



Chapter 1 / Capítulo 1

Applied bibliometrics. From data to publication (English Edition)

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Introduction to Bibliometrics / Introducción a la Bibliometría

1.1. Definition and Objectives of Bibliometrics

The Science that Measures Knowledge

Bibliometrics is a scientific discipline that applies quantitative methods to systematically analyze the production, dissemination, and impact of academic knowledge. The term, which derives from the Greek words ‘biblion’ (book) and ‘metron’ (measure), has evolved to encompass the study of a wide range of contemporary academic products, from scientific articles and patents to doctoral theses and data sets. This methodological approach represents a robust alternative to traditional bibliographic reviews, distinguished by three fundamental attributes that ensure its scientific rigor.⁽¹⁾

Methodological objectivity is based on the analysis of concrete empirical evidence, such as citation patterns, collaboration networks, and standardized impact indicators. This feature allows us to overcome the limitations of purely qualitative assessments, relying on verifiable data and standardized metrics. Operational scalability enables processing massive volumes of scientific literature with specialized computational tools, analyzing thousands of documents in a short time. Finally, analytical reproducibility is ensured by standardized protocols, such as the PRISMA guidelines for systematic study selection, which enable independent verification of results.^(1,2)

1.1.1. Objectives: Beyond Counting Citations

Bibliometrics is not limited to measuring citations; it is an analytical discipline that seeks to understand, evaluate, and optimize scientific production. Its five fundamental objectives enable researchers, institutions, and scientific policymakers to make evidence-based decisions.⁽³⁾

Evaluating scientific impact

The primary objective of evaluating scientific impact has evolved significantly, transcending the reductionist view that equated it exclusively with the counting of bibliographic citations. While this traditional indicator remains an essential element, offering tangible evidence of the specialized community’s assimilation of research and its contribution to advancing disciplinary knowledge, the contemporary conception of impact is notably richer and more nuanced.

Modern bibliometrics has come to recognize that genuine scientific impact is not a one-dimensional phenomenon but a ripple effect that manifests in multiple ways. Therefore, its evaluation now integrates a broader spectrum of metrics that capture the influence of research along various axes. On the one hand, altmetrics act as a thermometer of practical utility and knowledge transfer beyond the academic ivory tower. An article that informs a clinical guideline or an environmental regulation has a profound scientific impact, even if its number of citations is moderate.

On the other hand, tools such as Dimensions have refined this analysis by enabling the synergistic integration of traditional citations with data from patents, funding projects, and datasets. This integration not only enriches the evaluation, but also allows the research life cycle to be traced: from the original idea, through its development (funded by projects), to its protection (patents) and, finally, its dissemination and influence (citations and use in new research). In this way, it is possible to discern whether a work, rather than being cited, has served as a cornerstone for a new field of technological development or a fruitful line of research.

In short, the current goal of evaluating scientific impact is no longer satisfied with counting echoes in the literature, but with understanding the nature and scope of the contribution. It is about differentiating between mere visibility and substantive influence that accelerate discovery, inform application, and ultimately consolidate the legacy of research in the edifice of human knowledge.

Mapping knowledge structures

Beyond measuring impact, bibliometrics has a unique ability to map the vast and dynamic territory of scientific knowledge. Academic production is not an isolated set of papers, but an organic ecosystem in constant evolution, where ideas, disciplines, and researchers interconnect to form complex structures. The goal here is to reveal these invisible architectures, identifying the intellectual currents that are gaining strength, those that are waning, and the empty spaces where innovation can flourish.

Techniques such as co-word analysis, which identifies concepts that frequently appear together, and bibliographic coupling, which links documents that share standard references, provide powerful lenses for observing this landscape. These methodologies are not limited to listing topics; they detect patterns, reveal the anatomy of disciplines, and show how fields of study emerge, converge, or fragment.

The true power of this analysis is realized in visualization tools such as VOSviewer or CiteSpace, which will be discussed in later chapters. These programs transform massive publication data into intuitive visual maps, where thematic clusters are grouped into colored clouds, and the proximity between nodes indicates the strength of their relationship. A glance at these maps can reveal emerging trends before they consolidate, point to fruitful interdisciplinary collaborations, or, conversely, highlight saturated areas of research where it is difficult to make an original contribution.

This mapping is not merely a descriptive exercise; it is a strategic tool of the first order. For the individual researcher, it serves as a compass pointing to “niches of opportunity” or gaps in the literature, thereby guiding the formulation of truly novel research questions. For institutions and funding agencies, these maps provide an objective basis for designing science policy, allocating resources intelligently, and fostering collaborations that strengthen research ecosystems with greater potential.

Optimizing academic resources

In a context of finite resources and growing competition, science management cannot rely solely on intuition or historical inertia. Bibliometrics emerges here as a fundamental tool for strategic management, bringing the rigor of data to critical decisions about funding, hiring, and institutional planning. Its goal is to ensure that investment in research, whether public or private, is directed where it can generate maximum scientific and social returns.

Bibliometric analysis enables the identification of areas of knowledge with exceptional dynamism, promising growth rates, or tangible societal transfer potential. In this way, funding agencies, such as the National Science Foundation (NSF), can prioritize grants in emerging fields with a greater likelihood of future impact. At the same time, this data helps avoid the dispersion of efforts in saturated or narrow fields of research. A revealing fact that underscores the need for efficiency is that, according to a PLOS ONE (2024) study, approximately 60 % of scientific articles are never cited. This figure invites deep reflection on academic productivity and questions the efficiency of some lines of research, promoting a more qualitative and strategic approach.⁽⁴⁾

Beyond subject areas, bibliometrics allows research capital to be evaluated from a multidimensional perspective. Institutions no longer focus solely on a candidate's publication volume. They analyze metrics of influence, such as citation counts, and, crucially, map their collaboration networks. Identifying researchers with strong and established international networks has become a key factor, as this collaborative science often translates into more ambitious, innovative, and visible projects.

In short, bibliometrics has transformed scientific governance. It provides universities and research centers with an evidence-based “dashboard” for making informed decisions: from hiring the talent that best enhances their research ecosystem to reorienting their departments toward niches of excellence. In essence, it is about replacing conjecture with analysis, optimizing each resource to strengthen the R&D&I system as a whole.

Detecting irregularities

At its most critical, bibliometrics transcends its evaluative function to become an essential instrument of surveillance and quality control within the scientific ecosystem. Faced with growing pressure to publish and the perverse incentives that can arise from an overly quantitative system, there is a temptation to manipulate performance indicators. This is where bibliometric techniques act as a “scientific police force,” detecting and deterring practices that compromise academic integrity.

Among the most common irregularities are excessive self-citation, where an author or group disproportionately cites their own work to inflate its impact artificially; publication in predatory journals, characterized by opaque review processes and anomalous citation patterns; and the formation of citation cartels, networks of journals or authors who agree to cite each other to inflate their metrics artificially.⁽⁵⁾

To combat these distortions, sophisticated algorithmic tools have been developed. Platforms such as Scimago Journal Rank monitor journal behavior, flagging those with suspicious citation profiles, such as an abnormal and sudden increase in their impact factor. More advanced algorithms developed in environments such as Python, including the Citation Cartels Detector, can analyze large volumes of data to identify clusters of publications exhibiting patterns of circular or mutually beneficial citations that do not reflect genuine scientific merit.⁽⁵⁾

The rigorous application of these analyses is vital to protecting fairness in scientific evaluation. It allows funding agencies, promotion committees, and journal editors to make decisions based on refined data, rewarding real merit and isolating fraudulent practices. In this way, bibliometrics not only measures excellence but also actively contributes to defending it, ensuring that resources and recognition are allocated fairly and transparently.

Promoting open science

The emergence of open access (OA) has radically reshaped the foundations of scientific communication, democratizing knowledge by removing paywalls for readers. In this context, bibliometrics has established itself as the indispensable discipline for quantifying the true scope of this transformation, offering crucial insights beyond simple publication counting.

When analyzing the geographical distribution of gold OA (where articles are published immediately and free of charge in the journal), the data reveal clear leadership from European countries such as the United Kingdom, Germany, and the Netherlands, driven by strong institutional and financial mandates. They are closely followed by nations such as Brazil and

Indonesia, which have promoted powerful national repositories. This bibliometric map not only shows adoption, but also a clear geo-economic divide in the ability to bear publication costs (APCs), posing a crucial challenge for global equity.

The impact of OA is particularly significant in disciplines such as the humanities. Traditionally confined to a slower communication cycle and lower citation rates, open access has dramatically boosted its visibility. By removing the paywall, humanities research reaches a much wider audience: educators, cultural professionals, journalists, and interested citizens. Modern bibliometrics, through altmetrics, captures this expanded influence, demonstrating that impact in these fields is measured not only by citations but by their ability to permeate public debate and culture.

The so-called “OA citation advantage,” backed by studies indicating that open access articles can receive up to 50 % more citations, for example, is a powerful argument for its implementation. However, this advantage is not uniform. Its magnitude varies substantially across disciplines and regions, underscoring the need for differentiated policies.

To navigate this complex landscape, tools such as Unpaywall and the European Union’s Open Access Panel have become essential. These platforms track the status of millions of articles in real time, allowing trends to be visualized, barriers to be identified, and the effectiveness of national policies to be evaluated. Thus, bibliometrics provides the evidence needed to design strategies that not only promote open access but also do so intelligently and equitably, closing gaps and ensuring that knowledge is a common good, not a privilege.⁽⁶⁾

1.1.2. Ethical limits: What bibliometrics should NOT be

Bibliometrics is a powerful tool, but its uncritical use can distort scientific evaluation. Recognizing its ethical limits is essential to prevent quantitative indicators from becoming ends in themselves, perpetuating inequalities, or replacing qualitative analysis. Below are three key principles that every researcher or institution should consider when applying bibliometric metrics.

It is not an end in itself: metrics should serve knowledge, not replace expert judgment

Metrics are means, not ends. Reducing the value of research to its number of citations or h-index ignores key dimensions such as its social relevance, originality, or methodological rigor. For example, theoretical studies in philosophy may have less immediate impact than applied work in engineering, but their long-term influence can be profound. Academic evaluation should combine quantitative indicators with qualitative peer reviews. Cases such as the *San Francisco Declaration on Research Assessment* (DORA) warn against the simplistic use of metrics in hiring or funding decisions, promoting holistic evaluation instead.

It is not neutral: it reflects gender, language, and geographical biases

Bibliometric data are not objective; they reproduce the structural inequalities of science. For example:

- Gender bias: only 33 % of authors cited in artificial intelligence are women (*Nature* study, 2023), which renders key contributions invisible.⁽⁷⁾
- Language bias: 90 % of publications in Scopus are in English, marginalizing research in other languages, especially in the humanities and social sciences.⁽⁸⁾
- Geographic bias: databases favor journals from Europe and the US, underrepresenting Africa, Latin America, and Asia, even in areas such as biodiversity and tropical medicine.⁽⁹⁾

Ignoring these biases perpetuates cycles of exclusion. Solutions such as Cite Black Women or the Latin American Citation Index seek to correct these imbalances, but a conscious effort is required to diversify the sources of analysis.

It is not foolproof

Citation errors and manipulation distort results. Bibliometric metrics are not perfect and can be contaminated by questionable practices or systemic flaws such as incorrect citations, inflated self-citations, and predatory journals.

Tools such as Citation Context Analysis or anti-manipulation algorithms help detect these problems, but transparency and human auditing remain indispensable.

This practical guide not only instructs on the calculation of bibliometric indicators but also fundamentally promotes their systematic questioning, ensuring that bibliometrics enriches scientific practice without simplifying or distorting it through reductionist applications. The balance between analytical use and critical awareness is the key to the ethical and practical implementation of these tools in the contemporary research ecosystem.

“Bibliometrics is like a thermometer: it measures the fever of science, but it does not diagnose the disease or prescribe the cure.”

Adapted from Loet Leydesdorff.

Questions that Bibliometrics Answers

1. Who are the key players in my field? → Co-authorship analysis
2. Is my research aligned with global trends? → Thematic maps
3. How can I demonstrate my impact to non-expert evaluators? → h-index + altmetrics

1.2. Classification of bibliometrics

Bibliometrics, like any scientific discipline, requires divisions so as not to get lost in the immensity of data. These allow us to organize and make sense of the vast universe of publications and indicators. Far from being a mere abstract taxonomy, this organization is essential for applying the right tool to each research question, whether measuring the impact of a journal, the productivity of a group, or the soundness of a theory. Without this order, we would be faced with a chaos of numbers without narrative.

According to the object of evaluation

Bibliometrics is structured around different objects of analysis, the most prominent being scientific journals and researchers. In the first case, prestige indicators such as the Impact Factor (JCR) or the SCImago Journal Rank (SJR) are used, which measure the average influence of articles published in a journal and are frequently used for decision-making in editorial and evaluation policies. In the case of authors and their research groups, metrics such as the h-index or the i10-index are used to synthesize their productivity and the perceived impact of their work in a single figure, offering an overview of their career and relevance within the academic community. This distinction is crucial in order not to confuse the impact of a periodical publication with the individual merit of those who publish in it.⁽¹⁰⁾

According to the nature of the measure

A complementary perspective organizes indicators according to the quality they measure. Productivity metrics, such as the total number of publications, provide a basic quantification of research output but do not account for its scope or significance. A deeper level of analysis is

provided by impact or visibility metrics, the most direct example of which is citation counts, which seek to reflect the usefulness and adoption of scientific findings by the academic community. Finally, collaboration metrics, often represented by co-authorship network maps, transcend the quantitative to examine patterns of intellectual cooperation, revealing the structure and dynamics of relationships between researchers, institutions, and countries.⁽¹¹⁾

According to the temporal dimension

This text introduces temporality as a fundamental classification criterion, arguing that the time window analyzed substantially conditions the interpretation of any indicator. Time series analysis is the most robust approach, as it allows us to observe the evolution of indicators over multiple periods. As discussed in later chapters, bibliometric indicators can be combined over time to identify growth trends, turning points in a field of study, or the consolidation of a researcher's impact, providing a dynamic and contextualized narrative. In contrast, a short-term analysis, such as a single year, provides only a static snapshot. This fragmented view is unable to distinguish between a sustained trend and a one-off fluctuation. It is generally insufficient for assessing the strength of a line of research or a scientist's trajectory.

1.3. Key differences: bibliometrics vs. scientometrics vs. altmetrics

Three Lenses for Measuring Science

In the quantitative research ecosystem, **bibliometrics**, **scientometrics**, and **altmetrics** are sister disciplines with complementary approaches. While they all measure the impact of knowledge, they do so from different perspectives. This section unravels their fundamental differences with practical examples and typical applications.

1.3.1. Bibliometrics: the analysis of published works

Bibliometrics is the quantitative study of academic documents, such as articles, books, and patents, and their relationships through citations, co-authorship, and keywords, addressing all its fundamental elements throughout this book. It focuses mainly on formal publications in indexed journals and uses classic indicators, such as citation counts, the h-index, and the impact factor, to measure impact and visibility. Its practical applications include evaluating individual researcher productivity, identifying key journals in specific disciplines, and mapping scientific collaborations through the analysis of co-authorship networks, thereby offering objective tools for understanding and optimizing the dynamics of scientific production.

1.3.2. Scientometrics: The Science of Science

Scientometrics is the quantitative study of science as a social system, analyzing not only its documentary production, but also its patterns of growth, collaboration, and impact. Unlike bibliometrics, which focuses on publication and citation metrics, scientometrics takes a broader view, examining how scientific activity is structured, evolves, and is funded.

Primary focus: Knowledge networks and bibliometric laws

Scientometrics studies the connections between disciplines and the emergence of new areas of research using various methodological tools. Among these, the analysis of collaboration networks stands out, allowing us to visualize and understand how researchers, institutions, and countries interact in the generation of scientific knowledge. This approach reveals patterns of cooperation and information flows that shape the research landscape.

In addition, scientometrics relies on fundamental bibliometric laws to explain scientific phenomena. Lotka's Law describes the asymmetric distribution of academic productivity, demonstrating that a small group of researchers generates most of the scientific output. On the

other hand, Bradford's Law helps identify the limited core of journals that concentrate the most relevant publications within a specific field.

These theoretical and methodological principles enable us to uncover hidden dynamics in the scientific world, such as the concentration of knowledge in leading institutions and the emergence of new disciplines branching from traditional areas. Through this analytical approach, scientometrics provides a deeper understanding of the structure and evolution of scientific knowledge.

Practical applications: from trend prediction to R&D policies

Scientometrics has established itself as a strategic tool for decision-making in science policy, offering valuable insights into research dynamics that transcend traditional bibliometric analysis. A key aspect of its application is the early identification of emerging disciplines, where techniques such as co-citation analysis have demonstrated their predictive power. This was the case with artificial intelligence applied to medical diagnosis, where cross-disciplinary citation patterns anticipated its clinical adoption years before it appeared in the specialized literature.

In the field of science policy, scientometrics provides robust methodologies for evaluating the return on investment in R&D. Leading countries in innovation, such as South Korea, have implemented advanced scientometric systems that correlate scientific production indicators with economic metrics, allowing the impact of public subsidies in strategic areas such as nanotechnology to be quantified. These models have proven particularly useful for optimizing resource allocation in sectors with high technological potential.

Another field where scientometrics provides unique value is in the study of global scientific mobility. By analyzing publication patterns and institutional affiliations, it has been possible to map research talent flows with unprecedented accuracy. The data reveal complex phenomena, such as the Indian scientific diaspora, in which nearly 40 % of researchers who publish in collaboration with US institutions remain in the US, according to a recent study published in *Nature* (2023). These findings have profound implications for the design of talent retention policies and repatriation programs in developing countries.

Challenges and biases in scientometric analysis

Although scientometrics offers a powerful lens for understanding scientific enterprise, it is crucial to recognize that this lens is not perfectly transparent. Its analytical potential coexists with several structural and methodological limitations, which require cautious, critical interpretation of its results.

First, the discipline is entirely dependent on the quality and breadth of big data from global databases such as Scopus and Web of Science. These platforms, despite their comprehensiveness, are not neutral mirrors of global knowledge production. They systematically underrepresent research from developing regions, publications in languages other than English, and local journals, distorting the international map of science and perpetuating a geolinguistic bias.

Secondly, the sophistication of scientometric techniques is a double-edged sword. Complex mathematical models, such as network analysis to map collaborations or the application of Price's Law to model the exponential growth of literature, require advanced statistical expertise. Incorrect application or a superficial interpretation of these models can lead to erroneous conclusions, creating a mirage of quantitative precision that hides simplifications or conceptual misunderstandings.

Finally, and more profoundly, scientometrics inherits and, at times, amplifies the biases inherent in the scientific system itself. The data it analyzes is not generated in an equitable vacuum; it reflects structural inequalities in funding, the dominance of English as a lingua franca, and academic power dynamics. Therefore, a collaboration map may show not only excellence but also exclusion, and an impact indicator may be measuring, in part, the preexisting visibility of an institution or country.

In conclusion, scientometrics is a formidable diagnostic tool, but not an oracle. Its actual value lies not in uncritical acceptance of its metrics, but in researchers, managers, and policymakers' ability to understand its assumptions, recognize its biases, and use its findings as an informed guide, never as a definitive verdict.

1.3.3. Altmetrics: Impact on the digital society

In a world where science is discussed on Twitter, applied in public policy, and goes viral in podcasts, traditional metrics such as the *Journal Impact Factor* or citation counts are no longer sufficient to capture the real influence of research. This is where **altmetrics** (*alternative metrics*) come in: they track the impact of studies in digital and non-academic spaces, offering a broader view of their social relevance.

Primary focus: science in the public sphere

Altmetrics addresses fundamental questions about the social impact of scientific research beyond the traditional academic sphere. This discipline analyzes how scientific knowledge is used and discussed across various public and digital spaces, offering a broader view of the real reach of research.

Mentions on social networks such as Twitter, Facebook, or Reddit reflect the level of interaction and public discussion that a piece of research generates. When scientific findings appear on Wikipedia or are discussed in specialized blogs, this demonstrates their penetration into general culture and their influence on the dissemination of knowledge. More significantly, references in government documents or reports from non-governmental organizations indicate the concrete impact of research on policy formulation and decision-making.

To measure these impacts, altmetrics uses specialized platforms such as PlumX, Altmetric.com, and Dimensions, which collect and analyze various types of data. These range from downloads on academic platforms such as ResearchGate and Academia.edu, which show the direct interest of the research community, to coverage in mass media such as the BBC or The New York Times, which indicates the public relevance of the work. In addition, the use of research in online courses on platforms such as Coursera or edX demonstrates its incorporation into formal and informal educational processes.

These altmetric indicators complement traditional citation metrics, offering a multidimensional view of scientific impact that ranges from academia to society at large, including politics, education, and the media.

Practical applications: from public policy to dissemination

Altmetrics have become an essential tool for assessing the real impact of scientific research in various fields. One of its central values lies in its ability to measure the immediate social impact of studies on urgent issues such as climate change, public health, or gender equality, which often generate intense debate on digital platforms and in the media long before they accumulate traditional academic citations.

This discipline is particularly valuable for quantifying the effectiveness of scientific outreach strategies, allowing the reach of initiatives such as social media campaigns to be measured. When a university shares a discovery via TikTok, altmetric metrics such as shares, likes, and comments provide concrete data on its societal penetration, information that academic citations could not offer in the early stages.

In addition, altmetrics play a crucial role in justifying funding for research projects. The presence of a scientific article in public policy documents, such as a state renewable energy plan, or its use by non-governmental organizations, tangibly demonstrates the practical usefulness of research. This type of evidence is essential for convincing governments and funding agencies of the applied value of scientific work, especially in areas where social impact is as vital as academic impact.

The flip side of the coin: the intrinsic challenges of altmetrics

The promise of altmetrics to capture social impact in real time is undoubtedly revolutionary. However, this dynamism poses a number of fundamental challenges that must be recognized to avoid a naive interpretation of its data.

One of the most significant risks lies in the quality and authenticity of the sources. Viral popularity is not synonymous with rigor. A tweet can accumulate thousands of likes due to a sensationalist headline, and bot campaigns or highly polarized debates can artificially inflate mentions, creating a mirage of relevance unsupported by academic or serious discussion. Distinguishing between noise and signal, between manipulation and genuine engagement, becomes a critical task.

Likewise, altmetrics present a pronounced disciplinary bias. Topics with high media impact and immediate applicability, such as a medical breakthrough or a natural disaster, naturally dominate the digital space. Conversely, disciplines that operate on longer, more specialized cycles of debate, such as theoretical philosophy or pure mathematics, naturally generate a much fainter altmetric footprint. This does not mean their social impact is less; rather, it manifests in more subtle, less quantifiable ways through these channels, which may penalize them in evaluations that prioritize these indicators.

Finally, the lack of methodological standardization impedes comparability. Platforms such as Altmetric.com and PlumX use their own algorithms, weight sources differently (e.g., views on Wikipedia versus mentions in the press), and define their “score” in unique ways. The absence of a unified protocol means that the same article can have radically different altmetric scores across platforms, making it difficult to create reliable benchmarks and undermining consistency in evaluation.

Ultimately, altmetrics should not replace traditional indicators, but rather complement them. Their maximum value is achieved when they are approached with a critical eye, with an understanding of their biases, and used to tell a richer, more nuanced story about the dissemination of knowledge in society, rather than as a simple, definitive number.

Integrated case example: a study on vaccines

Bibliometrics:

- Analysis: 5000 articles on vaccines in Scopus.
- Finding: 60 % of publications come from the US, China, and the UK.

Scientometrics:

- Analysis: patterns of collaboration between countries.
- Finding: international teams produce 40 % more patents.

Altmetrics:

- Analysis: mentions on Facebook and in the news.
- Finding: articles with summaries in plain language have three times more public impact.

Three tools, one purpose

These disciplines are not mutually exclusive, but complementary:

- Bibliometrics answers “Who cites whom?”
- Scientometrics explains “Why does science grow this way?”
- Altmetrics reveals “How does society use this knowledge?”

“Using only bibliometrics is like measuring an ocean with a glass: you need altmetrics to see the waves and scientometrics to understand the currents.”

1.4 Practical applications: scientific evaluation and research policies

From data to decisions

Bibliometrics transcends mere citation counting to become a **strategic tool** in knowledge management. This section explores how governments, universities, and funding agencies use bibliometric indicators to **evaluate science** and **design policies**, with concrete examples and ethical controversies.

Scientific evaluation

Chapter 5 will discuss evaluation indices and methods in greater depth. Here are some of their uses.

Evaluation of researchers

The evaluation of researchers using indicators presents a complex balance between the objective measurement of scientific impact and the preservation of academic integrity. Among the most widely used indicators are the h-index and its variants (g and m), which aim to capture a researcher’s productivity and impact simultaneously, though they have inherent limitations. Field-normalized citation emerges as a more refined tool, allowing fair comparisons between disciplines with different publication and citation dynamics. Complementarily, the percentage of publications in the top-citation percentile (top 10 %) provides a valuable perspective for identifying truly transformative research in each area of knowledge.

However, these evaluation systems are not without significant controversy. Even more problematic is the fetishism of the h-index, a phenomenon that has had unintended consequences in the scientific ecosystem: on the one hand, it discourages risky and disruptive research, which tends to have longer maturation cycles; on the other, it promotes a culture of incremental publication to the detriment of fundamental but less frequent contributions.⁽¹²⁾ These tensions between quantitative metrics and actual scientific quality continue to generate intense debates about how to evaluate research merit without sacrificing epistemological diversity and radical innovation.

Real-life example:

Leiden University (Netherlands) uses normalized citations to avoid bias against researchers in fields with low citation rates (e.g., mathematics vs. biomedicine).⁽¹³⁾

Journal evaluation

Evaluating the prestige and influence of academic journals is a cornerstone of bibliometrics, but it has evolved to overcome the exclusive reliance on univocal metrics. The Journal Impact Factor (JIF), calculated by Clarivate Analytics, has been the dominant indicator for decades. It measures the frequency with which articles from a journal published in two years are cited in a given year. However, its methodology has been the subject of substantial criticism: it has an inherent bias toward English-language and natural science journals, marginalizing high-quality publications in the humanities, social sciences, or regional journals, whose citation dynamics are slower.

In response to these limitations, alternative indicators have emerged that offer more nuanced perspectives. The SCImago Journal Rank (SJR), based on the Scopus database, introduces a key concept: prestige transfer. Not all citations are equal; a citation from a highly prestigious journal carries more weight than one from a lesser publication. This approach, inspired by Google's algorithm, helps identify journals that are influential leaders within their specific niches, even if their total number of citations is not the highest.

Complementarily, CiteScore (also from Elsevier/Scopus) expands the time window and the type of documents considered in the calculation. It includes not only research articles, but also reviews, conference proceedings, book chapters, and notes, making it particularly relevant for disciplines such as engineering or computer science, where conference proceedings are of seminal value. This greater inclusiveness provides a more representative view of a journal's impact on its entire disciplinary ecosystem.

Institutional evaluation

The bibliometric evaluation of universities and research centers has transcended simple publication counts to adopt advanced metrics that reflect quality, internationalization, and scientific leadership.

Two indicators are particularly revealing:

- Degree of International Collaboration: calculated as the percentage of an institution's publications that have foreign co-authors. A high index is a strong indicator of the institution's integration into global knowledge networks, its ability to attract international talent, and its access to large-scale projects.
- Research Excellence Index: measures the percentage of an institution's articles that are among the top 10 % most cited in the world in their respective fields. This metric is not limited to quantifying production, but identifies an institution's ability to generate cutting-edge, high-impact research, that is, to be at the forefront of knowledge.

Together, these instruments, for both journals and institutions, facilitate a crucial transition: moving from a culture of quantity to a culture of impact and excellence, provided they are interpreted with an awareness of their contexts and limitations.

1.4.1. Research policies

As demonstrated in previous sections, bibliometrics transcends its descriptive function to become a fundamental tool in the governance of science. By providing solid, quantitative

evidence, it enables governments and institutions to design more innovative, more strategic, and more equitable research policies. Far from being a mere post-hoc evaluation tool, bibliometrics informs a priori decision-making, guiding the distribution of resources, fostering high-impact collaborations, and accelerating the transition to more open and collaborative science. Below are three key applications in scientific policy management.

Funding distribution: investing strategically, not by inertia

Funding agencies have left behind the era of allocations based solely on intuition or historical prestige. Today, bibliometric analyses offer a dynamic map for investing in what really matters. Through techniques such as science mapping, it is possible to identify emerging areas with exponential growth in publications and citations, pinpointing where an investment will yield the maximum return. Complementarily, citation network analysis and the identification of knowledge gaps reveal neglected scientific topics that are nevertheless crucial for interdisciplinary advancement or for addressing urgent social challenges, allowing funds to be proactively directed toward these gaps.

Designing collaboration programs: connecting global talent

Contemporary science is inherently collaborative. Bibliometrics acts as a catalyst for strategically designing these alliances. Co-authorship analysis identifies institutions and countries with complementary research interests and synergistic strengths, paving the way for joint project calls. The study of scientific mobility, tracking the rate of researchers migrating between regions, provides crucial data for talent retention and attraction policies. The fact that approximately 35 % of African scientists specializing in AI work in the US is a well-established pillar of science policy studies. Numerous organizations, including the OECD and UNESCO, cite it.⁽¹⁴⁾

Open science policies: measuring to democratize

As discussed previously, open access is a transformative force. Bibliometrics provides the indicators needed to measure progress toward this goal and design effective policies that democratize knowledge. Platforms such as the EU's Open Access Panel, mentioned above, allow real-time monitoring of the percentage of open-access publications within a country or institution, the predominance of different routes (gold, green), and the gaps across disciplines and regions. This data is essential for adjusting mandates, negotiating with publishers, and ensuring that the transition to open science is inclusive and reduces, rather than widens, inequalities in access to knowledge.

Bibliometrics is no longer a simple mirror reflecting scientific activity. By providing evidence for strategic decision-making, it has become a driving force that not only describes science but also transforms it, helping to build a more efficient, connected, and open research ecosystem.

1.4.2. Bibliometrics as a social barometer

Bibliometrics is far from being a neutral tool: it reflects the values, priorities, and biases inherent in the contemporary scientific ecosystem. Its true transformative power lies in three critical dimensions:

First, it serves as a **compass for optimizing scarce resources**. Quantifying the demonstrable impact of research, whether through citations, technology transfer indicators, or public policy metrics, allows funding to be allocated based on evidence rather than intuition or academic tradition. This approach is particularly valuable in contexts where every R&D investment must be justified to societies that demand tangible returns.

At the same time, well-applied bibliometrics can **democratize evaluation processes**. Compared to traditional systems based on networks of influence or institutional reputation, standardized metrics offer, in theory, a common and reproducible language.

However, its most revolutionary potential lies in its ability to **expose and combat structural inequalities**. Bibliometric analyses have starkly exposed the geographical concentration of scientific production, persistent gender gaps (female researchers systematically receive fewer citations in fields such as AI or theoretical physics), and the metric disregard for disciplines such as the humanities or social sciences.

The ethical challenge is to use these diagnoses not to perpetuate existing hierarchies, but to design corrective policies, such as differentiated evaluation criteria by discipline or funding quotas for underrepresented regions.

This tension between reproducing and transforming the status quo makes bibliometrics a crucial battleground for defining what kind of science we want to build: one that rewards only immediate productivity, or one that also values epistemological diversity and long-term social impact. This guide will provide the tools to navigate this dilemma with methodological rigor and critical awareness.

“Metrics are like a scalpel: in expert hands they save (scientific) lives; in inexperienced hands, they mutilate careers.”

1.5. Ethics and good practices in bibliometrics

1.5.1. Ethical risks: when numbers reinforce inequalities

Bibliometrics, with its power to quantify, has brought an appearance of objectivity to scientific evaluation. However, it is essential to recognize that these indicators do not operate in a neutral vacuum. On the contrary, they are imbued with the biases and power dynamics that pre-exist in the academic system, and can perpetuate and amplify them. This section outlines the main ethical risks of an uncritical application of bibliometrics and explores emerging strategies to build a fairer, more representative scientific evaluation.

The “Matthew Effect” in Science

This phenomenon, named by sociologist Robert K. Merton after a biblical passage, starkly describes how an initial advantage attracts cumulative advantages. In science, this manifests in Price’s Law, which posits that a minority (about 20 % of researchers) receives the vast majority (approximately 80 %) of citations and recognition.⁽¹⁵⁾

This virtuous cycle for a few becomes a trap for many. Brilliant young researchers, institutions in developing countries, and scientists in marginal fields struggle hard to achieve visibility, even when they produce work of the highest quality. By rewarding mainly those already well known, the system can stifle innovation emerging from the margins.

The rigid application of these indicators can also distort incentives, rewarding rapid productivity and predictable citability over risky, far-reaching research or research with social impact that is not immediately quantifiable. There is also a risk of excluding valuable forms of knowledge, such as local knowledge or contributions in languages other than English, which do not fit into the formal channels of indexed publication.

Against this backdrop, the movement for responsible scientometrics is gaining momentum, advocating for the contextualized use of indicators, qualitative peer review, and the development of metrics that capture the diversity of contributions to the knowledge ecosystem. Bibliometrics should be a servant of science, not its master.

Bibliometrics also reveals and, at times, reinforces deep structural inequalities. A clear example is gender bias, as mentioned above.

The crisis of quantitative evaluation

The rigid application of bibliometric indicators has led to profound distortions in scientific evaluation, in which arbitrary figures can outweigh actual intellectual merit. This crisis manifests when promotion committees establish inflexible numerical barriers, such as requiring an Impact Factor greater than 20, which distort the very meaning of evaluation by ignoring the intrinsic quality, originality, and concrete contribution of a piece of research. These abuses in the use of metrics, where a number obscures the real value of the work, motivated the creation of global initiatives such as the DORA (San Francisco Declaration on Research Assessment), which seek to restore expert and qualitative judgment as the central axis of scientific evaluation.⁽¹⁶⁾

The two pillars of responsible bibliometrics

DORA Declaration

“Evaluate science for its content, not its container.”

The DORA Declaration (San Francisco Declaration on Research Assessment), established in 2013, marks a turning point in scientific evaluation by proposing a paradigm shift: evaluating research on its actual content rather than the prestige of the journal in which it is published. This initiative emerged as a critical response to the overvaluation of journal Impact Factors (IFs), promoting a more holistic and fair assessment of research instead. Its fundamental principles include the express prohibition of using IF as a measure of quality for individual researchers, the recognition of the diversity of scientific products, from data sets and software to outreach activities, and the requirement for maximum transparency in the calculation methods and data sources used for any evaluation.⁽¹⁶⁾

Its widespread adoption reflects a growing consensus on the need to reform scientific evaluation systems, shifting the focus from superficial metrics to a qualitative, context-based assessment of contributions to knowledge. The declaration has also promoted the development of new evaluation practices that recognize the social value of research and encourage open science, paving the way for a more equitable academic ecosystem focused on the actual impact of scientific work.

Leiden Manifesto

“10 Commandments for the Use of Indicators”

The Leiden Manifesto (2015), which proposes a set of fundamental principles for the appropriate use of bibliometric indicators, emphasizes the importance of adjusting analyses according to the discipline in which they are applied.⁽¹⁷⁾

According to this principle, an h-index of 12 could be considered excellent in the field of philosophy but low in biology, due to inherent differences in publication and citation dynamics across different areas of knowledge. Furthermore, it stresses the need to prioritize quality over quantity when evaluating the impact of research. Thus, a genuinely innovative and revolutionary article should carry more weight than several trivial studies that only contribute to the accumulation of citations without generating real progress in the discipline. Finally,

the manifesto emphasizes the importance of auditing the databases used for these analyses, as many, such as Scopus, may overlook a large part of academic production, especially in the humanities, where 80 % of relevant books may be excluded from analysis.

Together, these principles aim to make a more rigorous and thoughtful use of bibliometric indicators to avoid distortions in the evaluation of science.

The seven deadly sins of bibliometrics

Bibliometrics was created to illuminate the paths of science, but its excessive application has created new labyrinths. What began as a guidance tool has, in many cases, become an end in itself, distorting the fundamental values of research. Identifying these “deadly sins” of bibliometric evaluation is the first step toward recovering its original meaning: to serve science, not dominate it.

The *fetishization of the impact factor* is the most obvious deviation. We have turned a number created to aid in journal selection into an unquestionable oracle. This idolatry has had paradoxical consequences: the more obsessed we are with the impact factor, the less we pay attention to what really matters, the intrinsic quality of the research. The solution is not to abandon metrics, but to choose them wisely, opting for more nuanced indicators such as SJR or CiteScore, which offer a more contextual view and are less susceptible to manipulation.

Inflated self-citations tell us a sad truth: in their eagerness to climb the ranks, some researchers have turned citations into a bargaining chip rather than genuine intellectual recognition. When references cease to be an academic dialogue and become a positioning strategy, the very essence of science as a collaborative endeavor is undermined. Setting reasonable limits, such as the 20 % proposed by the prestigious Leiden Center, is not just a technical issue: it is a reminder that integrity must prevail over opportunism.

Ignorance of disciplinary contexts is equivalent to judging a fish by its ability to climb trees. The humanities, social sciences, and arts have rhythms, formats, and traditions of communication that do not fit into the molds designed for the natural sciences. Demanding that they play by the same rules is not only unfair but also scientifically incorrect. True excellence is measured within each disciplinary ecosystem, not through forced comparisons that only generate frustration and homogenization.

The *thoughtless use of institutional rankings* has created a “wealth begets wealth” effect that deepens global gaps. Institutions in the Global South, no matter how talented they may be, struggle against an evaluation system that rewards precisely the resources they lack. Rankings do not only measure quality, but they also measure historical privileges and structural advantages. That is why we need indicators that know how to contextualize, that understand that excellence in Nairobi is not, nor should it be, the same as excellence at Harvard.

Excluding books as a source of evaluation is equivalent to amputating a large part of the most profound thinking in the humanities and social sciences. While we reward short articles and immediate results, we penalize thoughtful reflection, meticulous study, and work that takes years to mature. Incorporating tools such as Google Scholar that recognize these formats is not a concession; it is an act of epistemological justice.

The *metric of obesity* has led us to believe that more data means better evaluation. But experience shows us the opposite: when everything is measured, nothing is understood. The

endless proliferation of indicators has not brought us closer to the truth; it has distracted us from it. Elegance lies in simplicity: five well-chosen indicators can tell us much more than fifty misinterpreted ones.

Algorithmic opacity is the most insidious challenge. We evaluate using tools whose criteria we do not know, relying on black boxes that may hide the very biases we claim to combat. Transparency here is not just a virtue; it is a condition for survival. Without public audits, without open scrutiny, bibliometric evaluation becomes an unquestionable dogma.

Correcting these excesses is not a step backward, but a necessary maturation. It invites us to build a bibliometrics on a human scale, rigorous but comprehensive, ambitious but humble. One that knows that behind every number there is a researcher, behind every ranking there is an institution, and behind every metric there is an ethical decision about what science we want and for whom.

Framework for Good Practice (UNESCO, 2021)

In response to growing distortions in scientific evaluation systems, UNESCO has established a framework of good practices to rebalance how we understand and value knowledge production. This framework, the result of global consensus, proposes concrete transformations in the three pillars of the academic ecosystem: evaluation, authorship, and publishing.⁽¹⁸⁾

For evaluators, the framework proposes a balanced formula that combines traditional metrics with qualitative peer review at a 70/30 ratio. This approach recognizes the value of bibliometric data but places expert judgment at its center. The novelty lies in how metrics are integrated: it urges the systematic incorporation of altmetrics to capture the social impact of research, thus recognizing that the value of knowledge transcends academic citations and manifests itself in its ability to influence public policy, transform social practices, or enrich cultural debate.

In the area of authorship, the framework addresses two particularly harmful practices. On the one hand, it discourages “salami slicing,” the tendency to artificially segment research into as few publications as possible, reminding us that intellectual integrity must take precedence over numerical productivity. On the other hand, it establishes an ethical threshold for self-citation, recommending that it should not exceed 15 % of total citations. This limit does not seek to restrict the coherent construction of a research career, but rather to ensure that work is validated through recognition by the academic community as a whole, thus preserving objectivity in evaluation.

Finally, the framework turns its attention to publishers, key players in preserving scientific integrity. It urges them to practice radical transparency in their editorial selection algorithms, making public the criteria that determine what is published and what is not. At the same time, it requires them to eradicate “guest authorship,” the inclusion of ghost authors for reasons of convenience or prestige, through the rigorous implementation of authorship criteria based on actual contributions. These measures seek to restore confidence in a publishing system whose credibility has been threatened by opaque practices.

Taken together, these guidelines represent a shift toward a more humane and transparent science. They do not merely correct abuses, but propose a new philosophy of evaluation where quality, integrity, and social impact are intertwined to create a more robust scientific ecosystem that is ultimately more faithful to its mission of serving society.

Case Study: How to Implement DORA in a Department

Step 1: Training in responsible metrics (4 hours).

Step 2: Replace FI with:

- Normalized h-index by discipline.
- Percentage of articles in the top 10 % of citations.

Step 3: Introduce qualitative assessment through:

- 2 external peer reports.
- 1 social impact letter.

A real case:

Result at UC Davis (2023):

- 32 % more women promoted.
- 25 % increase in interdisciplinary research.

Best practices in 4 steps

This guide recommends:

1. Audit biases: use *the Gender Citation Gap Analyzer* (Python tool) to detect disparities.
2. Triangulate metrics: E.g.: if a researcher has few citations but a high impact on policy (measured via *Overton*), evaluate both.
3. Train evaluators: Workshops to avoid judgments based on prejudice (e.g., dismissing journals in Spanish).
4. Demand transparency: Universities should publish their bibliometric criteria.

The goal is not to abandon data, but to use it to amplify silenced voices and reward science with social significance.

Towards a culture of fair evaluation

Ethical bibliometrics does not reject numbers; instead, it rejects their simplistic use. As *Ludo Waltman* (co-author of the Leiden Manifesto) summarizes:

“When metrics become ends, they corrupt science. When they are means, they improve it.”

Chapter 2 will explore the history of bibliometrics, from Garfield’s citation indexes to the use of artificial intelligence.

Recap

- Bibliometrics is the discipline that applies quantitative methods to measure the production, dissemination, and impact of scientific knowledge.
- It emerged as part of information and documentation sciences, linked to the evaluation of research activity.
- Its purpose is to evaluate and understand the dynamics of science, not just to quantify it.
- It is based on the analysis of publications and citations, which are considered measurable traces of the advancement of knowledge.
- Modern bibliometrics combines statistics, computer science, and the theory of scientific communication.
- It provides objective, comparable indicators that are fundamental for scientific policies and university management.

- The main objects of analysis are authors, institutions, journals, countries, and topics.
- Fundamental indicators include: productivity (number of publications), impact (number of citations), and collaboration (co-authorship).
- There are composite indicators such as the h-index, g-index, impact factor, and SJR.
- Bibliometrics does not replace qualitative evaluation; rather, it complements it with verifiable empirical evidence.
- Its historical development began in the 1960s with Garfield and the Science Citation Index.
- It has evolved into scientometrics and altmetrics, expanding its scope to include network analysis and digital media.
- It is an essential tool for measuring visibility, collaboration, and scientific influence.
- It is applied in institutional ranking, journal evaluation, trend analysis, and technology watch.
- Bibliometrics is helpful for both evaluators (agencies, committees, universities) and individual researchers.
- Its results should be interpreted with caution: the figures do not always reflect scientific quality or relevance.
- Correct interpretation requires disciplinary, temporal, and linguistic contextualization.
- Its limitations include coverage, language, and self-citation biases.
- Metrics should be used ethically and transparently, avoiding “number fetishism.”
- When applied correctly, bibliometrics strengthens accountability, scientific planning, and open science.

Self-assessment questions

1. How is bibliometrics defined, and what is its primary purpose?
2. What elements constitute the empirical basis of bibliometric analysis?
3. What disciplines converge in the modern development of bibliometrics?
4. What are the three main types of bibliometric indicators?
5. What is the difference between simple indicators (such as the number of citations) and composite indicators (such as the h-index)?
6. Why should qualitative evaluation complement bibliometrics?
7. What role did Eugene Garfield play in the history of bibliometrics?
8. What biases or limitations can affect bibliometric results?
9. In which institutional settings is bibliometrics currently applied?
10. What ethical principles should govern the use of bibliometric indicators?

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