Chapter 5 / Capítulo 5

Applied bibliometrics. From data to publication (English Edition)
ISBN: 978-9915-9680-7-0
DOI: 10.62486/978-9915-9680-7-0.ch05

Bibliometric Indices / Índices Bibliométricos

5.1. Classification

Bibliometric indices are at the heart of quantitative analysis in science, technology, and innovation studies, providing standardized measures for evaluating the impact, productivity, and influence of scientific output. Their correct classification and interpretation are essential for drawing valid conclusions and avoiding the frequent errors that arise from mechanical applications without adequate contextualization. This chapter presents a comprehensive framework for understanding the taxonomy, calculation, and interpretation of the leading bibliometric indicators used in contemporary scientific evaluation.

Scientific Production Indicators quantify the volume of research results generated, providing an initial basis for evaluating scientific activity. The most basic metric is the total number of publications. A low count may be a symptom of limited productivity or a deliberate strategy to publish exclusively in high-impact journals, which involve more extensive review processes. Conversely, a high volume suggests high productivity, but it can also signal a possible fragmentation of results, where the findings of a single study are divided across multiple articles. The standards for what is considered "high" or "low" vary widely across disciplines and career stages.

To refine the measurement, the individual productivity index adjusts a researcher's contribution score by accounting for factors such as their position on the author list and the type of contribution. A low value on this index indicates majority participation as a co-author in secondary positions, suggesting a supporting role in projects. A high value, on the other hand, denotes frequent primary authorship (as first or last author), reflecting sustained intellectual leadership. Although there is no universal threshold, in many disciplines, a value above 0,7 on normalized scales is considered a substantial contribution and a sign of leadership.(1)

The collaboration index measures teamwork by averaging the number of co-authors per publication. A low value, close to 1, is characteristic of traditionally solitary fields such as philosophy or the humanities. A high value, which can exceed ten in areas such as particle physics or genomics, reflects eminently collaborative research. The interpretation of this indicator must take disciplinary norms into account, as multiple authorship responds to scientific traditions and methodological needs that differ significantly between fields of knowledge.(2)

Citation-based impact indicators assess the relative influence and importance of scientific publications by measuring how they are received and used by the academic community through the references they receive.

The total number of citations provides a crude measure of cumulative impact. However, its interpretation requires temporal and disciplinary normalization. A low value may indicate research that is uninfluential or highly specialized, while a high value suggests fundamental contributions that have resonated in the field. There is no universal standard, as several citations considered low in immunology could be exceptionally high in philosophy.

The h-index is a bibliometric indicator that balances a researcher's productivity with the impact of their work. It is calculated by ranking an author's publications by the number of citations received, in descending order.

The h-index corresponds to the point at which the order number of an article (h) coincides with the number of citations that article has received. For example, an h-index of 10 means that the author has 10 articles that have been cited at least 10 times each.

A low value may indicate a fledgling scientific career or a specialization in an area of study with a generally low citation rate. Conversely, a high h-index usually reflects an established career and the consistent production of work that has had a significant impact in its field.

To make a fairer comparison between researchers in different fields, the discipline-corrected h-index is used. It is calculated in several steps. First, the researcher's primary discipline is identified. Then, the average h-index for all researchers in that discipline is obtained from a standardized bibliographic database.

Finally, the researcher's individual h-index is divided by this reference average. The result is a value that indicates whether their impact is above or below the average for their specialized field.

As a reference, Hirsch proposed that, for active scientists, an h-index approximately equal to the number of years in their career (m) is characteristic of a "successful" researcher. A value around 2m would correspond to "outstanding researchers," while an $h \approx 3m$ would be associated with "truly unique scientists," always considering the particularities of each discipline.[3]

To complement this, the g-index gives greater weight to exceptionally cited publications, being more sensitive to the presence of seminal works within an author's output. A g-index value that is significantly higher than the h-index suggests that the researcher has one or more highly cited articles with an extraordinary impact. Finally, the m-index adjusts the h-index for years of research career, providing a measure of annualized impact productivity. An m value greater than 1 is considered very good, as it indicates that the researcher generates, on average, more than one "h" article per year.[3]

The m index adjusts the h index for years of research experience, with lower values indicating decreasing impact and higher values indicating sustained productivity.

Scientific Collaboration Indicators analyze the networks and patterns of cooperation between researchers, institutions, and countries, revealing the social dynamics behind knowledge production. The cooperation index calculates the percentage of publications with multiple authors. Low values may indicate individualistic work or be characteristic of traditionally solitary fields. Conversely, high values, often above 80 % in the experimental sciences, reflect eminently collaborative research, typical of modern science where collective authorship is the norm for addressing complex problems.

The international collaboration index measures the proportion of works with foreign co-authors. A low value is often indicative of a certain scientific isolation or a research approach with mainly local relevance. A high value, on the other hand, demonstrates active integration into global knowledge networks and is often correlated with greater impact. In institutional evaluations, the aim is usually to have this index exceed 30-40 %, with values above 50 % considered high. Similarly, the institutional collaboration index assesses the diversity of affiliations in publications, indicating the ability to establish strategic alliances beyond the institution.

Source Quality Indicators focus on evaluating the prestige and influence of scientific dissemination channels, such as academic journals, assuming that the quality of the publication vehicle reflects, to a certain extent, the quality of the articles it contains. The Impact Factor (IF), calculated annually in the Journal Citation Reports, measures the average frequency with which articles in a journal are cited in a specific period. Low values may correspond to highly specialized or regional journals. High values, on the other hand, typically reflect leading journals in their fields.

To overcome the limitations of IF, alternative metrics have been developed. The SCImago Journal Rank (SJR) reflects the prestige of citing journals and is more sensitive to the quality of citations received. CiteScore uses a broader citation window. Source Normalized Impact per Paper (SNIP) corrects for differences in citation practices between disciplines, where values below 1 indicate an impact below the average for their field and values above 1 indicate an effect above the average. These indicators should be used critically, avoiding inappropriate extrapolations at the article or individual researcher level.(4)

Influence and Leadership Indicators assess the specific role and actual contribution of a researcher within scientific networks, going beyond metrics of volume or raw impact. The individual h-index excludes self-citations to strictly measure external impact and recognition by peers outside the researcher's immediate circle. A low value on this index may indicate a high dependence on self-citations to maintain a citation profile or a limited impact. A high value, on the other hand, reflects strong external recognition.

The leadership index calculates the proportion of publications in which the researcher appears as a corresponding or first author, roles that typically denote a primary intellectual contribution. Low values suggest secondary or supporting roles in extensive collaborations, while high values indicate active leadership in projects. In advanced career stages, this index is expected to remain above 0,5 to reflect research independence. Complementarily, the originality index measures the diversity of cited sources; a high value indicates greater interdisciplinarity. An alternative to this, for the diversity of cited sources (interdisciplinarity): The Rao-Stirling Index is an established metric for measuring diversity and interdisciplinarity based on cited references.(5)

Composite and Normalized Indicators integrate multiple dimensions of scientific activity into comprehensive measures that enable fairer, more nuanced comparisons among researchers, institutions, or countries, while accounting for the particularities of each field. Field-Weighted Citation Impact (FWCI) is a key indicator that compares the citations received by a set of publications against the global average in their respective specific fields. A value of 1 represents exactly the expected impact for the global average. Values below 1 indicate an impact below expectations, while values above 1 indicate an impact above expectations.(6)

Excellence indicators identify the percentage of a researcher›s publications that are among the top 10 % most cited worldwide in their respective years and fields. This is a high-impact threshold. Low values, for example, below 5 %, suggest that contributions are in the average range. Conversely, high values, above 10 % or especially 15 %, indicate consistently influential and elite production, demonstrating a recurring ability to generate state-of-the-art research in their field. These indicators are handy for identifying exceptional performance.(7)

New emerging indicators broaden the traditional metric spectrum into complementary dimensions, capturing aspects such as immediate visibility, the sustainability of impact, and the diversity of the research footprint. The i10 index, popularized by Google Scholar, counts the number of publications with at least 10 citations. It provides an immediate measure of the influence of moderately influential works. A low value may indicate a predominance of very recent publications that have not yet accumulated citations, or a specialization in niche fields. A high value suggests several works that have achieved significant penetration in the literature.

The impact sustainability index assesses the temporal persistence of citations received by analyzing the decay curve of citations over time. Sharply declining values may indicate early obsolescence or that the research responds to passing trends. Stable or slowly declining values, on the other hand, indicate prolonged relevance and that the contributions remain helpful within the scientific community several years after publication, a sign of fundamental work. This index is crucial for distinguishing between transient and lasting impact.

The thematic diversity index is another indicator in this group that measures the variety of scientific areas in which a researcher publishes. Low values reflect high thematic specialization, with a deep focus on a well-defined field. High values indicate research versatility and an ability to contribute to multiple disciplines, which can be an advantage in interdisciplinary environments and is increasingly valued in solving complex problems that require integrative perspectives. A researcher with a diversified profile typically has an index above 0,5 on thematic entropy scales.

The responsible interpretation of any bibliometric index requires an understanding of its methodological foundations, technical limitations, and specific disciplinary context. No single indicator captures the multidimensionality of scientific impact, so its combined and critical use is essential for balanced evaluations.

Transparency in calculation methods, the selection of appropriate indicators for each evaluative purpose, and the consideration of complementary qualitative factors are crucial principles in the ethical application of bibliometrics to contemporary scientific evaluation. Each index should be understood as a particular lens that reveals specific aspects of the complex phenomenon of scientific communication, where its value emerges from the integrated, contextualized analysis of multiple metric perspectives.

5.2. Temporal Evolution of Bibliometric Indicators

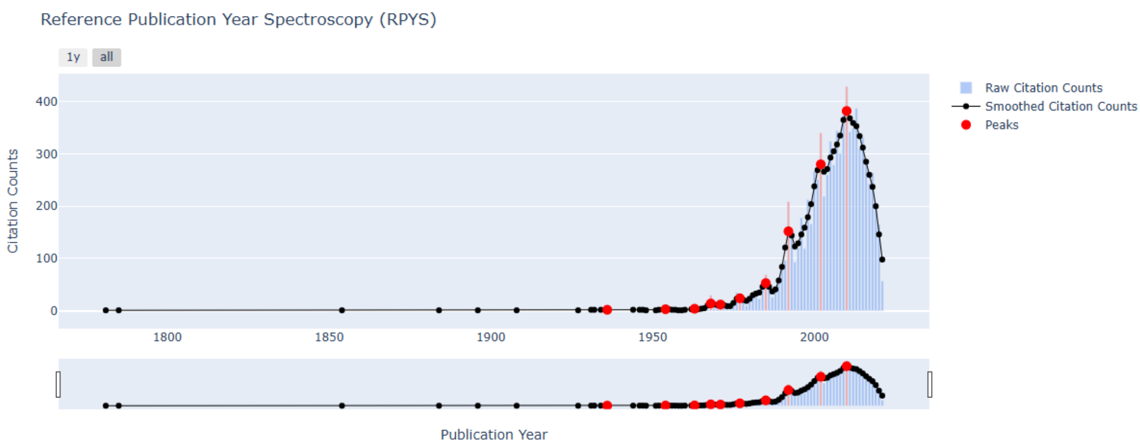

Figure 5.1. Example of a graph of citations/publications per year in spectroscopy

The temporal evolution of bibliometric indicators provides a dynamic perspective that is crucial for evaluating research trajectories, transcending the mere static snapshot offered by point values. Longitudinal analysis reveals patterns of professional development, publication strategies, and the sustained impact of scientific contributions. The interpretation of this evolution varies substantially across indicators, requiring careful contextualization within the researcher's career stage and the norms of their discipline.

In production indicators, an upward trend in the number of annual publications suggests expanding productivity, associated with the consolidation of a research group or the acquisition of funded projects. Conversely, a sustained decline may indicate a transition to more administrative roles, a deliberate strategy of quality over quantity, or difficulties in maintaining competitive activity. The evolution of the collaboration index, when it shows a progressive increase, usually reflects growing integration into broader and more complex scientific networks.

The trajectory of the h-index is particularly informative. Linear or accelerated growth in the early years of a career indicates successful scientific consolidation. During the mid-career stage, sustained growth is expected, while stabilization in the later stages may be natural. However, premature stagnation or decline could suggest a loss of scientific relevance. The m-index, when adjusted for years of activity, allows us to determine whether a researcher maintains a constant rate of impactful output or whether this rate dilutes over time.

In impact indicators, the evolution of the Field-Weighted Citation Impact (FWCI) shows how a researcher's work is received within their field. An upward trend indicates growing influence and that their recent work is receiving greater interest than their previous work. A downward trend, especially if it falls below 1, suggests that the research is not at the forefront of the field. Time windows should analyze the percentage of publications in the top 10 % of citations to identify whether excellence is being maintained, improving, or declining.

The sustainability of impact is visualized by the curve of cumulative citations over time for different publications. Seminal works exhibit a steady, steep growth curve, indicating prolonged relevance. Current works proliferate but may soon saturate, indicating temporary interest. A flat citation profile suggests limited influence. Analysis of the evolution of international collaboration, which shows an increase in its proportion, points to a progressive internationalization of the research profile, a factor highly valued in global evaluation contexts.

5.3. Combination of Bibliometric Indicators with Contextual Variables

The analytical power of bibliometric indicators is multiplied when they are systematically combined with contextual variables. These integrations transcend one-dimensional evaluation, enabling scientific activity to be dissected to answer complex questions about equity, mobility, specialization, and knowledge transfer. Each combination pursues a specific analytical goal, revealing structural patterns and underlying dynamics that would otherwise remain hidden in aggregate averages.

The combination of the journal's impact factor and the author's position and gender is used to identify potential gender biases in scientific communication. This triangulation allows us to investigate whether there are systematic differences in visibility and leadership, for example, whether male authors tend to publish as first or last authors in more prestigious journals more frequently than their female colleagues. A recurring finding across some fields is the overrepresentation of men as corresponding authors, suggesting barriers to access to positions of intellectual leadership. This approach is essential for designing evidence-based policies that promote equity in science.

The relationship between country of affiliation, international collaboration index, and normalized impact (FWCI) is used to assess the geostrategic position of national science and technology systems. A country with a high rate of international collaboration but a moderate FWCI could indicate a successful internationalization strategy that does not yet translate into global scientific leadership, suggesting a role more as a participant than as a driver. Conversely, a nation with an FWCI well above one and selective international collaboration indicates a position of scientific leadership and autonomy.

This combination is crucial for funding agencies seeking to calibrate their international cooperation policies.

Integrating researcher seniority (years since first publication) with the leadership index and thematic diversity allows for the study of career trajectories and the evolution of scientific interests. High seniority with a low leadership index may indicate a career spent mainly in support roles, while the same seniority with increasing thematic diversity suggests an evolution towards interdisciplinary interests.

This combination helps institutions understand and support different trajectories and patterns of intellectual mobility within their research staff.

The combination of document type (article, review, patent, conference proceedings) with the industrial collaboration index and citations received in patents sheds light on the mechanisms of knowledge transfer and innovation.

A high percentage of publications and conference proceedings, together with high industrial collaboration, suggests research oriented towards development and immediate application. In contrast, a profile dominated by basic research articles and reviews, even with high academic impact, may indicate a disconnect with productive sectors. This composite metric is vital for innovation policies.

Cross-referencing thematic specialization indicators with institutional origin (university, public research organization, hospital, company) and the centrality index in co-authorship networks allows for the mapping of knowledge ecosystems. An institution with a high specialization index and low centrality acts as a specialized but potentially isolated node. The same institution with high centrality is configured as an essential hub in that niche. These strategic combinations are indispensable for planning and informed decision-making in science policy at the macro and meso levels.

5.4. Practical calculation

5.4.1. With R/Bibliometrix (biblioAnalysis())

Calculating bibliometric indices with R and the Bibliometrix package is among the most robust and comprehensive methodologies currently available. The biblioAnalysis() function is at the core of the analytical process, processing complete bibliographic datasets to generate an object containing more than 30 different indicators. The practical implementation begins by loading the dataset into a data frame, as seen in previous sections, and then applying the primary function*: results <- biblioAnalysis(dataframe)*. This operation automatically performs all the necessary calculations, from fundamental productivity indicators to advanced collaboration and impact metrics, and returns the result as plain text.

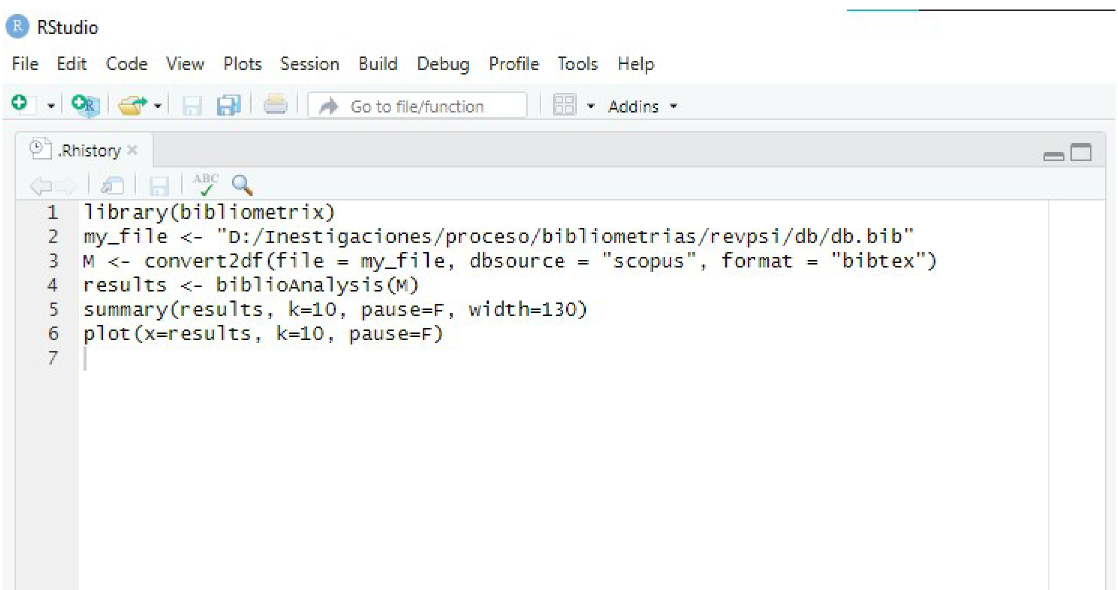

Figure 5.2. Basic project in R Bibliometrix

Specific results are extracted using complementary functions that access the object generated by *biblioAnalysis()*. To obtain the h-index and variants, *summary(results)$h.index* is used, while international collaboration statistics are retrieved with *summary(results)$Collaboration*. The *plot(results)* function generates immediate visualizations of the temporal distributions of publications and citations, which can be viewed in the lower-right panel of RStudio.

The customization of calculations in Bibliometrix allows analyses to be tailored to specific research needs. Using parameters such as sep = ";" in the initial function, the author and institution separators are adjusted based on the dataset's characteristics. For comparative analyses across periods, the timeslice function divides the time series into specific segments and calculates evolutionary indicators. Integration with other R libraries, such as igraph, enriches analytical capabilities, enabling the calculation of customized centrality indices and the analysis of communities in complex co-authorship and citation networks.

Figure 5.3. Loading a dataset in PyBibx

The calculation of bibliometric indices using PyBibX represents a modern approach that combines the flexibility of Python with algorithms specialized in scientific literature analysis. Installation is performed with pip install pybibx, creating an environment ready to process datasets in multiple formats, including BibTeX, RIS, and CSV. Initializing the analysis requires creating a specific parser object based on the input format: *from pybibx import BibtexParser* for BibTeX files or *RisParser* for RIS formats, then loading the dataset using *parser.parse_file('file_path') or pbx_probe(), as shown in the image*. This structured approach ensures accurate interpretation of bibliographic metadata before metric calculation.

The analytical core of PyBibX resides in the MetricsCalculator class, which implements specialized methods for each indicator category. After loading the data, the calculator is instantiated using *calculator = MetricsCalculator(parsed_data)* and specific techniques are invoked, such as *calculator.h_index()* for the h-index, *calculator.g_index()* for the g-index, and *calculator.m_index()* for the time-normalized version. For collaboration analysis, *a calculator.collaboration_metrics()* generates multi-level co-authorship indicators, while *calculator.citation_analysis()* provides detailed statistics on citation distribution. Each method returns not only the numerical value but also contextual metadata that facilitates the interpretation of results.

PyBibX's advanced capabilities include temporal analysis using the *temporal_analysis()* function, which segments data by user-defined periods and calculates the evolution of indicators. To identify seminal works, *burst_detection()* applies citation burst detection algorithms. Integration with pandas allows results to be converted into DataFrames for further analysis, while native visualization utilities generate time-series graphs and collaboration networks. This combination of metric and visualization capabilities positions PyBibX as an exceptionally versatile tool for researchers who require comprehensive bibliometric analysis within the Python ecosystem.

The code example available in the official PyBibX documentation contains the code needed to run all these indexes, so, as mentioned above, it will not be necessary to memorize or write them manually.

5.4.2. Alternatives: Publish or Perish and Excel (formulas)

For researchers who require immediate solutions without programming, Publish or Perish is an alternative. Once the data is loaded, it will display various indices, such as h, g, and m, in a panel on the right.

Although Excel spreadsheets are not initially designed for bibliometric analysis, they can be used effectively through the strategic application of formulas and functions. The h-index can be calculated by sorting the citations per article in descending order and applying the formula *=MAX(ROW(A1:A100)*(A1:A100>=ROW(A1:A100)))* as a matrix, where A1:A100 contains the number of citations per publication. For the g-index, the approximation requires *=MAX(ROW(A1:A100)*(A1:A100^2>=SUM(A1:A100)))*, while the i10 index is simply calculated with *=COUNTIF(A1:A100;">=10")*. These implementations, although basic, provide independent verification of results obtained using specialized tools.

Excel's analytical capabilities are significantly enhanced by combining statistical functions with pivot tables. For collaborative analysis, the *COUNTIF* and *IF* functions allow the calculation of international and institutional co-authorship percentages using formulas such as *=COUNTIF(affiliation_range;"*country*")/COUNT.A(affiliation_range)*. Pivot tables facilitate aggregations by author, institution, or time period, while integrated charts provide immediate visualizations of citation distributions and productivity patterns. For advanced users, VBA macros enable automation of recurring calculations and the generation of standardized reports, transforming Excel into a surprisingly competent bibliometric tool for moderate-scale projects.

5.5. Critical interpretation

The interpretation of bibliometric indices must fundamentally recognize the profound differences in publication and citation cultures between academic disciplines. In hard sciences such as physics or biomedicine, publication cycles are rapid, with a high prevalence of multiple authorship and high citation rates that reflect both genuine impact and established practices of routine citation. An h-index of 20 in particle physics might be considered moderate, while the same value in the humanities would represent exceptional influence. This disparity arises from structural differences: the sciences generate more publications per researcher per year and have developed citation traditions that prioritize the constant updating of references.

The humanities and social sciences operate under radically different paradigms, in which books constitute the primary format for scientific communication and evaluation cycles are substantially longer. The specialized monograph, with its deep and sustained argumentation, rarely receives metric recognition proportional to its actual intellectual influence when indicators designed for scientific journal articles are applied.[(8)]

Engineering and applied technologies present hybrid patterns in which academic citations coexist with other indicators of impact, such as patents, technological developments, and transfers to the productive sector. An engineering researcher may have a modest h-index while generating innovations with significant industrial impact, creating a dangerous disconnect between academic metrics and real impact. These disciplines often publish in specialized conferences whose citations are not fully captured by traditional bibliographic databases, systematically underestimating their intellectual implications.

The health sciences show particular biases derived from the concentration of citations in systematic reviews and meta-analyses, which receive disproportionately more citations than primary studies. A clinical researcher engaged in complex longitudinal studies but with limited samples may appear less influential than colleagues who publish frequent reviews, distorting the evaluation of substantive contributions to the advancement of medical knowledge. Extreme specialization across subfields with varying sizes of academic communities introduces additional variation that invalidates direct comparisons.

Interdisciplinary evaluation represents the most complex challenge, where researchers working at the frontiers between fields face a double penalty: their publications may be less cited in each discipline while remaining outside the core areas that concentrate citations. A computational neuroscientist, for example, might publish in neuroscience and computer science journals, dividing their impact between two communities with different citation practices and failing to reach critical visibility thresholds in either one separately, despite potentially transformative contributions at the disciplinary intersection.

Disciplinary normalization attempts to correct these biases through comparisons within defined fields, but faces significant methodological limitations. Indicators such as Field-Weighted Citation Impact (FWCI) use broad categories that often group subdisciplines with heterogeneous publication cultures. An analytical philosopher and a historian of philosophy share a category but operate in substantially different citation ecosystems, effectively invalidating many statistical corrections. The solution lies in supplementing quantitative metrics with contextualized qualitative assessment by disciplinary experts who understand these subtle but crucial differences.

Recap

- Bibliometric indices are quantitative measures used to evaluate scientific productivity, impact, and influence.
- They serve as a basis for comparing authors, journals, institutions, or countries within the same field of knowledge.
- They are mainly derived from publication and citation records in databases such as Web of Science, Scopus, and Google Scholar.
- The indicators are grouped into three broad categories:
    - Scientific productivity (number of publications).
    - Impact or influence (citations received).
    - Collaboration and networks (co-authorships, affiliations).

- The Impact Factor (IF), created by Eugene Garfield, measures the average number of citations received by articles in a journal over two years.
- CiteScore (Elsevier) evaluates citations received over four years, covering more journals than the IF.
- The SCImago Journal Rank (SJR) weights citations according to the relevance of the issuing journals, based on the PageRank algorithm.
- The Source Normalized Impact per Paper (SNIP) adjusts citation impact to account for differences across disciplines.
- At the author level, the most commonly used indicators are the h-index and the g-index.
- The h-index reflects the balance between productivity and citation: an author has an h-index if they have published h articles with at least h citations each.
- The g-index, proposed by Egghe, gives greater weight to the most cited articles.
- There are variants such as h5, hm, hg, hI, and hIa, which are applied to adjust for differences in academic age or co-authorship.
- For scientific journals, the most common indicators include FI, SJR, CiteScore, SNIP, and Eigenfactor.
- The Eigenfactor measures a journal's importance by considering the entire structure of its citation network.
- Collaboration indices are calculated using co-authorship, institutional networks, and affiliation analysis.
- In institutional or national evaluation, aggregate metrics are used (e.g., total number of citations or publications per field).
- Indicators should be interpreted in context, avoiding comparisons between disciplines with different citation habits.
- The use of standardized indicators and complementary metrics (altmetrics, downloads, social visibility) is recommended.
- Bibliometric indices, although useful, have ethical and methodological limitations when used as the sole evaluation criteria.
- A responsible evaluation combines quantitative indicators and qualitative review, in accordance with the San Francisco Declaration on Research Assessment (DORA) and the Leiden Manifesto.

Self-assessment questions

1. What is the primary function of bibliometric indices?
2. Into which three broad categories are bibliometric indicators grouped?
3. Who created the Impact Factor, and what is its fundamental principle?
4. How does CiteScore differ from the Impact Factor?
5. How does the SJR indicator weight citations?
6. What does the h-index measure, and how is its value interpreted?
7. What does the g-index contribute to the h-index?
8. What characterizes the SNIP indicator in comparison with other indices?
9. What principles do DORA and the Leiden Manifesto promote in scientific evaluation?
10. Why is it necessary to contextualize the results of bibliometric indices?

BIBLIOGRAPHY

1. Moed HF. Citation analysis in research evaluation. Dordrecht: Springer; 2005. doi: 10.1007/1-4020-3714-7.

2. Bornmann L, Daniel HD. What do citation counts measure? A review of studies on citing behavior. J Doc. 2008;64(1):45–80. doi: 10.1108/00220410810844150.

3. Gingras Y. Bibliometrics and research evaluation: Uses and abuses. Cambridge (MA): MIT Press; 2016. ISBN: 9780262337663.

4. Egghe L. Theory and practice of the g-index. Scientometrics. 2006;69(1):131–52. doi: 10.1007/s11192-006-0144-7.

5. Leydesdorff L, Bornmann L, Mutz R, Opthof T. Turning the tables on citation analysis one more time: Principles for comparing sets of documents. J Informetrics. 2019;13(3):1020–30. doi: 10.1016/j.joi.2019.05.010.

BIBLIOGRAPHIC REFERENCES

1. Brand A, Allen L, Altman M, Hlava M, Scott J. Beyond authorship: attribution, contribution, collaboration, and credit. Learned Publishing. 2015;28(2):151–5. https://doi.org/10.1087/20150211

2. Bornmann L, Bauer J. Evaluation of the highly-cited researchers' database for a country: proposals for meaningful analyses on the example of Germany. Scientometrics. 2015;105(3):1997–2003. https://doi.org/10.1007/s11192-015-1754-3

3. Hirsch JE. An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences. 2005;102(46):16569–72. https://doi.org/10.1073/pnas.0507655102

4. Waltman L, van Eck NJ, van Leeuwen TN, Visser MS, van Raan AFJ. Towards a new crown indicator: some theoretical considerations. Journal of Informetrics. 2011;5(1):37–47. https://doi.org/10.1016/j.joi.2010.08.001

5. Stirling A. A general framework for analysing diversity in science, technology and society. Journal of the Royal Society Interface. 2007;4(15):707–19. https://doi.org/10.1098/rsif.2007.0213

6. Purkayastha A, Palmaro E, Falk-Krzesinski HJ, Baas J. Comparison of two article-level, field-independent citation metrics: field-weighted citation impact (FWCI) and relative citation ratio (RCR). Journal of Informetrics. 2019;13(2):635–42. https://doi.org/10.1016/j.joi.2019.02.005

7. Elsevier. SciVal metric – Pure. 2025. https://helpcenter.pure.elsevier.com/en_US/metrics-in-pure/scival-metric

8. Kulczycki E, Engels TCE, Pölönen J, Bruun K, Dušková M, Guns R, et al. Publication patterns in the social sciences and humanities: evidence from eight European countries. Scientometrics. 2018;116(1):463–86. https://doi.org/10.1007/s11192-018-2711-0