CWTS
Meaningful metrics

Bibliometrics for Research Management and Research Evaluation

A Brief Introduction

Universiteit Leiden

Bibliometrics for Research Management and Research Evaluation

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Ludo Waltman

Ed Noyons

March 2018

CWTS BV
P.O. Box 905
2300 AX Leiden, The Netherlands
Tel. +31 71 527 3909
Fax +31 71 527 3911
E-mail info@cwts.leidenuniv.nl

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Preface

The use of bibliometrics in research management and research evaluation is widespread. Consequently, a strong need has emerged for information about the application of bibliometrics in this context. Our center, the Centre for Science and Technology Studies (CWTS) at Leiden University, has a long tradition in providing bibliometric training and education. By bringing together the most essential information about the use of bibliometrics in research management and research evaluation, the present report serves to anchor the knowledge our center has developed over the years.

This report is intended for anyone with a professional interest in the application of bibliometrics in the context of research management and research evaluation. Target audiences include policy makers, research managers, and their support staff at research institutions and research funders, as well as university librarians and individual researchers. The report offers a brief introduction into the use of bibliometrics to support research management and research evaluation. It covers the most important topics, but does not aim to be comprehensive. References to other sources are provided for more detailed information.

We hope that this report will contribute to an improved understanding of the use of bibliometrics in research management and research evaluation. Feedback on the report will be greatly appreciated. If you have any comments or suggestions for improvements, please do not hesitate to contact us.

We gratefully acknowledge the feedback provided by our colleagues at CWTS on an earlier version of this report. We also acknowledge funding provided by the Austrian Science Board to support the work on this report.

Ludo Waltman
Deputy director
CWTS

Ed Noyons
Operational director
CWTS BV

1 Introduction

Bibliometrics is the quantitative analysis of written documents. It is frequently used to analyze scientific and scholarly publications. Researchers may for instance use bibliometrics in order to get an overview of their research field and of the connections with neighboring research areas. Bibliometrics is also often used in research management and research evaluation. This application of bibliometrics is our concern in the present report. The report is based on the longstanding experience of our center, the Centre for Science and Technology Studies (CWTS) at Leiden University, with the use of bibliometrics in research management and research evaluation (see Box 1).

Box 1. Centre for Science and Technology Studies (CWTS)

The Centre for Science and Technology Studies (CWTS) is an interdisciplinary research institute at Leiden University that studies scientific research and its connections to technology, innovation, and society. CWTS is a world-leading center of expertise on bibliometrics and scientometrics. It extensively studies the use of bibliometrics and scientometrics in research management and research evaluation.

CWTS BV is a company owned by Leiden University that offers bibliometric and scientometric analyses to support research management and research evaluation. Analyses performed by CWTS BV are for instance used by universities and other research organizations, research funders, governments, and scientific publishers, mostly in Europe but also elsewhere in the world. CWTS BV also provides consultancy and training in the areas of bibliometrics, scientometrics, and research evaluation.

For more information, visit www.cwts.nl and www.cwtsbv.nl.

Research management involves complex decision making, for instance about setting research priorities and allocating resources. Bibliometrics offers quantitative information that can be used to support decision making in a research management context. This information is often provided by quantitative indicators (sometimes also referred to as 'metrics', although in this report we will not use this term). The journal impact factor and the h-index are probably the best-known examples of such indicators. However, bibliometric information can also be made available in other ways, for instance by presenting lists of influential publications or by presenting information in graphs and other types of visualizations.

Bibliometric indicators

In a bibliometric analysis, we are often interested in obtaining quantitative measurements of concepts such as scientific output, scientific impact, or scientific collaboration. Exact measurements usually cannot be obtained. Instead, we typically work with indicators that provide a proxy of the concept of interest. For instance, indicators based on citation counts are usually interpreted as proxies of scientific impact. They do not provide exact measurements of scientific impact, but they do offer approximate information about the scientific impact of publications, researchers, or research institutions. Indicators of scientific output and scientific impact are the best-known bibliometric indicators, but bibliometric indicators can also be used to provide other types of information, for instance related to scientific collaboration, mobility, interdisciplinarity, gender, and open access publishing.

When using bibliometric indicators, it is essential to keep in mind that indicators do not usually provide an exact measurement of the concept of interest, but can only provide approximate information. This is one of the reasons why important research management decisions should not be made based solely on bibliometric indicators. Bibliometric indicators provide relevant information that is often helpful in supporting decision making. However, for most decisions the information provided by bibliometric indicators is too limited to rely on this information exclusively.

Beyond bibliometrics

Bibliometric information can be seen as one element within a broader range of information sources available to support decision making in a research management context. Relevant information can for instance also be obtained from peer review as well as from other quantitative sources, such as data on research funding and research staff and altmetric data. However, a discussion of these information sources is beyond the scope of this report.

Organization of this report

This report provides a brief introduction into the use of bibliometrics in research management and research evaluation. Chapter 2 discusses the most important data sources available for bibliometric analyses. Chapters 3 and 4 offer an overview of different types of bibliometric analyses, focusing in particular on analyses of scientific impact. Finally, Chapter 5 addresses the responsible use of bibliometrics.

Summary

- Bibliometric information can be made available in different ways, but most often quantitative indicators are used.
- Bibliometric indicators provide approximate information. They do not offer an exact measurement of a concept of interest.
- Bibliometric information can be seen as one element within a broader range of information sources available to support research management and research evaluation.

Further reading

Moed, H.F. (2017). *Applied evaluative informetrics*. Springer.

Sugimoto, C.R., & Larivière, V. (2018). *Measuring research: What everyone needs to know*. Oxford University Press.

2 Bibliometric data sources

Bibliometric analyses require a bibliometric data source. Simple analyses can sometimes be carried out using a research institution's internal data sources, for instance using data extracted from a university's internal information system. In most cases, however, an external data source is needed. Web of Science, produced by Clarivate Analytics, and Scopus, produced by Elsevier, are the two most commonly used bibliometric data sources. Google Scholar is also used quite frequently. In addition, bibliometric analyses that are restricted to a particular scientific field sometimes rely on a field-specific data source, such as INSPIRE (high energy physics), MathSciNet (mathematics), PsycINFO (psychology), or PubMed (biomedical research and life sciences). Similarly, bibliometric analyses that focus on a particular region may use a data source oriented specifically on that region. Examples of such data sources include the Chinese Science Citation Database, the Russian Science Citation Index, and the SciELO Citation Index. Interesting new data sources that can potentially be of value for bibliometric analyses are Microsoft Academic and Crossref. However, at the moment the use of these new data sources is still in an early stage and therefore experience with them is still quite limited.

Web of Science and Scopus

Web of Science consists of a number of citation indices. The most commonly used citation indices are part of the Web of Science Core Collection. This includes the Science Citation Index Expanded, the Social Sciences Citation Index, the Arts & Humanities Citation Index, and the Emerging Sources Citation Index. These indices cover scientific journals in the sciences, social sciences, and arts and humanities. In addition, the Conference Proceedings Citation Index and the Book Citation Index, which cover conference proceedings and books, are also included in the Web of Science Core Collection. Like Web of Science, Scopus covers journals, conference proceedings, and books in the sciences, social sciences, and arts and humanities. Although Web of Science and Scopus provide a broad coverage of scientific and scholarly literature, it is important to be aware that especially in the social sciences and humanities their coverage is limited. Coverage of conference proceedings and books also is far from complete.

Web of Science and Scopus both require a subscription. Subscribers have access to the data sources through a web interface. These web interfaces can be used to search for scientific and scholarly literature and also to perform simple small-scale bibliometric analyses. However, they are not suitable for carrying out large-scale bibliometric analyses. Such analyses can be performed using InCites and SciVal, commercial bibliometric analysis tools that make use of, respectively, Web of Science and Scopus data. There is also the possibility of performing large-scale bibliometric analyses based directly on Web of Science or Scopus data, but this requires a special license that provides direct access to the data. CWTS for instance has a license that provides direct access to Web of Science data for carrying out large-scale bibliometric analyses.

Google Scholar

Google Scholar is an online search engine for scientific and scholarly literature. It can also serve as a data source for bibliometric analyses. Compared to Web of Science and Scopus, Google Scholar has two key advantages. One advantage is that Google Scholar is freely available. No subscription is required. The other advantage is that Google Scholar offers a more comprehensive coverage of scientific and scholarly literature. This is important especially for bibliometric analyses in computer science, the social sciences, and the humanities, and also for bibliometric analyses oriented not only on international scientific and scholarly literature but also on national and regional literature. For such analyses, Web of Science and Scopus provide only limited coverage, while the coverage of Google Scholar is more comprehensive.

However, Google Scholar also has some major limitations. First of all, it lacks transparency. Very little information is available on what is and is not covered by Google Scholar. Second, Google Scholar data is of lower quality than Web of Science and Scopus data. Duplicate records for instance represent an important problem in Google Scholar. Web of Science and Scopus also suffer from data quality problems, but their data is of significantly higher quality than data in Google Scholar. Researchers can also manipulate Google Scholar data more easily than Web of Science and Scopus data, in particular by making fake publications available online. Finally, although Google Scholar has a more comprehensive coverage of scientific and scholarly literature than Web of Science and Scopus, it is very difficult to use Google Scholar for large-scale bibliometric analyses. Google Scholar does not provide large-scale access to its data.

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Summary

- Web of Science, Scopus, and Google Scholar are the most commonly used bibliometric data sources.
- Large-scale analyses based on Web of Science or Scopus can be performed using InCites or SciVal. Alternatively, direct access to Web of Science or Scopus data is required.
- Google Scholar is freely available and provides a more comprehensive coverage of the scientific and scholarly literature. However, Google Scholar lacks transparency, suffers from data quality problems, and is very difficult to use for large-scale analyses.

Further reading

Halevi, G., Moed, H., & Bar-Ilan, J. (2017). Suitability of Google Scholar as a source of scientific information and as a source of data for scientific evaluation—Review of the literature. *Journal of Informetrics*, *11*(3), 823–834.

Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: A comparative analysis. *Scientometrics*, *106*(1), 213–228.

3 Bibliometric analyses

Bibliometrics can be used for a broad range of problems in research management and research evaluation. It can for instance be applied to support strategic decision making by the management of a research institution, to support the evaluation of research institutes and research groups, or to provide information for assessing candidates for a scientific position. In many cases, bibliometric information is made available to peer reviewers, resulting in so-called informed peer review. Bibliometric information can also be used to define indicators for allocating research funding.

Types of information

A bibliometric analysis can yield different types of information. Important types of information include:

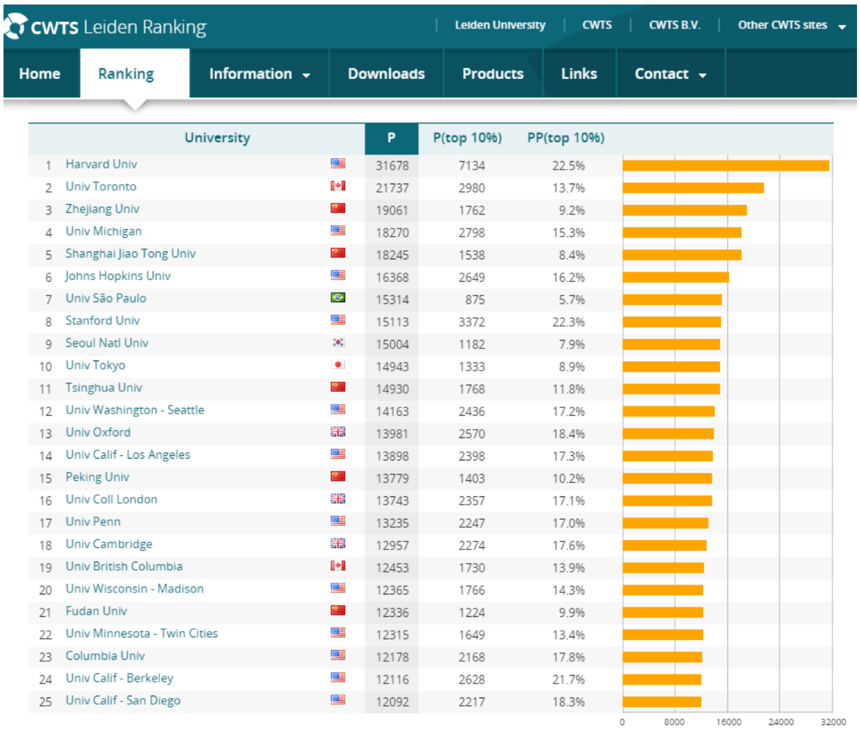
- *Scientific output*. Information about the number of publications produced by a research unit.
- *Scientific impact*. Information about the number of citations that publications have received.
- *Scientific collaboration*. Information about co-authored publications, focusing for instance on national and international collaboration or on university-industry collaboration.
- *Mobility*. Information about researchers that change their affiliation.
- *Interdisciplinarity*. Information about the interdisciplinarity of publications, usually based on the fields that are cited by a publication.
- *Gender*. Information about the gender of the authors of publications.
- *Open access publishing*. Information about the open access status of publications, distinguishing for instance between gold open access, green open access, and no open access.

Because bibliometric indicators of scientific impact play a prominent role in many research evaluations, we discuss these indicators in more detail in the next chapter.

Level of detail

The level of detail at which information is presented in a bibliometric analysis can be adjusted to the objective of the analysis. Strategic decision making at the level of an entire research institution requires a high-level overview that may be best served by a limited set of quantitative indicators, perhaps complemented with time trends and breakdowns by scientific field. Such a high-level overview is for instance provided in the CWTS Leiden Ranking (see Box 2). Decision making at lower levels within an organization may benefit from richer bibliometric analyses in which quantitative indicators are complemented with other more in-depth types of bibliometric information, for instance by providing bibliometric visualizations that offer more detailed insights. Likewise, when comparing candidates for a scientific position, it may be helpful to have a comprehensive bibliometric profile of each candidate, which presents not only quantitative indicators but also links these indicators to the underlying bibliometric information. For instance, the profile does not just report the number of highly cited publications of a candidate, but also presents a list of these publications, thereby enabling a more substantive evaluation of the publications.

Box 2. CWTS Leiden Ranking



	University	P	P(top 10%)	PP(top 10%)
1	Harvard Univ	31678	7134	22.5%
2	Univ Toronto	21737	2980	13.7%
3	Zhejiang Univ	19061	1762	9.2%
4	Univ Michigan	18270	2798	15.3%
5	Shanghai Jiao Tong Univ	18245	1538	8.4%
6	Johns Hopkins Univ	16368	2649	16.2%
7	Univ São Paulo	15314	875	5.7%
8	Stanford Univ	15113	3372	22.3%
9	Seoul Natl Univ	15004	1182	7.9%
10	Univ Tokyo	14943	1333	8.9%
11	Tsinghua Univ	14930	1768	11.8%
12	Univ Washington - Seattle	14163	2436	17.2%
13	Univ Oxford	13981	2570	18.4%
14	Univ Calif - Los Angeles	13898	2398	17.3%
15	Peking Univ	13779	1403	10.2%
16	Univ Coll London	13743	2357	17.1%
17	Univ Penn	13235	2247	17.0%
18	Univ Cambridge	12957	2274	17.6%
19	Univ British Columbia	12453	1730	13.9%
20	Univ Wisconsin - Madison	12365	1766	14.3%
21	Fudan Univ	12336	1224	9.9%
22	Univ Minnesota - Twin Cities	12315	1649	13.4%
23	Columbia Univ	12178	2168	17.8%
24	Univ Calif - Berkeley	12116	2628	21.7%
25	Univ Calif - San Diego	12092	2217	18.3%

The CWTS Leiden Ranking is a bibliometric ranking of about 900 major universities worldwide. The Leiden Ranking is produced annually by CWTS based on data from Web of Science. It offers bibliometric indicators of scientific output, impact, and collaboration. A breakdown of the bibliometric statistics is provided at the level of five broad fields of science, and the statistics are presented in three different ways, referred to as the list view, the chart view, and the map view. The Leiden Ranking is available at www.leidenranking.com.

Bibliometric visualizations

Bibliometric visualizations offer a powerful way to present more detailed information in a bibliometric analysis. Visualizations may for instance provide a geographical perspective (e.g., bibliometric indicators at the level of countries or institutions presented in a geographical map) or a network perspective (e.g., co-authorship networks or citation networks, visualized for instance using the VOSviewer software developed at CWTS; see Box 3). When dealing with large numbers of publications, an overview of the content of the publications can be obtained by presenting a visualization of the most important terms occurring in the titles and abstracts of the publications. Moreover, using so-called overlay visualization techniques, it is possible to include additional information in such a visualization, for instance to show developments over time (see Box 3).

Summary

- Examples of applications of bibliometrics in research management and research evaluation include supporting strategic decision making, supporting the evaluation of research institutes and research groups, informing the assessment of candidates for a scientific position, and allocating research funding.
- A bibliometric analysis may provide information about scientific output, scientific impact, and scientific collaboration as well as a number of other types of information.
- Depending on the objective of a bibliometric analysis, the information that is provided may range from a limited set of quantitative indicators to a comprehensive bibliometric profile.
- Bibliometric visualizations offer a powerful way to present more detailed information in a bibliometric analysis.

Further reading

Van Eck, N.J., & Waltman, L. (2014). Visualizing bibliometric networks. In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), *Measuring scholarly impact: Methods and practice* (pp. 285–320). Springer.

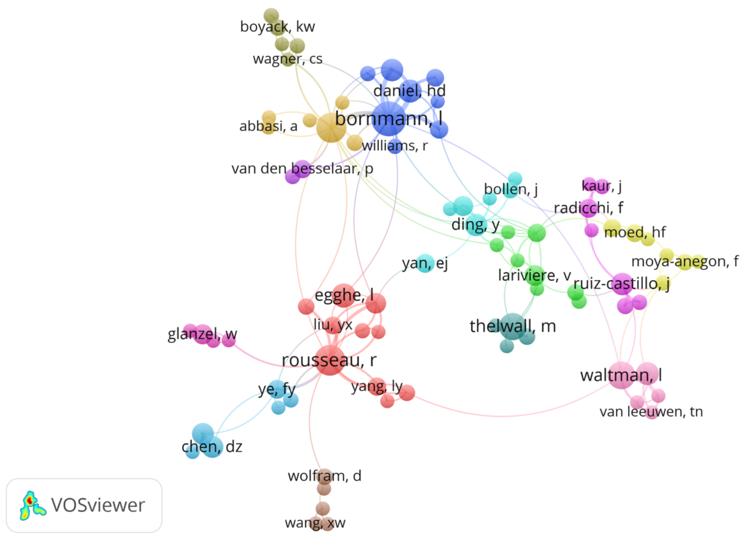
Van Raan, A.F.J. (2018). Measuring science: Basic principles and application of advanced bibliometrics. In W. Glänzel, H.F. Moed, U. Schmoch, & M. Thelwall (Eds.), *Handbook of science and technology indicators*. Springer.

Waltman, L., Calero-Medina, C., Kosten, J., Noyons, E.C.M., Tijssen, R.J.W., Van Eck, N.J., ... Wouters, P. (2012). The Leiden Ranking 2011/2012: Data collection, indicators, and interpretation. *Journal of the American Society for Information Science and Technology*, *63*(12), 2419–2432.

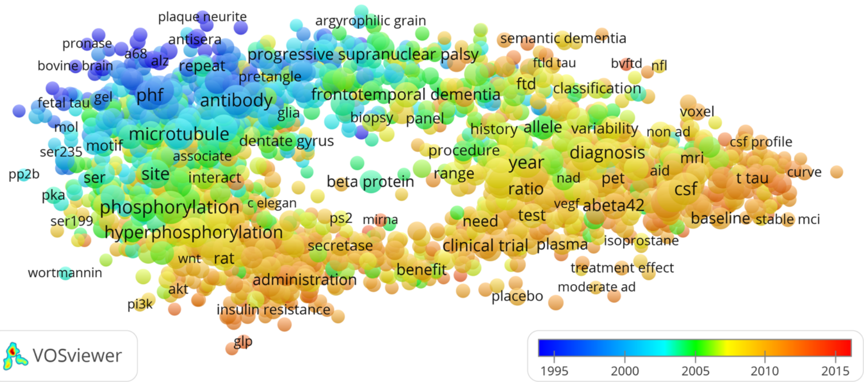
Box 3. Bibliometric visualization using VOSviewer

VOSviewer is a popular software tool for producing bibliometric visualizations. It is developed by CWTS and is freely available at www.vosviewer.com.

The figure below presents a VOSviewer visualization of a co-authorship network. Each circle represents a researcher. The size of a circle indicates the number of publications of a researcher. Lines indicate co-authorship links between researchers. Colors designate clusters of researchers that are strongly connected to each other by co-authorship links.



A second VOSviewer visualization is presented below. This visualization shows the most important terms occurring in the titles and abstracts of publications on Alzheimer’s disease. Terms that are located close to each other in the visualization tend to occur together in a large number of publications. These terms can therefore be considered to be strongly related. Colors show the development of research on Alzheimer’s disease over time. Terms colored blue occur mainly in older publications, while terms colored yellow, orange, or red occur mainly in more recent publications.



4 Bibliometric indicators of scientific impact

Scientific impact is typically analyzed by counting the number of citations that publications have received. There are many different impact indicators, with the journal impact factor and the h-index being the best-known examples. Citations occur for a variety of reasons. Some citations indicate that the citing publication builds on the cited publication. These citations may be seen as an acknowledgment of the impact of the cited publication on the citing one. Negative citations are of an opposite nature. They reflect the citing publication's critical perspective on the cited publication. However, many citations are neither positive nor negative. These citations often reflect a more superficial connection between the citing and the cited publication. They are sometimes referred to as perfunctory citations. Given the diversity of citations, citation counts provide only an approximate indication of scientific impact.

Citation counts are also sometimes interpreted as indicators of scientific quality rather than scientific impact. However, this interpretation is of an even more approximate nature. The quality of a publication can be expected to influence the number of citations the publication will receive, but a high-quality publication on an obscure topic is likely to receive fewer citations than an average-quality publication on a popular topic.

Types of impact indicators

Impact indicators can be classified in many different ways. An essential distinction is between size-dependent and size-independent impact indicators. Size-dependent impact indicators reflect the total scientific impact of a research unit's publications, while size-independent impact indicators reflect the average scientific impact per publication. A further distinction is between impact indicators that count citations directly and impact indicators that first identify highly cited publications and then count these publications.

Table 1 summarizes the above classification of impact indicators. The different types of impact indicators are labeled according to the terminology used at CWTS. The simplest impact indicators are based on direct counts of citations. These are the size-dependent total citation score and the size-independent mean citation score.

The total citation score equals the total number of citations received by a research unit's publications, while the mean citation score equals the average number of citations received per publication. Impact indicators based on counting highly cited publications first require the choice of the threshold n that determines whether a publication is classified as highly cited or not. A publication is classified as highly cited if it has received at least n citations. The value of n is variable and could for instance be set at 10, 20, 50, or 100, depending on how strict one would like to be in classifying publications as highly cited. After choosing the threshold n, the number and the proportion of a research unit's highly cited publications can be calculated. These indicators provide respectively a size-dependent and a size-independent perspective on the scientific impact of the research unit's publications.

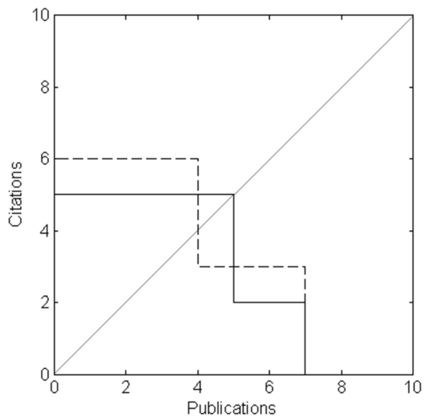
Table 1. Classification of impact indicators.

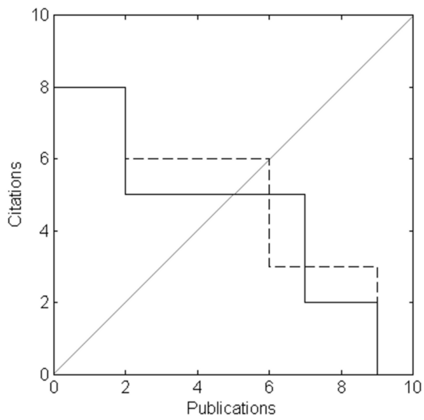
	Size-dependent	Size-independent
Citations	Total citation score TCS	Mean citation score MCS
Highly cited publications	Number of highly cited pub. P(≥ n cit.)	Prop. of highly cited pub. PP(≥ n cit.)

Compared to impact indicators based on a direct count of citations, impact indicators based on counting highly cited publications are less sensitive to publications that have received a very large number of citations. Impact indicators based on counting highly cited publications are therefore more robust, which is often seen as an advantage of these indicators.

The classification of impact indicators presented in Table 1 includes some commonly used indicators, but many indicators are not included. An example is the h-index. The h-index of a research unit equals the largest number h such that the research unit has h publications that have received at least h citations each. The h-index is a size-dependent impact indicator. Like the number of highly cited publications, it is relatively insensitive to publications that have received a very large number of citations. CWTS normally does not use the h-index. This is because of its inconsistency. When two research units make the same improvement in terms of publications and citations, their ranking relative to each other according to the h-index may reverse. The inconsistency of the h-index is illustrated in Box 4.

Box 4. Inconsistency of the h-index





The above figures illustrate the inconsistency of the h-index. The solid and the dashed line indicate the number of citations received by the publications of, respectively, research unit A and research unit B. Publications are presented in decreasing order of their number of citations. The left figure shows the initial situation, in which the h-index of research units A and B equals, respectively, 5 and 4. The right figure shows the situation after research units A and B have both published 2 new publications, each with 8 citations. In the new situation, the h-index of research units A and B equals, respectively, 5 and 6. Hence, compared to the initial situation, the two research units have made the same improvement in terms of publications and citations, but their ranking relative to each other according to the h-index has reversed. This shows why the h-index is inconsistent.

Normalization for scientific field and publication age

Different scientific fields have different citation practices. Because of this, there are large differences between fields in citation density, that is, in the average number of citations received per publication. For instance, the average number of citations received by publications in mathematics is about an order of magnitude smaller than the average number of citations received by publications in some fields in the life sciences. When a bibliometric analysis of scientific impact covers multiple fields, it is often desirable to correct for differences between fields in citation density. Performing such a correction is called field normalization. Field normalization is usually carried out by comparing the number of citations of a publication to the number of citations of other publications in the same field.

Older publications have had more time to be cited than more recent publications. On average, older publications therefore tend to have received more citations than more recent publications. Again, a normalization can be performed to correct for this. Such a normalization is carried out by comparing the number of citations received by a publication to the number of citations received by other publications from the same year.

Table 2 presents the normalized counterparts of the non-normalized impact indicators listed in Table 1. The indicators are again labeled according to the terminology used at CWTS. The total and the mean normalized citation scores equal, respectively, the total and the average normalized number of citations received by a research unit's publications. A publication's normalized number of citations is calculated by dividing the number of citations of the publication by the average number of citations of all publications in the same field and from the same year. In the case of impact indicators based on counting highly cited publications, a publication is classified as highly cited if it belongs to the top *x*% most highly cited publications of its field and its year. The focus is often on the top 10% most highly cited publications, but it is also possible to consider for instance the top 1%, top 5%, or top 50% most highly cited publications.

Table 2. Classification of normalized impact indicators.

	Size-dependent	Size-independent
Citations	Total normalized citation score TNCS	Mean normalized citation score MNCS
Highly cited publications	Number of highly cited pub. P(top *x*%)	Prop. of highly cited pub. PP(top *x*%)

The use of normalized impact indicators involves some choices. Normalization for scientific field requires the choice of a field classification system. In practice, the journal categories in Web of Science and Scopus are often used as a field classification system. An alternative is to define fields at the level of individual publications instead of journals. This can for instance be done by algorithmically grouping publications into fields based on citation relations. A publication-level classification system will typically be more fine-grained than a journal-level classification system. Normalization based on a publication-level classification system can therefore be expected to yield more accurate results. However, normalization based on a journal-level classification system may be more transparent and easier to understand.

Another choice that needs to be made relates to the minimum age of publications that are included in the calculation of normalized impact indicators. Very recent publications usually have received no or almost no citations. Normalization for publication age does not give meaningful results for these publications. Very recent publications (e.g., less than one year old) are therefore often excluded from the calculation of normalized impact indicators.

Credit allocation

In most scientific fields, a large majority of publications are co-authored by multiple researchers, often also affiliated to multiple research institutions and residing in multiple countries. This leads to the problem of credit allocation. When a publication is co-authored by multiple research units, how should the credits of the publication be allocated to the different research units?

The two most commonly used approaches for addressing the issue of credit allocation are referred to as the full and the fractional counting approach. In the full counting approach, the credits of a publication are fully allocated to each of the co-authoring research units. In the fractional counting approach, the credits of a publication are fractionally allocated to each of the co-authoring research unit. For instance, in the case of a publication co-authored by three research units, each unit receives one-third of the credits of the publication.

Table 3 illustrates the full and the fractional counting approach in the calculation of the total and the mean citation score of a research unit. We are interested in research unit A. This research unit has authored three publications. It is the only author of publication 1, while it has co-authored publications 2 and 3 with other research units. For each publication, Table 1 reports the number of citations received by the publication. In the full counting approach, the three publications and their citations are fully assigned to research unit A. This results in a total and a mean citation score of, respectively, 17 and 17 / 3 = 5.67 for research unit A. In the fractional counting approach, publications and citations are allocated fractionally to research unit A. Consider for instance publication 2. As can be seen in Table 3, this publication is co-authored by two research units, A and B, and therefore the publication is allocated to research unit A with a weight of 1 / 2 = 0.50. The publication has received 3 citations, which are allocated to research unit A with a weight of 0.50, yielding 0.50 × 3 = 1.50 citations for research unit A. By performing these calculations for all three publications, the fractional counting approach results in a total citation score of 10.17 and a mean citation score of 10.17 / 1.83 = 5.55.

Table 3. Example illustrating the full and the fractional counting approach.

	Co-authoring research units	No. of citations	Fractional publication allocation	Fractional citation allocation
Publication 1	A	6	1.00	6.00
Publication 2	A, B	3	0.50	1.50
Publication 3	A, B, C	8	0.33	2.67
Total		17	1.83	10.17

Opting for either the full or the fractional counting approach should be informed by the requirements of a particular analysis. However, when working with normalized impact indicators, the fractional counting approach has an important advantage over the full counting approach. Using the fractional counting approach, normalized impact indicators correct not only for differences between fields in citation density, but also for differences between fields in collaboration practices. The use of the fractional counting approach is recommended especially for analyses in which normalized impact indicators are applied at high levels of aggregation, for instance at the level of countries or institutions.

In addition to the full and the fractional counting approach, there are also other approaches that can be taken to address the issue of credit allocation. Most of these approaches rely on the order of the authors in the author list of a publication. This may involve allocating the credits of a publication mostly, or even exclusively, to the first or the last author of a publication, or to the corresponding author. However, there are no universal norms that determine the order of the authors in the author list of a publication, and relying on this order therefore always involves some uncertainty. Most importantly, different fields have different practices for determining the order of authors. In some fields, in particular in economics, high energy physics, and mathematics, it is common practice to order authors alphabetically. Clearly, credit allocation in these fields should not be based on the order of authors.

Author self-citations

Author self-citations are often excluded from the calculation of impact indicators. Many self-citations are given for perfectly valid reasons. Nevertheless, if self-citations are not excluded from the calculation of impact indicators, they can be used to manipulate the indicators in a relatively easy way. Such manipulation can be prevented by excluding self-citations.

Impact indicators for journals

Indicators of scientific impact can also be calculated for journals. The best-known example of an impact indicator for journals is the journal impact factor. The impact factor of a journal is essentially determined by calculating the average number of citations received in a certain year by publications that have appeared in the journal in the two preceding years. Journal impact factors, calculated by Clarivate Analytics based on Web of Science data, are published in the Journal Citation Reports. Other examples of impact indicators for journals are the 5-year impact factor, the eigenfactor, and the article influence score, which are also published in the Journal Citation Reports, and CiteScore, SJR, and SNIP, which are made available by Elsevier based on Scopus data.

Journal impact indicators are often used not only for evaluating journals, but also for evaluating individual publications in a journal or the research units by which individual publications have been authored. This is a controversial way of using journal impact indicators. Within a journal, there are typically large differences between publications in the number of citations received, and therefore it is often considered inappropriate to use a journal impact indicator for evaluating individual publications in a journal. The San Francisco Declaration on Research Assessment (www.ascb.org/dora/), an influential statement that has been signed by a large number of individuals and organizations, for instance rejects the use of the journal impact factor and other journal impact indicators at the level of individual publications.

CWTS recognizes that the journal impact factor often plays a too dominant role in research management and research evaluation. An obsessive focus on the journal impact factor, or on any other bibliometric indicator, is harmful. However, CWTS does not reject the use of journal impact indicators for evaluating individual publications and their authors. Journals have different standards for selecting the research they publish. As a result, some journals on average publish higher-impact research than other journals. Journal impact indicators provide information about the average impact of the publications in a journal. The average impact of the publications in a journal can serve as a proxy of the impact of an individual publication. Because of this, journal impact indicators can be helpful tools for evaluating individual publications in a journal.

In addition to the journal impact indicators mentioned above, other journal impact indicators can be used as well. For instance, the mean normalized citation score, discussed earlier in this chapter, can also be calculated for journals. The publications of a research unit can then be evaluated based on the mean normalized citation scores of the journals in which they have appeared. This results in an indicator that is referred to as the mean normalized journal score at CWTS.

Summary

- Citation counts provide approximate information about the scientific impact of publications.
- Impact indicators can be classified as size-dependent or size-independent. In addition, they can be classified based on whether they count citations or highly cited publications.
- The h-index is inconsistent. The indicator behaves counterintuitively in certain situations.
- Normalized impact indicators correct for differences between fields in citation density and for differences in the age of publications.
- Co-authorship of publications leads to the problem of credit allocation. Full and fractional counting are two approaches for dealing with this problem. Fractional counting corrects for differences between fields in collaboration practices.
- To prevent manipulation of impact indicators, author self-citations are often excluded from the calculation of the indicators.
- Journal impact indicators may provide helpful information to support research management and research evaluation, but these indicators should not play a too dominant role.

Further reading

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5 Responsible use of bibliometrics

Bibliometrics offers valuable information to support research management and research evaluation. However, this information should be used responsibly. The following eight principles can serve as guidelines for the responsible use of bibliometric information.

1 Be aware of the limited coverage of bibliometric data sources

Bibliometric data sources such as Web of Science and Scopus offer only a limited coverage of the scientific and scholarly literature. International journals in the sciences are typically well covered, but coverage of national journals, journals in the social sciences and humanities, and conference proceedings and books is much more limited. One should be aware of these limitations when performing bibliometric analyses.

2 Acknowledge the importance of accurate data collection

Accurate data collection is essential for high-quality bibliometric analyses. Poor data collection may result in bibliometric analyses that provide incorrect or misleading conclusions. The efforts needed for accurate data collection should not be underestimated. In a research evaluation context, the units under evaluation should have the opportunity to verify the data collection.

3 Recognize that bibliometric analyses capture research performance only in a partial manner

It is essential to recognize that bibliometric analyses reflect only specific aspects of the performance of research units. For instance, citation statistics provide insight into the scientific impact of research units, but they do not capture the broader societal impact. Even scientific impact is captured only partly by citation statistics, since these statistics consider only scientific impact that results from publications. Scientific impact resulting from other activities, such as curation of data sets and development of software tools, is not taken into account. Furthermore, bibliometric analyses focus on the outputs of the research process and typically do not consider the inputs. This for instance means that bibliometric analyses provide no insight into the productivity of research units.

4 Account for differences between scientific fields in publication, authorship, and citation practices

Different scientific fields have different publication, authorship, and citation practices. Publications in the life sciences for instance tend to have more authors and tend to receive more citations than publications in the social sciences. In bibliometric analyses that cover multiple fields, differences between fields should be carefully accounted for. This can be done by normalizing bibliometric indicators for field differences or by comparing research units to relevant benchmarks active in the same field.

5 Find an appropriate balance between transparency and analytical sophistication

Transparency of a bibliometric analysis helps to ensure that the analysis is interpreted correctly and facilitates a well-informed discussion about the outcomes of the analysis. Analytical sophistication, for instance the use of advanced field-normalized bibliometric indicators, has the potential to provide insights that are hard to obtain using more straightforward bibliometric approaches. However, an increase in analytical sophistication often causes a decrease in transparency. Bibliometric analyses therefore require a careful trade-off between transparency and analytical sophistication.

6 Embrace the value of multidimensional and contextualized bibliometrics

Bibliometrics is sometimes used as a tool for making one-dimensional performance measurements. When bibliometrics is used in this way, its value is limited. To take full advantage of bibliometric information, a multidimensional and contextualized approach to bibliometrics needs to be adopted. Such an approach recognizes that research management and research evaluation benefit from being supported by diverse types of bibliometric information. It also recognizes the necessity of contextualizing bibliometric information (e.g., by explicitly linking the information to the underlying data) in order to enable in-depth interpretation of the information.

7 Use bibliometrics as part of a broader range of information sources

Bibliometrics offers just one source of information to support research management and research evaluation. There are other sources of information as well. In addition to quantitative sources, such as data on research funding and research staff and altmetric data, this also includes peer review by scientific experts. The use of bibliometrics should be considered within this broader framework. The best way to support research management and research evaluation typically is to combine bibliometric information with other information sources.

8 Anticipate the effects of bibliometric analyses on the science system

The use of bibliometrics in research management and research evaluation is likely to influence the behavior of researchers and other actors in the science system. These actors may change their behavior both in intended and in unintended ways. It is important to anticipate these effects of the use of bibliometrics and to be aware that a strong reliance on bibliometrics may have undesirable consequences (e.g., researchers trying to improve their citation statistics in questionable ways).

Leiden Manifesto

The above principles for the responsible use of bibliometrics have partly been derived from the Leiden Manifesto, an influential statement presenting best practice guidelines for the proper use of quantitative indicators in research evaluations. The Leiden Manifesto is available at www.leidenmanifesto.org.

Summary

- Eight principles have been presented that can serve as guidelines for the responsible use of bibliometrics.

Further reading

Hicks, D., Wouters, P., Waltman, L., De Rijcke, S., & Rafols, I. (2015). The Leiden Manifesto for research metrics. *Nature*, *520*, 429–431.

Centre for Science and Technology Studies – Leiden University

Postal address

CWTS B.V.

P.O. Box 905

2300 AX Leiden

The Netherlands

Office address

Willem Einthoven Building

Kolffpad 1

2333 BN Leiden

The Netherlands

Contact info

Tel. +31 71 527 3909

Fax +31 71 527 3911

E-mail **info@cwts.nl**

www.cwts.nl