered to remove non-scholarly sources. In contrast, unfiltered web or URL citation counts are easy to spam and many citations are created for navigation, self-publicity or current awareness and so it does not seem likely that they would genuinely reflect the wider impacts of research, without time-consuming manual filtering out of irrelevant sources.

5. Citations from specific parts of the general Web

In addition to searching for citations from the general web, citations can be counted from specific parts of the web, including types of website and types of document. This information can be extracted from appropriate searches in commercial search engines and automated with the *Bing* API. The discussions below cover online presentations, syllabi and science blogs, although there is also some evidence that mentions in news websites and discussion forums may also be useful (Costas; Zahedi; Wouters, 2014; Thelwall, Haustein; Larivière; Sugimoto, 2013). Citations from online grey literature seem to be an additional useful source of evidence of the wider impact of research (Wilkinson; Sud; Thelwall, 2014), but there do not seem to be any systematic studies of these.

5.1. Online presentations

Conferences are important for sharing scientific results in some areas of Science (Drott, 1995). In Computer Science and engineering, refereed conference papers are particularly important research outputs. For example, over 40% of citations to highly cited publications in Computer Science are from proceedings papers (Bar-Ilan, 2010). The share of cited proceedings in *Thomson Scientific* citation indexes 1980-2005 was about 20% in Computer Science, about 13% in Electrical Engineering; Electronics, and 11% in Civil Engineering. Proceedings papers tend to receive citations earlier than does the cited literature in general (Lisé; Larivière; Archambault, 2008).

Conference papers are presumably initially given with the aid of presentation files (e.g., in *Microsoft* .ppt and .pptx or *Apple* .key). Presentations in the same format may also be used for teaching and informal seminars. These presentations may then be posted online and become searchable by commercial search engines or available through slide-sharing sites such as *Slideshare.net*. This gives them the potential to be used for a new type of online citation analysis. Although most scientific results in presentations will be formally published later in proceedings or journals, some academic presentations may never appear elsewhere. For instance, there are about 11,000 citations to *PowerPoint* presentation files (.ppt and .pptx) in the references of *Scopus* publications, a quarter of them in Computer Science, suggesting that their content was useful enough to be cited by other research even though they were not formally published. Authors' data, see:

<http://www.kousha.tripod.com/citationtopowepoints.jpg>

Citations from academic publications can be systematically gathered by automatically submitting queries to commercial search engines, such as through the *Bing* API, using bibliographic information for the query and specifying presentation files only in the results (e.g., adding *filetype:ppt* to each query). Based on a study of about 1,800 *WoS*-indexed journals in ten Science and ten Social Science fields, citations from online presentations were found to be too rare for general impact assessment, but presentation citations could be helpful to identify important articles in popular magazines like *Scientific American* and *Harvard business review* (Thelwall; Kousha, 2008). A classification of reasons for mentioning Social Science journals in 756 *PowerPoint* files from American university websites found that about 60% occurred in formally cited references and 15% were in course reading lists, indicating that the majority (about 75%) represented a type of intellectual impact. However, about 15% of the journals were mentioned for reasons not reflecting intellectual impact, such as CVs and publishers' lists of journals (Thelwall; Kousha, 2008). Presentations are easy to spam, however, even if they are only searched for in academic websites.

5.2. Online course syllabi

Course syllabi often record the most important textbooks for students to read and so are a logical source of information about whether books and articles are useful in teaching. There have been many content analyses and com-

parative studies of the contents or structure of academic course syllabi (e.g., **Pieterse et al.**, 2009; **Mishra; Day, Littles; Vandewalker**, 2011; **Homa et al.**, 2013), but syllabi have not been used for research assessments. Nevertheless, the educational impact of publications seems to be important for teaching-based fields, and particularly in the less hierarchical knowledge structures of the Social Sciences and Humanities, where textbooks, edited books and monographs can have educational value rather than, or in addition to, research impact (e.g., **Gurung; Martin**, 2011; **Gurung; Landrum; Daniel**, 2012).

Mentions of publications (e.g., textbooks or articles) in online academic course syllabi can be automatically retrieved from the web using appropriate *Bing* API searches, making syllabus mentions a practical indicator for research assessment (**Kousha; Thelwall**, 2015). One early study searched for mentions of over 70,000 journal articles published in 2003 in online course syllabi in multiple fields, finding substantial numbers of mentions in some Social Science disciplines (e.g., Political Sciences and Information Science), but syllabus mentions were less than 13% as frequent as citations in each of the fields analysed and were less than 0.1% as frequent in mathematics. A case study of Library and Information Science articles showed that the articles that were most recommended in academic syllabi tended to be reasonably highly cited but that the converse was not true (**Kousha; Thelwall**, 2008a). This confirms that some articles can have more educational influence than research impact and since this study more syllabi or course reading lists may be available online, especially from an international perspective, perhaps allowing more inclusive teaching impact assessment.

Academic course syllabi citation searches seem to be more useful for the educational impacts of books and monographs

Statistics about the uptake of academic publications in academic syllabi may be useful in teaching-oriented and book-based fields, where the main scholarly outputs of teaching staff are articles or monographs for which students are an important part of the audience, or textbooks. It is practical to harvest such data from the minority of syllabi that have been published online in the open web and indexed by search engines, but it seems that such syllabus mentions may be useful primarily to identify publications with a particularly high educational impact rather than for the systematic assessment of the educational impact of research. Syllabus mentions have most potential for the Humanities and Social Sciences, where they are most common and where educational impact may be most important. Academic course syllabi citation searches seem to be more useful for the educational impacts of books and monographs, as discussed in Part 3 of this literature review.

5.3. Science blogs

There are many science blog hosting services, such as *scienceblogs.com*, *blogs.nature.com* and *blogs.plos.org*, where academics can discuss scientific issues. Another important genre is the medical blog, which tends to have an educated professional author that attempts to communicate the implications of research findings to the general public (**Kovic; Lulic; Brumini**, 2008). The contributions that academic blogs can make to informal scholarly communication have been widely recognised and analysed (e.g., **Ewins**, 2005; **Luzón**, 2007, 2009; **Davies; Merchant**, 2007; **Kirkup**, 2010; **Shema; Bar-Ilan; Thelwall**, 2012; **Mewburn; Thomson**, 2013; **Su; Akin; Brossard; Scheufele; Xenos**, 2015). In terms of authorship, about 60% of a sample of 126 *ResearchBlogging.org* bloggers were affiliated with academic institutions, 65% were graduate students, and 72% of *ResearchBlogging.org* blogs were written by one or two male authors, indicating important gender differences (**Shema; Bar-Ilan; Thelwall**, 2012). Academics appear to be less dominant in one German scientific blogging platform, however, and 60% declared that dissemination of their field of research to general public was their main reason for blogging (**Puschmann; Mahrt**, 2012). This is consistent with blogs being an alternative platform to present ideas and “to write outside the boundaries of traditional academic publication” (**Davies; Merchant**, 2007, p. 177; see also: **Groth; Gurney**, 2010; **Kirkup**, 2010; **Mortensen; Walker**, 2002). Academics may also use blogs to get feedback from the public about their own research (**Gregg**, 2006) or to interact with other academics (**Kjellberg**, 2010; **Mewburn; Thomson**, 2013). Blogs can also provide inputs to formal scholarly communication and citations to major blogs (e.g., *ScienceBlogs* and *BlogSpot*) from *Scopus* publications have increased from 21 citations before 2003 to just under 5,000 in 2011 (**Kousha; Thelwall**, 2014).

Blog posts may include links or references to other publications and these citations could perhaps be gathered to form an indicator of the impact of the cited research. Hyperlinks in academic blogs seem to be created for many informal scholarly reasons, such as to increase the visibility and collaboration of bloggers in their scientific community or to publicise their research outputs (**Luzón**, 2009). One study found that about 30% of academics frequently linked to articles, newspapers and other documents that they discussed or provided commentary about (**Luzón**, 2009). It is possible to manually search for blog citations with *Google Blog Search* to try to gather evidence about the social impact of the cited research, although one study found that few articles from two information science journals were cited in blogs (citation means: 0.34 and 0.44) in comparison to *WoS* (11 and 8) (**Kousha; Thelwall; Rezaie**, 2010).

A study using blog citation data for 13,300 Medical and Biological Sciences articles from *altmetric.com* (**Adie; Roe**, 2013) found them to correlate with *WoS* citation counts at a low but statistically significant level ($r=0.201$; $p<0.01$) (**Thelwall; Haustein; Larivière; Sugimoto**, 2013). Another inves-

tigation found that for 58% and 68% of journals published in 2009 and 2010, respectively, articles blogged in *Research Blogging.org* tended to subsequently receive more citations than did other articles from the same journal (**Shema; Bar-Ilan; Thelwall**, 2014). These studies and the research above show that blog citations can perhaps be considered as evidence of a combination of academic interest and a potential wider social interest, even if the bloggers themselves tend to be academics. In addition, the evidence that more blogged articles are likely to receive more formal citations shows that blog citations could be used for early impact evidence. Nevertheless, blog citations are not straightforward to collect and so, as a practical step, may need to be provided by specialist altmetric software or organisations, and are easy to spam.

“The evidence that more blogged articles are likely to receive more formal citations shows that blog citations could be used for early impact evidence”

5.4. Other sources of online impact

In addition to the types of web citations discussed above, preliminary research is evaluating online clinical guidelines, government documents and encyclopaedias. Online clinical guidelines (see: **Manchikanti; Benyamin; Falco et al.**, 2012) could be useful for medical research funders to help them to assess the societal impact of individual studies (**Kryl; Allen; Dolby; Sherbon; Viney**, 2012). In support of this, one study extracted 6,128 cited references from 327 documents produced by the *National Institute of Health and Clinical Excellence (NICE)* in the UK, finding articles cited in guidelines for health professionals tend to be more highly cited than comparable articles (**Thelwall; Mafrahi**, in press).

With millions of articles in English, many of which have references, *Wikipedia* is a valuable body of knowledge that may reflect wider uses of research (**Bar-Ilan; Aharony**, 2014). Moreover, references within *Wikipedia* articles on academic topics may be high quality selected publications (e.g., **Stankus; Spiegel**, 2010). Significant correlations between *WoS* citations to scientific journals and citations from *Wikipedia*, suggest that *Wikipedia* citations have promise for research evaluation (**Nielsen**, 2007). However, another study on a sample of over 24,000 articles published by the *Public Library of Science* showed that only 5% were cited in *Wikipedia*, whereas 80% had at least one *Mendeley* bookmark (**Priem; Piwowar; Hemminger**, 2012). Thus, *Wikipedia* citations may be too rare for routine use in research evaluation, even though they could be automatically extracted without too much difficulty from copies of *Wikipedia* freely provided by its owners:

http://en.wikipedia.org/wiki/Wikipedia:Database_download

6. Conclusions

This literature review has discussed findings about potential sources of web-based evidence about the impacts of published academic articles, excluding social web sources

(covered in Part 2). The research reviewed above shows that *Google Scholar* is more comprehensive than *WoS* or *Scopus* for Social Science, Arts and Humanities, and Computer Science citation-based data, and, except for its potential for manipulation, seems to be better than *Scopus* for Arts and Humanities research, at least in the UK. It is therefore a particularly valuable source of evidence but its data cannot be collected automatically and its coverage is unknown and can be gamed, all of which are practical disadvantages.

Bibliometric indicators do not show the usage of a published work by non-authors, such as students, some academics, and non-academic users who do not usually publish but may read scholarly publications. Usage-based statistics for scientific publications may therefore help to give a better understanding of the usage patterns of documents and can be more recent than bibliometric indicators. Many studies have found correlations between usage and bibliometric indicators for articles and usage data could be extracted from different sources such as publishers, aggregator services, digital libraries and academic social web sites. Nonetheless, the usage statistics could be inflated or manipulated and some articles may be downloaded or printed but not read or may be read offline or via different websites such as authors' CVs and digital repositories (**Thelwall**, 2012). Hence, integrated usage statistics from different sources such as publisher's websites, repositories and academic social web sites, if they are not manipulated in advance, would be optimal for global usage data. This does not seem to be practical yet, however.

Patent citations can give useful information about the commercial utility of academic research in some areas and *Google Patents* citation searches is a free source of this information. Nevertheless, the value of patent citations is far from universal because patents are not used in many areas of industry, so the lack of a citation from a patent is not evidence that an article has had no direct commercial value.

Citations from online presentations can be automatically collected through web searches and could perhaps be a helpful source of impact in conference-based fields, such as Computer Science and Engineering, although they seem to be too rare for this data to be worth routinely collecting for research assessment purposes. Web syllabus citations may be useful as evidence of educational impact of all types of publications and it may be possible to filter out manipulated mentions because such syllabi must be posted prominently on university websites to be credible. The main drawback of this method is that the syllabi posted online probably form a small and biased sample of the population of academic syllabi used. In contrast, citations from science blogs can be evidence of wider scholarly interest in a published work but seem to be difficult to gather systematically and so may not be a practical source of evidence. Nevertheless, they may be particularly useful to study small areas of research that generate large amounts of interest, such as controversial, popular or fraudulent science.

All of the new data sources discussed here show evidence of value for indicators of aspects of research impact but all also have limitations in practice. All are susceptible to ga-

ming to some extent and so should not be used in formal research evaluations, but could be used in formative evaluations, such as self-evaluations. Moreover, it is not possible to gather *Google Scholar* citations automatically, which is a practical problem for its use in large-scale evaluations. The other indicators discussed here need some effort to collect on a large scale and so the trade-off between the amounts of time needed to gather them and the value of the information that they give needs to be considered. Their use may be made easier, however, if they are provided as part of a suite of indicators that can be gathered together. This is an attraction of academic data providers like *ImpactStory*, *altmetric.com* and *Plum Analytics*. When used for formative evaluations, any indicators need to be normalised for year and discipline in order to avoid being misleading. This is achieved by some altmetric data providers through a ranking percentage, such as stating that an article is in the top 10% for a given subject area and year. An alternative method is to provide the median for the field and year in addition to the raw data for a collection of articles.

For future research, ongoing studies are needed to evaluate changes in coverage of *Google Scholar* because of its importance as a citation index, in addition to its main literature search database role. Since its wide coverage makes it tempting for use in research evaluations, especially in non-English speaking nations without good research coverage in the *Web of Science* or *Scopus*, research is also needed to assess the extent to which undesired types of content or spam are indexed in it, and whether it is possible to devise strategies to prevent authors from gaming the system. *Google Patents* also seems to be particularly promising as a source of commercially-related citations to academic research and seems difficult to manipulate. Studies are needed to identify whether it is useful in practice, how best to use it, and precisely which areas of research and countries can benefit from using it. It also seems to be a useful new source of wider evidence about the important issue of the connection between university research and commercial uptake. Finally, more investigations into citations from specific parts of the web (e.g., presentations, online syllabi, blogs) are needed in order to assess whether they can give useful information about the process of research and their limitations in practice, the extent of any national biases, and to develop methods to identify them in languages other than English.

Note

1. For the number of *WoS* records the query used in the “publication name” field was: (A* OR B* OR C* OR D* OR E* OR F* OR G* OR H* OR I* OR J* OR K* OR L* OR M* OR N* OR O* OR P* OR Q* OR R* OR S* OR T* OR U* OR V* OR W* OR X* OR Y* OR Z* OR 0* OR 1* OR 2* OR 3* OR 4* OR 5* OR 6* OR 7* OR 8* OR 9*)

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<http://www.hefce.ac.uk/rsrch/metrics>

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Appendix A: Comparisons between GS and conventional citation indexes

Article	Dataset / discipline	Main results	Conclusions for research evaluation
Bauer & Bakkalbasi (2005)	Articles from the <i>Journal of the American Society for Information Science and Technology (Jasist)</i> published in 1985 (41 papers) and 2000 (105 papers).	GS retrieved 4.5 and 3.9 times more citations than did WoS and Scopus, respectively, for papers published in 2000. However, WoS citations were 8.7 times higher than GS for older papers published in 1985.	"A search of Google Scholar will likely reveal both traditional journal articles, some of which will also be covered in Web of Science and Scopus, and additional unique material, but the scholarly value of some of the unique material remains an open question." (No page, online)
Meho & Yang (2007)	Over 1,457 publications by 25 library and information researchers	GS located 53% more citations than the union of WoS and Scopus and increased the total number of citations by 93%. There were significant correlations between GS and both WoS (0.874) and Scopus (0.970).	"GS stands out in its coverage of conference proceedings as well as international, non-English language journals." (Page: 2105).
Kousha & Thelwall (2007a)	A sample of 1,650 journal articles published in 2001 in Science and the Social sciences (Biology, Chemistry, Physics, Computing, Sociology, Economics, Psychology, and Education)	GS citations were more numerous than WoS citations in Economics (769%), Education (507%) Computer science (201%), Sociology (219%), Psychology (200%), but not in Science excluding Computer science (201%). GS citations highly correlated with WoS citations across all fields (from 0.825 in Biology to 0.551 in Education).	"There are clear disciplinary differences between conventional and Web-based citation patterns... and Google Scholar is a more comprehensive tool for citation tracking for social science. However, the quality of sources of citations (citing documents) retrieved by Google Scholar is an important factor to take into account" (Pages: 1063-1064)
Mayr & Walter (2007)	9,500 journals from five databases, Thomson Scientific (SCI, SSCI, AH), Directory of open access journals (DOAJ) and German social sciences literature (Solis)	About 86%, 88% and 80% of WoS-indexed journals in SCI, SSCI and AH were identified in GS searches (January 2007), respectively. About 68% of DOAJ journals and 70% of Solis journals were found in GS.	"The study shows that the majority of the journals on the five lists queried can be retrieved in Google Scholar... The international journals from the Thomson Scientific List (particularly from the area of STM) are fairly well covered." (Page: 828). However, its coverage of the DOAJ list and German literature was lower than that of Thomson Scientific databases.

Meho & Rogers (2008)	22 top Human-computer interaction researchers	Average <i>Google Scholar</i> h indexes (20.6) were higher than for <i>Scopus</i> (12.3) and <i>Web of Science</i> (8.0) and there was a significant correlation (Spearman 0.960) between the <i>GS</i> h index and h indexes for <i>Scopus</i> and <i>WoS</i> .	"The main difference between the two rankings is that <i>Google Scholar</i> helps distinguish between the researchers in a more nuanced fashion than the union of <i>Scopus</i> and <i>Web of Science</i> , as evidenced by the larger variance between top-ranked and bottom-ranked researchers" (Page: 1724).
Vaughan & Shaw (2008)	A sample of 1,483 publications of Library and Information Science faculty	<i>GS</i> citation medians (ranging from 1-3) were significantly higher than <i>WoS</i> citation medians (zero for all types of publications except for books with median 1). Significant correlations between <i>WoS</i> and <i>GS</i> citations and manual (0.43 to 0.75 depending on the type of publication) and checking of citing <i>GS</i> citing sources revealed that about 92% of <i>GS</i> citations represent intellectual impact (e.g., formal citations)	"In its current incarnation, <i>Google Scholar</i> has problems. Citing and cited papers are confused; and a single citation act may be represented multiple times when one citing work appears on several web pages. In spite of these problems, <i>Google Scholar</i> is a promising tool for research evaluation. If the current, beta, version of <i>Google Scholar</i> evolves in the right direction, it could be a serious challenger to <i>WoS</i> ." (Page: 328)
Bar-Ilan (2008)	47 highly cited Israeli researchers and three Nobel Prize winners	In many cases h-indexes of highly-cited Israeli researchers from <i>GS</i> were higher than from <i>WoS</i> and <i>Scopus</i> , especially for mathematicians and computer scientists. The average number of citations that the top h documents received in <i>GS</i> (153) was much higher than in <i>WoS</i> (21).	"The findings show that it matters which citation tool is used to compute the h-index of scientists. Also there seems to be disciplinary differences in the coverage of the databases. The differences in citation counts create a dilemma for science policy makers and promotion committees." (Page: 269)
Kousha & Thelwall (2008)	A sample of 882 articles from 39 <i>ISI</i> -indexed journals in 2001 from Biology, Chemistry, Physics and Computing	43% of <i>GS</i> citations were also in <i>WoS</i> , although there were disciplinary differences. OA articles from non- <i>WoS</i> journals (34.5%), conference papers (25.2%), and e-prints/preprints (22.8%) were the most common sources of <i>GS</i> unique citations and the majority of <i>GS</i> unique citations (70%) were from full-text documents.	<i>GS</i> seems useful tool "for researchers using the citation tracking capability of <i>Google Scholar</i> for selecting a wider range of citations for their own work and non-evaluative purposes... However, the minimal amount of information known about <i>Google Scholar</i> 's contents suggests caution for those seeking to use its citation data for research evaluation." (Page: 290)
Bornmann et al. (2009)	1,837 articles accepted for publication in the journal <i>Angewandte chemie internationale edition</i>	Median citations for accepted papers derived from <i>WoS SCI</i> , <i>Scopus</i> and <i>Chemical Abstracts</i> (23, 23 and 25 respectively) were much higher than <i>GS</i> citation counts (1). This was due to poor coverage of the citing articles that <i>GS</i> couldn't access through the fee-based database providers at the time of the study.	They concluded that in the field of Chemistry "on the one hand, the convergent validity of citation analyses based on data from the fee-based databases and, on the other hand, the lack of convergent validity of the citation analysis based on the <i>GS</i> data." (Page: 33). However, <i>GS</i> citations might be beneficial for the fields of Engineering, Computer Science & Mathematics, Social Sciences, Arts & Humanities, where wider publication types are needed for citation analysis.
Kulkarni, Aziz, Shams & Busse (2009)	328 articles published in <i>JAMA</i> , <i>Lancet</i> , or the <i>New England journal of medicine</i> (October 1999-March 2000)	The <i>GS</i> citation median (160) was higher than <i>Scopus</i> (149) and <i>WoS</i> (122). <i>GS</i> retrieved a median of 37% more citations for <i>JAMA</i> , 32% for <i>Lancet</i> , and 30% for <i>NEJM</i> articles than <i>WoS</i> .	" <i>Web of Science</i> , <i>Scopus</i> , and <i>Google Scholar</i> produced quantitatively and qualitatively different citation counts for articles published in 3 general medical journals. In offering alternative scopes of coverage and search algorithms, new citation databases raise questions of how to count citations. For example, should a citation on a non-peer-reviewed web page be viewed as quantitatively equivalent to a citation in a high-profile peer-reviewed medical journal?" (Page: 1096)
Franceschet (2010)	A sample of the publications of a group of Italian Computer science scholars	<i>GS</i> extracted metrics were much higher than those from <i>WoS</i> : five times higher for paper-based indicators, eight times for citation-based indicators and three times for h type indicators. There were significant correlations between <i>GS</i> and <i>WoS</i> citation indicators (for citations 0.92 and for the h index 0.65)	"...Great care must be taken when selecting the data source for the analysis. Our advice here is to perform a (time-consuming) join of the publications and citations contained in the two databases and use the combined universe to compute the h index for scholars and journals." (Page: 257)
Henzinger, Suñol & Weber (2009)	5,283 computer scientists and 1,354 physicists in <i>WoS</i> and <i>GS</i>	The average h index derived from <i>GS</i> was 3.54 for computer scientists and 2.19 from <i>WoS</i> . In contrast, for physicists the average h index in <i>WoS</i> (7.15) was slightly higher than for <i>GS</i> (6.70), although in both fields the <i>GS</i> citation medians were higher than those of <i>WoS</i> .	They concluded that "wherever possible at least two different databases should be consulted and the relative ranking should only be trusted if it is consistent between the databases." (Page: 473)

Lasda-Bergman (2012)	The top five journals ranked highest by the 556 faculty members surveyed in the field of social work	GS citations were more frequent than (3,272) <i>Scopus</i> (2,126) and <i>WoS</i> (1,741). About 44% of GS citations were neither in <i>WoS</i> nor <i>Scopus</i> , whereas only 25% of citations of both <i>WoS</i> and <i>Scopus</i> were in GS. The overlap between GS and both <i>WoS</i> and <i>Scopus</i> was about 31%.	" <i>Google Scholar</i> may not be as reliable as either <i>Scopus</i> or <i>Web of Science</i> as a stand-alone source for citation data. Nonetheless, to obtain the most comprehensive citation count, one must use all three resources." (Page: 378)
Mikki (2010)	Publications of 29 Earth sciences authors	Just under 70% of the publications found were in <i>Google Scholar</i> alone, in contrast to 5% for publications in <i>WoS</i> alone. Nevertheless, citation and h-index values of common publications for authors were almost identical in the two databases. There was a high correlation between GS and <i>WoS</i> citation counts (0.74)	"The amount of earth science content is comprehensive in <i>Google Scholar</i> . It covers about 85% of content indexed by <i>ISI WoS</i> ." (Page: 330)
Mingers & Lipitakis (2010)	Over 4,600 publications in Business and Management from three UK business schools 2001–2007.	Just under half (48%) of the publications by the Business and Management researchers were in <i>WoS</i> , whereas GS searches found 66% of them (including about 90% of the journal articles). GS mean citations per paper were almost twice as much as <i>WoS</i> , although there were disciplinary differences.	They concluded that because <i>WoS</i> includes less than half of the journals, papers and citations found by GS, it is reasonable to use GS for impact assessment of scholars in Business and Management. " <i>Web of Science</i> should not be used for measuring research impact in management" (Page: 613)
Kousha, Thelwall & Rezaie (2011)	1,000 books submitted to the 2008 UK <i>Research Assessment Exercise (RAE)</i> in seven book-based disciplines (Archaeology, Law, Politics and International Studies, Philosophy, Sociology, History, and Communication, Cultural and Media Studies)	<i>Google Scholar</i> citations to books were 3.2 times more common than <i>Scopus</i> citations and their medians were more than three times as high as <i>Scopus</i> median citations (medians of 13 and 4 respectively). There were strong correlations between GS and <i>Scopus</i> citations to books (ranging from 0.744 in history to 0.833 in sociology). Based on a sample of 100 books, GS retrieved 84% unique citations that were not in <i>Scopus</i> , whereas the corresponding figure for <i>Scopus</i> was 45%.	In terms of practical implications for the UK, "the absence of a plan to use citation information to inform expert reviewers about the impact of research outputs in the REF in the Arts, Humanities and a number of other panels... may be a drawback in quality assessment of UK research because of the difficulty in assessing large numbers of books." (Page: 16)
Amara & Landry (2012)	Faculty members in Canadian Business schools	For GS the mean number of publications (21.6), citations (271.5), and the h-index (4.6) were much higher than <i>WoS</i> (5, 50.8 and 1.9, respectively). High significant correlations between <i>WoS</i> and GS were found for contributions (0.793), citations (0.819), and h-indices (0.815).	In the field of Business and Management, universities or other agencies "should complement the data provided in <i>WoS</i> with those provided in GS." (Page: 554)
De Groot & Raszewski (2012)	The publications of 30 College of Nursing faculty	h-indexes extracted from GS, <i>WoS</i> and <i>Scopus</i> strongly correlated with each other (0.835 for GS, <i>WoS</i> and 0.830 for GS and <i>Scopus</i> and 0.869 for <i>WoS</i> and <i>Scopus</i>). GS provided the highest h-indexes and more unique citations than <i>Scopus</i> and <i>WoS</i> (1312, 250 and 93 unique citations, respectively).	"More than one tool should be used to calculate the h-index for nursing faculty because one tool alone cannot be relied on to provide a thorough assessment of a researcher's impact. If nursing researchers are interested in the most comprehensive individual h-index, several databases should be searched to obtain the most comprehensive list of citing articles." (Page: 391)
Minasny, Hartemink, McBratney & Jang (2013)	340 early-career and highly-cited soil researchers from all over the world.	The number of papers and citations to them in GS were 2.3 and 1.9 times higher than for <i>WoS</i> for soil researchers. High correlation between the h index of the researchers using GS, <i>WoS</i> and <i>Scopus</i> .	"There is a large difference between the number of citations, number of publications and the h index using the three databases." (No page, online)
De Winter, Zadpoor & Dodou (2014)	Two highly-cited classic articles and 56 articles from various subjects.	The retroactive growth of GS citation (median of 170%) was considerably higher than <i>WoS</i> (median of 2%). The actual growth of GS was also slightly higher than <i>WoS</i> (54% and 41%, respectively).	"GS has exhibited a striking retroactive expansion, considerably increasing its coverage of scientific literature as compared to 1 year after its inception. It is possible that GS fully covers <i>WoS</i> in the foreseeable future. However, improved metadata, more sophisticated search functions, and a stricter control against citation manipulation are challenges for GS yet to be met." (Page: 1562)