An Introduction to Bibliometrics

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New Development and Trends

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ELSEVIER
CP
CHANDOS
PUBLISHING
An imprint of Elsevier

Chandos Publishing is an imprint of Elsevier
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
The Boulevard, Langford Lane, Kidlington, OX5 1GB, United Kingdom

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-0-08-102150-7 (print)
ISBN: 978-0-08-102151-4 (online)

Publisher: Jonathan Simpson
Acquisition Editor: Glyn Jones
Editorial Project Manager: Ashlie M. Jackman
Production Project Manager: Debasish Ghosh
Cover Designer: Miles Hitchen

Typeset by SPi Global, India

CHAPTER 1

Preface

In 2016, bibliometrics turned one hundred years old. It is not a new invention by the media company, Thomson Reuters (now Onex and Baring Asia), which generates a vast turnover with its various databases, such as the Science Citation Index, and makes a fortune. Nor was it invented by the media group Elsevier, the Science Citation Index's only serious competitor, which inundates universities with a whole series of science evaluation products today.

Instead, bibliometrics emerged from the idea of supporting librarians in their daily work, selecting literature, and optimising holdings management. This was the underlying concept behind the first bibliometric analyses and also the approach adopted by the American chemist, Eugene Garfield, who began to evaluate papers systematically in the 1950s based on the literature used and cited.

In the first half of the twentieth century, questions regarding the type and frequency of scientific publications, and how science works and publications come about were therefore not exactly important issues and even less the subject of quantitative study methods for scientific output, like bibliometrics today.

In any case, the output from scientists during this period was completely immaterial. Good professors had many students, received a sizeable amount of so-called student funding and, at least in Germany, lived off incomes that were among the highest in society [1]. In the early twentieth century, the director of a major bank earned around a third less than a university professor.

At this time, and against the aforementioned backdrop, the written research output in the form of books and papers or talks was not really relevant. Only those who had something to say were heard: They wrote books, gave talks and published scientific papers in journals, which were slowly beginning to catch on.

Those who didn't, however, did not have a problem and, above all, did not have to fear any repercussions. In those days, target agreements on a

An Introduction to Bibliometrics. http://dx.doi.org/10.1016/B978-0-08-102150-7.00001-3

minimum number of scientific publications per year, as has long been commonplace at many medical and scientific institutes, were unimaginable.

As a method to evaluate the scientific achievements of people and institutions, bibliometrics therefore also became a child of mass-produced science, which emerged after the Second World War. As the number of scientists, the fragmentation of the disciplines and therefore also the demand for specialised publication organs, journals, book series and conferences skyrocketed, the number of publishing houses and especially publications also increased. And so, it was merely a question of time before there was a need to record and evaluate the written output of scientists and their institutions.

First of all, bibliometrics measures the number of papers published by an individual, for instance. This is the easy part as it does not yet require any suppositions and still yields direct information, such as that a scientist has published 200 papers and five books in his or her career. Attempting to gauge the quality and significance of the articles and books, however, is a much trickier business. Here, bibliometrics opted for a simple route that is still applied in practice to this day: A publication is all the more important the more it is perceived. To quantify this perception, bibliometrists chose citation as the indicator: A publication that is cited frequently in other publications is an important publication, a publication that is cited rarely or not at all less so.

Once a paper is published, other scientists cite it and the entire process is measured and written down. The almost endless variation of the indicators currently discussed in bibliometric literature, which has become so extensive that it is virtually impossible to overlook, does not alter the fact that the original principle has remained the same to this day. The fundamental assumption of bibliometrics essentially means that an article is all the more important the more frequently it is cited.

Anyone who fails to follow this basic assumption cannot use bibliometrics; Anyone who justifiably rejects this basic assumption will not be able to generate any insights from bibliometrics.

Moreover, comprehensive databases (which used to be published as printed directories) that record the respective citations are needed so they can be evaluated. As mentioned earlier, Eugene Garfield started the systematic evaluation of papers back in the 1950s and this has blossomed into a vast collection of data, upon which the majority of bibliometric analyses are based.

For half a century, classic bibliometrics has been based on the Science Citation Index database and its extensions and features. Nevertheless, the underlying measuring principle and above all the assumptions and conclusions from the data collected have remained the same to this day. And in principle, the Scopus database by Elsevier, effectively the Science Citation Index's only commercial competitor, does not do anything different, either.

As far as the contents and logic are concerned, these systems are also based on Garfield's mentality, the clever founder of the Web of Science and the Science Citation Index.

Although the age of bibliometrics based on this underlying theory of a simple correlation between publications and citations is far from over, new methods are emerging that are bound to supersede their predecessors one day: Usage metrics, for instance, uses a fundamentally different approach to classic citation bibliometrics and is no longer based on the fundamental theory that has been valid for almost a century, namely that a much-cited paper is a more important publication than one not cited as frequently.

Admittedly, usage metrics does not inherently solve the problem of evaluating the significance of a scientific paper as nobody can determine how important a paper is, how often it is read and how much insight the reader actually gains from it using indirect methods. However, usage metrics does enable a clear approach to this fundamental issue, which ultimately lies at the heart of bibliometrics.

For the first time, usage metrics allows a relationship between usage and significance to be established as opposed to merely determining the importance of scientific publications by exclusively conveying the citation rate indirectly.

However, this correlation can still be optimised further. Usage metrics opens up the possibility of recording publication downloads. Other applications might register and statistically evaluate the user's processing time, the time spent on the document and the manner in which it is processed via highlighting or copying. The forwarding of a document or its sharing with others on social media may also provide information on a scientific paper's importance.

Libmetrics (library metrics), on the other hand, establishes a connection between the importance of a scientific paper or book and its availability or usage in a library, such as by measuring how often it is procured or borrowed from the library. The depth of the penetrability of library holdings with a book, for instance, may contain information on how relevant the work in question is deemed. The edition of the book or the turnover generated by the book trade allows inferences to be made regarding a work's appeal. However, libmetrics is still very much in its infancy. The publication of scientific papers in electronic form, whether it be as journal articles, eBooks, blogs, chats, website articles or multimedia articles in an indeterminate media format, has become an established form of scientific communication and the dissemination of results.

Apart from new possibilities, the free internet, the development of scientific communication and social networks simultaneously opens up other needs to rethink the measurement and determination of scientific output.

Besides the aforementioned altmetrics options, the use and combination of all free network data and the application of big data technologies to the system of publications and their measurement will yield new insights.

> *As the internet renders this kind of information accessible all over the world and the technology has become second nature to us, the digital public can report on things, people, experiences and events in real time [2].*

Although classic bibliometrics and its indicators have not yet had their day, the information they provide is increasingly being reduced to what they mean: an only very indirect theory that a frequently cited publication is an important one.

Half of all scientific papers from the European Union (EU) are already freely available on the web today [3]. With the development of freely available scientific web contents on this side of the paywall, new possibilities have long since emerged to adjudge the significance of scientific output more effectively, directly and accurately.

While the amount of scientific output is ballooning, science and research has long ceased to take place in the unobserved cocoon of the scientific ivory tower, but rather on the social battlefield in the war for money, honour and recognition. Whether science and its researchers wants to accept it or not, they are competing with swimming pools, motorways, the new European combat helicopter and spiralling welfare costs in the struggle for state resources.

Society is growing tired of forking out money for science to keep beavering away with no strings attached. Quite rightly, it also demands accountability from those who conduct research with taxpayers' money, the point of which is not immediately clear. And, in my opinion, quite rightly, it expects scientists to be measured according to standards that are internationally recognised and comparable – not by the impenetrable self-affirmation of the 'inner circle', a sworn community that keeps congratulating itself on how great and outstanding its results are and how fundamental its research is for the future of the human race. The taxpayer, quite rightly, would like to know which standards should be applied to facilitate a fair and honest measure of the achievements of science and research, not to mention scientists who are funded by society while representing the excellence of the people or institutions involved or not.

The quantification of scientific output is the core theme of bibliometrics, gauging the performance of institutions and people with all the uncertainties involved in weighing things up.

Many disciplines, such as medicine, large parts of the natural sciences and parts of the economic science, have long had an established system for evaluating scientific output. Although the indicators are widely accepted, there is still plenty of room for improvement in these subjects, too. New metrics become possible thanks to technological progress on the one hand (webometrics) and changes in publication habits on the other.

Nonetheless, not every discipline is willing to show its hand. The humanities, parts of the social and economic sciences, and law still doggedly insist on qualitative criteria for the evaluation of scientific achievements, partly from fear of being disturbed in the subjective protective atmosphere of scientific freedom, partly out of ignorance of the methods of bibliometrics and partly from fear of using quantitative metrics, towards which people also have an ambivalent attitude outside science.

However, we have to remain fair: The publication culture in the humanities and social sciences differs greatly from that in medicine and the natural sciences, and in actual fact it is not always easy to quantify their scientific output. Moreover, bibliometrics wantonly neglected this topic for far too long. It was much easier to tot up the citation figures for a biological paper over the years than find a fitting acknowledgement of the research achievements of an editorial scientist in German studies.

Bibliometric issues that range from medicine and the natural sciences all the way to the humanities and social sciences are complex and extensive.

Knowledge and the evaluation of the respective publication cultures is required. Only thus can obstacles and reservations be broken down and suitable methods developed.

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CHAPTER 2

Introduction and History

Everyone is graded. Lovers by lovers under a veil of silence; traders by vociferous customer complaints; the media by quotas; doctors by patient flows; the elected by voter reactions [1]

(Michel Serres)

According to Derek J. de Solla Price, academic publications in today's sense have only been mentioned since the 1920s, though the academic journal *Philosophical Transactions* was first published in 1665 [2]. Nevertheless, so-called 'big science', which is characterised by the exponential growth of academic publications, can only be referred to since the second half of the twentieth century. De Solla Price believed that the exponential growth of academia would be visible through around a million academic journals and a thousand relevant secondary information sources by the year 2000. This figure does not exactly tally with the actual number of academic journals, which is estimated at around 180,000 in Ulrich's (Ulrich's International Periodicals Directory). At the macro level, which refers to all disciplines, subjects and countries, the number of journals is growing by approximately 3.3% a year [3].

It was also de Solla Price who, two years later, referred to the topic of networks between authors in an article in *Science* in 1965 and examined the citation behaviour of scientists [4]. Today, these so-called cluster analyses are a modern bibliometric research field.

The evaluation of academic productivity and production, and its resonance as measured by citations, is therefore all the more necessary the greater the quantity of published academic output. In times when financial resources are tight, the performance-oriented allocation of funds relies heavily on objective parameters of the performance and productivity of science and scientists. This also calls into question whether the quality of academic work is open to an ultimate quantitative justification through the direct assumption of bibliometrics, much like the quantitative assessment of individual scientists, institutes, facilities or even countries, which has already become a reality. The fact that the use of bibliometric methods in academic

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evaluation is already commonplace alone makes it necessary to render the highly complex topic easy to understand and read for all groups involved and also to go deep into its complexity [5].

Research and academic rankings are popular. There is not one university president who does not know his or her institution's position in the national and international comparison (and is unable to explain or exploit it), and no politician can do without them: 'Science and politics will influence and observe each other' [6]. Today, bibliometrics is increasingly associated with performance measurement, performance assessment, evaluation and steering science policy.

As a quantification of academic output, bibliometrics is the result of the pressure to justify in science and research, which initially defies pure science in the Aristotelian sense as knowledge for the sake of knowledge. Still today, the right to freedom in research, which is granted to professors at universities in many countries, testifies to this original understanding of science.

In the 1960s, however, the public perception of these academic privileges in the research environment of publicly funded universities and research centres began to change in the wake of the democratisation of society and its universities.

Tuition fees were scrapped and the funding for the sheer number of students ceased to flow. The students' participation began as a revolution in 1968 which wanted to get rid of the 'thousands of years of mustiness from the gowns' and also relativised the untouchable in a professor's status, as well as his or her research freedom and status quo in the organisation of the university and bourgeois society. Back then, there were around 5000 professors in Germany.

As the number of scientists increased, the number of doctoral students and postdocs also ballooned, which inundated the universities with scientists and ended the elevated status of a professor once and for all with the mass university of the 1970s. Nowadays, more than 40,000 people in Germany bear the title of professor. Professors practically became a normal employee at the university and all that remains of the elite status they enjoyed in the early twentieth century is the right to freedom of research and teaching, which is virtually claimed as a knee-jerk reaction to this day. This means that any full professors appointed can research and teach what they like and choose what they deem useful.

As *DIE ZEIT* wrote in an article entitled 'Mythos Professor 2011': "Anyone who considers the fall of the German professor from mandarin to normal working person can understand the melancholy with which his guild still clings to the heroic years of the German university before the outbreak of the First World War in 1914" [7].

The introduction of performance measurement by quantifying academic output, such as through bibliometrics, is almost the only way to gauge the performance of scientists today; after all, the right to a free choice of research subjects is still part of the (German) appointment system.

Consequently, quantifying achievements in the academic environment (using bibliometric methods) is often perceived as unreasonable pressure on academics, just like the latest regulation of the State of Baden-Württemberg, which requires its scientists to publish research results obtained with taxpayers' money in open-access mode and thus make it available to society free of charge [8].

The introduction of bibliometrics at universities and among scientists, and its acceptance is therefore not only a problem of methodology or understanding or a problem of the vague data basis and the different publication cultures; it is simultaneously a psychological issue as, to many scientists, it does not seem to befit their status to have to prove their performance quantitatively.

At the same time, the twenty-first century is based on the omnipresence of data. Consequently, the motto of CEBIT 2014 included the made-up term *datability*. The availability of data on the web and the presence of personal data on social media, however, also make scientists think and act in this new dimension of datability. Malirsch describes it negatively: "Humankind sees itself as a product that has to be sold, a changing advert, an administrator of its own life and the entrepreneur of its own possibilities" [9],

Conceived like that, it is in a scientist's own interests to also quantify and even advertise his or her own achievements. This can even lead to findings initially being withheld out of self-interest, only to assert them later at a suitable time. Today's opportunities for sharing, collaborating on and working jointly on the progress of knowledge, however, are still curiously disproportionate to the individual reward and career system in public science and research.

Many scientists point out the irony that just now, at a point in history when we've got the technology that facilitates a global availability of scientific data and its distributed processing, where collaboration can be deepened and discoveries expedited, that at this very time we spend our time keeping this very data under wraps and thus prevent the use of equally as advanced technologies to index them [10].

Two main principles are used to evaluate academic output and its influence on the development of a discipline: the qualitative method and the quantitative method. One is the peer review, the other bibliometric analysis.

Compared to bibliometric methods, the peer review method can scarcely be determined by objective characteristics. It involves appraisals by competent experts, which are often described as subjective. At the very least, they cannot be quantified.

Bibliometric data, on the other hand, provide an insight into all the key components of science at a macroresearch level: the structure of academic activities in individual disciplines at the national level, academic productivity broken down by country, the influence of individual countries or regions on particular knowledge domains, international and regional collaboration, the knowledgeability of scientists regarding developments of individual branches of academia in the direct or wider area, the use of formal communication channels in a country, the scientific product and its influence, institutional collaboration, etc. Objects of this research are producers of publications (individual authors, teams, institutions, countries and regions), the publications themselves (journals, articles, secondary information sources), and their descriptive characteristics and citation analyses, which academic communication processes render accessible [11].

Bibliometrics is an instrument to ascertain objective publication data that is often used as performance data and can help complete the tasks mentioned. It can be considered highly mathematically and statistically or be rendered comprehensible and transparent for nonmathematicians in its basic features. Opposition to and misgivings regarding gathering data on research performance primarily stem from people who do not understand the method and who fear it and regard it as manipulation. Consequently, it is not only important to render bibliometrics comprehensible and transparent, but also to simultaneously reveal its limits and name alternatives.

The modern term *bibliometrics* is still in its infancy. It was coined by Pritchard as ‘statistical bibliography’ in 1969 [12], although the term had already been used in a different context back in 1934.

Today, Gorraiz defines it as the “use of mathematical and statistical methods to explain the processes of written communication” [13].

By contrast, the contents of bibliometrics are much older, albeit used in a way in which they scarcely exist today: as bibliographical statistics to examine publications on special thematic issues. The results of these studies served exclusively to evaluate content on particular issues by topic. This shows that the actual and original use of bibliometrics was more a library one.

The first bibliometric analysis stemmed from Cole and Eales. In 1917 the authors studied which books on human anatomy had been published between 1550 and 1860 [14]. The article is regarded as the first bibliometric analysis, even though it did not yet use any citations. The aim of the project was to detect content-related focuses and variations in the extent of the publications on the topic during this period. It was therefore a pure output analysis, not a perception analysis.

The first bibliometric work to study citations was by Gross and Gross in 1927 [15]. They analysed the citations made in footnotes in chemistry, which enabled them to compile a ranking of the key chemical journals of the time based on how frequently they were cited. On the one hand, the specialist community used this information to assess the important publication organs, which echoes the fundamental concept of journal rankings and the impact factor that is so important today. On the other hand, Gross and Gross were librarians and intended to help libraries decide on the procurement of journals with their study. In their analysis, they detected an irregular distribution of citations among the various journals and thus provided the basis for Bradford's law, which was developed in 1934 and according to which the key academic publications were concentrated on a handful of core journals [16]. In 1948 Brian C. Vickery described this 'skewed distribution' mathematically as Bradford's Law of Scattering [17].

Back in 1926, the American mathematician Alfred James Lotka researched the productivity of scientists and described the correlation between authors and publications, according to which the publication output was inversely proportional to the number of scientists in a subject. In other words, only very few authors have many publications, and many authors have only a few. This correlation is referred to as Lotka's law [18].

In the United States, the chemist Eugene Garfield began to develop an interest in the topic and started compiling a collection of publication data and its citations. Up to that point, he had published *Current Contents*, an inventory of the contents of key journals. In an article, he proposed the systematic recording and evaluation of citations in academic publications [19].

As he did not receive any public funding for his index, he founded the Institute of Scientific Information (ISI) and sold his data collection commercially from 1963. By establishing the globally successful Science Citation Index, Garfield created a lasting institution. Nonetheless, he had initially set out to help librarians decide on purchasing literature, especially journals. Consequently, the printed Science Citation Index was also created. To this day, Garfield rejects the use of his indicators to evaluate people and institutions, especially the most famous one, the Journal Impact Factor.

The Science Citation Index, which has long been available as a highly complex online electronic database, is still regarded as an international benchmark for academic evaluation. It was not until the 1990s that a competitor product, the database Scopus, was developed by the academic publisher and media company Elsevier. The development of the internet also increased the competition in the field of bibliometric data for academia and research with the establishment of the database Google Scholar by the internet group Google.

Another development also took bibliometrics into academia through the omnipresence of the internet and free web content. Besides counting publications and analysing citations, there were now quantitative parameters that expanded the indicator spectrum (e.g. the number of downloads, the time spent on a document, the prioritisation of the in- and outlinks), but also the evaluable sources.

Essentially, bibliometrics always corresponds to the development of knowledge and its communication. The classic notion that knowledge progresses in distinct steps that become manifest through concrete, completed publications had crumbled by the beginning of the twenty-first century. With the continuous, fluid academic communication of liquid documents and incomplete knowledge portals, it became clear (again) that knowledge per se does not evolve stepwise in stable little packages of truth that masquerade as publications, either.

> *In the West, for thousands of years, we imagined knowledge as a system of stable and consistent truths. Might this tell us more about the limitations of knowledge media than about knowledge itself? If knowledge is communicated and conserved by committing it to paper in ink, then knowledge is precisely what makes it through institutional filters and does not change. The new medium of knowledge, however, is less a system for the publication of essays or books than a networked audience. Perhaps we can produce new knowledge with the aid of Data Commons, although this knowledge will then take on more the form of a permanent discussion, within which it is sometimes dragged here, sometimes there. This is what knowledge in the age of the internet looks like. It is never really stable, never written down in full and never entirely complete [20].*

The object of bibliometric measurements is therefore no longer solely literature published traditionally by publishing houses, but also (freely) accessible academic material on the internet, such as open-access publications, contents of specialist and institutional repositories, or personal and institutional homepages.

Webometrics not only extends the structural notion of bibliometrics, but also its range of applications. At the same time, it shows just how complex and diverse the measurement of the academic output of people and institutions has become. The analysis of large quantities of data ('big data') as a new challenge or better, as a fresh opportunity, facilitates an increasingly detailed record and analysis of academic results.

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CHAPTER 3

Bibliometric Methods: Basic Principles and Indicators

> *Counting and measuring is the basis for the most fruitful, secure and precise academic method.*
>
> **(Hermann von Helmholtz, 1879)**

The basic idea of bibliometrics is to quantify the academic output of people and institutions. In a second step, qualitative conclusions are drawn from the figures and values.

The quality and evaluation of academic results (for bibliometrics, written output) is especially of great interest to scientists themselves, but also academic managers and policy-makers, not to mention all decision-makers in strategic positions at universities, research facilities and ministries.

Moreover, all public or private sponsors require criteria for academic quality to be classified and evaluated.

Bibliometrics is one of several possibilities to achieve this. The bibliometric method constitutes an indirect approach that infers the academic quality itself from the quantification of the academic output and publications.

Besides classic publications, there is also a whole series of other quantifiable factors that help evaluate academic performance and quality, such as the number of final projects supervised (doctoral theses, postdocs, etc.), the raising of external funding, the number of pending patents, the number of exhibitions and their visitors, appointments on relevant national and international committees, the number enrolled students per chair or professor, and the extent and number of assessments.

Bibliometrics, on the other hand, focuses exclusively on measuring publications. Thus far, however, the term *publication* has been relatively ambiguous: It includes books, book chapters, journal articles and papers in conference volumes.

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With the advent of the internet and the changes in academic communication, this term has become increasingly fuzzy. Anyone who uses bibliometrics today therefore needs to define clearly what is being measured and what kind of publication is to serve as the basis for the individual bibliometric analyses and their statements.

Besides classic publications, there are increasingly academically relevant articles on the internet, such as blog entries, tweets and involvement in portals.

Although these new online articles are also publications and point towards the quality of the authors' work, they are yet to be covered by classic bibliometrics. With the trend towards 'going digital', the majority of future academic communication will be electronic.

Moreover, broad sections of the academic community are already invited to join in the discussion and evaluation of partial results at a very early stage in the generation of knowledge. Communication software also allows people or research groups who are far away from each other to take part. Ideas are generated as a chat in the virtual discourse. Academic preprints are examined in a public peer review, and thus the 'sharpening' of a final publication is no longer a qualitative leap. For bibliometrics, the loss of an authorship that can be ascribed clearly and individually has dramatic consequences. With the blurring or even disappearance of a clear definition of when and by whom an academic project was published and is thus citable, traditional bibliometric methods reach their limits.

We are only just beginning to grasp how the existence of dynamic documents revolutionises fundamental academic results and output in the form of academic publications in that knowledge acquisition and processing, and the propagation and discussion of ideas, have entered into a 'real-time ratio'.

Therefore it is evident that the proportion of academic output from people and institutions that serves as the basis for analyses in classic bibliometrics is becoming smaller and smaller.

This ultimately begs the key question as to the extent to which bibliometric methods are still able to provide a complete and therefore objective picture of the performance and quality of scientists and their institutions in each case by limiting the measurement of classic forms of publications.

Chapter 4, 'Bibliometrics in the Humanities and Social Sciences: Special Forms and Methods', will examine this separately.

The basic methods of bibliometrics run along a succession line, which begins with determining the number of published papers (Section 3.1) and, in the second step, ascertains their perception and reception in the community (Section 3.2). Then the classic bibliometric methods have already been exhausted. The combination of quantity and perception is then used to infer the quality and draw comparisons between people and institutions (Section 3.3).

A direct measurement of the quality of academic publications is not possible using this technique. When it comes to researching the communication of academic findings and determining their quality, it is extremely important to establish the succession line from the number of publications produced, their perception, through their usage and propagation all the way to their internalisation by the readers themselves.

The next step that could provide information on the significance and quality of a publication is to gauge its usage. This area is not accessible to the classic method of bibliometrics, but rather points to new techniques, which are also dubbed 'alternative metrics' or 'altmetrics' (Section 3.5). This especially involves analysing the use of electronically available documents and measuring the 'scientific traffic' on the internet.

All these methods rely on the principle of the cleanest and most precise data possible. It is correlated in relational databases and then retrieved according to various contexts. Nothing other than what was previously entered can come out in the result. By contrast, the big data approach is completely new. It not only involves the clean collection of information with metadata and its processing on a database, but also the algorithmic processing of enormous quantities of data.

If sufficient numbers of publications by people and institutions are to be freely available on the web in future, big data methods can be used to generate insights that have been deemed impossible thus far. This principle will also revolutionise bibliometrics (Section 3.6).

Selecting the right indicators is crucial for the preparation of bibliometric analyses. A bibliometric indicator is a quantitatively ascertainable and therefore quantifiable figure that makes a statement about an academic publication. In theory, the number of possible indicators that make a statement about an academic publication is unlimited. The question as to which statement is to be made is always vital for the selection and use of an indicator. The purpose and objective of a bibliometric analysis and therefore the question regarding a scientific publication determine the sensible choice of indicator.

For instance, one might want to find out how often Publication A has been cited by others. The indicator to be chosen therefore needs to make a statement on the number of other publications in which Publication A is cited. This indicator is the citation frequency. However, we might also want to know which scientists cited Publication A, in which case the citation frequency is of little use. The answer to this question will be a list of the names of the individual scientists who cited Publication A. And if we want to find out the countries of origin for the publications in which Publication A is cited, the result is a list of countries. This indicator is not a standard indicator, either. Further questions on Publication A are also conceivable. For instance, we might want to know the disciplines from which the scientists citing Publication A come, how long they have been working in academia, their importance in the academic community and so on.

As a result, there is a large number of conceivable indicators, not all of which can be measured, however. This means another, this time formal, restriction of the potential variety of indicators.

What this means in a nutshell: First, a bibliometric indicator must provide an answer to the concrete question directed at an academic publication; second, the indicator must be measurable, as a conceivable indicator that cannot be ascertained is no use; third, it must be possible to determine the indicator with a high degree of accuracy and quality – in other words, its values must not be fluke results; and finally, it must be possible to ascertain the indicator with a correlation between the effort and benefit that has been stipulated beforehand.

3.1 THE NUMBER OF SCIENTIFIC PUBLICATIONS: OUTPUT ANALYSIS

The academic output of a person, organisation, region, nation or nation groups is determined by totting up the number of academic publications. While this already yields an initial indication of a scientist's or country's productivity, no qualitative aspects are taken into consideration. Someone who publishes a lot therefore is not necessarily a good scientist and certainly may be no better than one who has published less. As a direct indicator, the number of publications says little if it is not compared with other factors.

Nevertheless, gauging the number of published units forms the basis for all other so-called indirect bibliometric methods. It usually is far from easy to ascertain this basic number. Where it comes from also boils down to the database used.

Consequently, it is vital to name the data basis, that is, to clearly define which kind of academic output was considered in the individual analysis. The most important forms of written output are publications in journals and conference volumes, books and presentations. However, the change in academic communication has led to a greater variety of publication types with the result that entries in (academic) blogs and chats, Twitter channels, on YouTube and other (social) networks can certainly signify relevant academic output that is worthy of consideration (see Section 3.5).

The basic parameter for a bibliometric output analysis is the amount of academic output by a person, institution, country or other group (aggregated on different levels).

This excludes entire areas of bibliometrically unsuitable academic achievements from the very start. Bibliometrists must not tire of pointing out that, besides talks, seminars, hearings, exhibitions, commentaries, reviews, external funding acquisitions, the number of doctoral students and postdocs, honours and awards, many other kinds of academic output are not bibliometrically ascertainable and therefore have to be acknowledged outside this measuring logic.

As a result, only forms of output that are deemed (classic) publications and can be recorded accordingly find their way into bibliometric analyses. An extension of this understanding of bibliometrics has actually just been attempted in alternative metrics ('altmetrics'), which also includes webometrics.

The number of academic publications is practically the only bibliometric figure where its ascertainment depends on the relevant, available and special bibliometric databases. After all, the number of publications can be counted very easily by including all the available reference tools of a thematic and formal nature (e.g. general and specialised databases), as well as taking into account and evaluating any internet sources, printed sources and bibliographies by the authors themselves.

This facilitates a completeness with a good approximation that is no longer possible per se when ascertaining indirect indicators, such as the citation rate.

This results in a large amount of effort involved in determining the number of academic publications via the necessary redundancy comparison required if many different sources have been used to ascertain the output amount and overlaps thus occur.

Based on Tijssen (1992), Gorraiz summarises which quantifiable statements can be derived from academic publications: “The amount or size of the academic activity reflected in the output as the number of publications, the transfer of knowledge and the social and cognitive networks in academia (the structure) by analysing the co-authors, addresses (affiliation), lists of references and keywords”.

The initial result of an output analysis is a list of publications. The abbreviation for the number of papers is N(p).

The sheer number of publications does not yet provide a truly usable and qualified statement on the performance of the individual being examined, however.

Consequently, in a second step, the output can be classified according to publication type.

Although this subdivision is free and therefore, to a certain extent, discretionary, certain standard forms have become prevalent in practice that are regularly taken into consideration. For instance, publications are subdivided into monographs (i.e. books), articles in books, journal papers and conference articles in collected volumes.

In a third step, we can differentiate the specifics of the journal articles. In doing so, we pose the following questions, for instance: In what kind of journal was the paper published? What is the journal's significance and quality (impact factor!)? And are the articles subject to quality control or a peer review?

Naturally, various other studies can be conducted with the results of the output analysis without having to attempt a resonance analysis and its special indicators. However, the meaningfulness of the questions posed regarding the results list and its individual entries is always important. For instance, the article length can be analysed (the statement value is bound to be debatable), and the language or countries in which the articles are published ascertained. Nevertheless, it might also make sense to examine whether other authors cowrote the publication (coauthors) and how many there were. Based on this, we can then attempt to investigate (and find out bibliometrically) which institutes, countries or even (other) disciplines the coauthors come from.

This reveals – already at this early stage in a simple output analysis – whether an author frequently publishes with other authors, whether it is a 'team' that collaborates (more often?) or whether there is an obvious academic collaboration between different institutions. We can also find out and (possibly) substantially interpret that these publications are associated with an interdisciplinarity that might previously have gone unseen. We could then endeavour to discover which different disciplines collaborate on a research topic.

The output quantity can also be presented in relation to its production costs: Herbertz and Müller-Hill dub this the 'performance indicator', which is defined as the average costs per publication or per citation (whereby the latter relation already refers back to the perception).

Temporal progressions in the publication frequency can also be presented: We can examine whether there have been phases of intensive publishing activity and deduce which topics were particularly important at which times for the institute or person in question.

An output analysis's statement value, that is, the first bibliometric step, is therefore really not so low. Of course, the 'bare' figure is not yet able to say anything about how good or bad a scientist or institute really is. And a ranking based on pure output figures does not yet reveal anything, either.

An in-depth analysis as touched upon in the aforementioned examples, however, may very well facilitate qualitative statements about the course of research, special thematic focuses or academic research collaborations (between countries and institutions).

Back in 1975, when bibliometrics was still by no means widespread, Nobel Prize Laureate W. Shockley already proposed using the number of works as an indicator of academic productivity.

All in all, however, gauging the number of publications only provides an indication of the productivity of the institution or individual in question, not their relevance. A comparison of the people from different disciplines or even merely different research focuses, for instance, cannot be interpreted qualitatively based on an output measurement. The individual publication cultures and habits are too different for a reliable statement to be derived from a pure comparison of productivity.

3.2 THE PERCEPTION OF ACADEMIC PUBLICATIONS: RESONANCE ANALYSIS

Resonance analysis is the next step in the bibliometric method and follows on from the pure ascertainment of the output quantity. It goes beyond purely counting publications. Not only is the number of publications by a person, organisation or region simply determined here, but also scientific community's perception of them. But how can perception be ascertained? The academic system of knowledge acquisition is based on the gradual addition of new insights to existing knowledge. In a critical appraisal of what others have already achieved and published, new aspects are added to a question or existing ones are corrected. However, a scientist always refers to the current status quo, which he or she takes into account and cites according to the meaningfulness.

It was not until the late 17th century, however, that the practice of consistent citations and referencing gradually began to take hold. Up to that point, scientists were less inclined to refer to other scientists and their publications, which only occurred if they expected to gain prestige themselves from the mention.

This system, which recognises or criticises the achievements of other scientists, but always mentions them, gives rise to a particular perception story of ideas and findings that might also be referred to as *reception history*. Unlike how the notion of reception history is understood in literature and history, however, in bibliometrics it means the measurement of the resonance, that is, the frequency of citations of particular publications by other scientists. This is the most important basic indicator of resonance analysis. Initially, the citation frequency only describes the number of citations of a particular publication in a specific period. The measure of the citation frequency is a simple number, such as 97, which means that Publication A was cited 97,000 times in other academic publications in the particular timeframe.

The use and acceptance of perception analysis and its assertion that the number of citations constitutes a meaningful gauge for the quality of an academic project, however, assumes (like all bibliometric methods based on it) that there is a reliable correlation between the number of citations of a work and its quality.

Here, the assumption that a publication with many citations is a key work is more probable than the assumption that a publication with few or even no citations is insignificant or even worthless.

If this assumption cannot be followed (and there are also reasons for this), a qualitative statement and assessment is not possible using established bibliometric indicators.

Nonetheless, a vast number of scientists accept these assumptions at least to a certain extent, even if it is unclear what mathematical relation the number of citations bears to the quality of the work. There certainly is no linear correlation between these two factors, and it is unclear whether a mathematically describable connection between the number of citations and the quality of the cited work can even be made.

An indirect bibliometric analysis as represented by resonance analysis can therefore only ever provide an idea of a publication's quality, but never proof.

Another limitation emerges from the available sources, which can be used to determine the number of citations. Not even the well-known and (globally) recognised databases record anywhere near all publications. Consequently, there may be a considerable number of publications that cite a particular work, but the citations of that work cannot be channelled into the evaluation because nothing is known of the sources of the citations, which are not indexed. This ‘dark figure’ is not negligible. Especially in the natural sciences, medicine and engineering, however, there is a notion that the relevant citations are indexed in the established databases. In other words, if an academic work cited in a publication is so insignificant as not to be evaluated in the relevant databases, it is also irrelevant if this citation is not counted.

Nevertheless, not only is part of the academic output and the associated academic communication ignored with this limitation to a small and clearly limited number of relevant databases for the evaluation of citability; a system is also cemented that defines by itself which works are good and which are not of (international) importance.

3.2.1 Citation Frequency and Citation Rate

The basic indicator of resonance analysis is the 'number of citations'. It can be related to other (performance) indicators in various ways.

The number of variations is virtually incalculable and new (statistical) variants are added in the literature every day. In the process, all critical concerns are factored in, such as the number of self-citations, the consideration of citation circles, the publication culture of the individual academic discipline in general, the number of authors, the position of the authors in the order listed, the time lag between the appearance of the publication and the citation, and the quality of the citing publication and/or citing author.

With the parameters *citation frequency* and *citation rate* begins the complexity of indirect bibliometric indicators, which cannot be derived directly from the publication list, and their value only achieves meaning via an indirection assumption.

> *The simplest indicator is the sheer number of citations. As E. Garfield very clearly puts it, this indicator reveals what effect a specific work has on the academic community; it measures the impact of this work for other scientists as citing in an academic publication means recognising the effect and influence the author cited has exerted on the work in question [1].*

If the number of publications can still be elicited relatively easily and, in case of doubt, without any additional aids, a need for (mechanical) mass evaluation emerges in gauging the citation rate. After all, the citation rate determines the number of citations a particular publication has received. Here, it already becomes noticeable in the approach that determining the citation rate is fraught with three uncertainties:

First, the figure obtained can never be complete as it is virtually impossible for anyone to scour all the publications worldwide for citations of the initial publication; second, determining the number of citations is 'bulk business' and practically unrealisable by hand.

This already means we have to rely on evaluations by third parties who scrutinise the academic publications for citations in other publications and reference them accordingly. This work is performed by thousands of scientists and other staff members at the major media groups offering bibliometric databases on the market – both manually and mechanically. In conducting bibliometric resonance analyses, on the one hand we are dependent on the supplier's market data collected based on the division of labour. At the same time, however, we cannot expect any completeness.

Third, we still need to interpret (or rather estimate statistically) which qualitative statement is behind the number of citations ascertained. Without prior knowledge (and this must be enormous) or a comparison, we are unable to make a statement as to whether it is too many or too few if a publication has been cited 10, 100, 1000 or 10,000 times.

Once again, these values only make sense in the context of other figures, which means that citation figures are always relative statements. A rate of 1000 citations only seems high if the statistical average for all citations is 100, for instance. By the same token, it might seem low to us if the number of citations of publications in general lies at 10,000. We need to know (or establish) this before a (relative) classification of the basic indicator ‘number of citations’ can even be made at all.

Another assumption is even more significant: Only someone who accepts that many citations signal a more important work and few citations a less important work can use the citation indicators with all their derivatives in bibliometrics for qualitative statements. Unfortunately, there is no proof of this assumption, at best, only clues.

The basic indicator for the number of citations is N(C).

As with the basic indicator N(P), the N(C) can be placed and interpreted in any relation. In this chapter, we will examine the most important.

In determining the citation frequency, it is usually not the absolute number of citations that is selected, but the number of citations per publication, which is referred to as the *citation rate* and abbreviated to CPP (citations per paper).

Much like the number of citations, the citation rate can be calculated for an individual, institution, region or country.

For a specific scientist, for instance, the citation rate is calculated by dividing the number of all the citations that his or her publications have received by the number of publications; in other words, $CPP = N(C)/N(P)$.

Here is an example: If the scientist has written 50 papers and received 1000 citations from 1990 to 2010, his or her citation rate is 20 ($1000/50 = 20$) for the period stipulated.

The number of citations or the citation rate can be related to any other indicators in the publishing environment.

For instance, the period in question can be varied, temporal progressions displayed, the level of the citations structured in groups (e.g. high, medium and low citations), and older articles compared with more recent ones and their citation rates.

However, there is another special effect in resonance analysis: The citing publications, namely the publications that have cited the initial paper, can be studied for a wide variety of different factors here. This generates a citation analysis on a meta level (or even meta levels of the first, second or the nth order) by revealing which scientists cite the initial publication, in which countries they work, which languages they use and to which disciplines they belong, for example.

This yields a vast variety of combination possibilities and new questions that can be asked regarding the citers and the citing paper.

Nonetheless, the initial question keeps having to be answered concisely, namely what a 'correlation' means and what statement is really being made. It is no secret that nonsense can also be compared with statistics, which is why it is necessary to begin by clarifying the question to which we are looking to find an answer or (if answers emerge from statistics) which statements the relations received really bear.

Frequently, authors cite themselves in academic articles and refer to other papers they have published. Although this is nothing exceptional or objectionable at first glance, references are often (and reasonably) made to their own academic groundwork and, as authors, they are frequently among the few experts in their research field. Nevertheless, authors can send their own citation rate sky high via frequent self- or autocitation and thus gain a competitive edge.

As a result, in bibliometric resonance analyses the proportion of self- or autocitations is often subtracted out to guard against manipulations and achieve comparability. At the same time, the assumption is that a citation by someone else carries more academic clout than a self-citation.

If we analyse citations in the course of time, we receive an ideal course. The citations can begin to be calculated 2 years after publication, for instance, as it takes a while for the paper to reach and be received by the community in question. The number of citations increases to a certain level and drops again after a relatively short time (a few months to a few years). This 'normal' course therefore reflects the life cycle of an academic publication.

After a publication, it takes a certain amount of time (around 2 years) to reach the maximum appreciation. The publication is then cited constantly for a few years before fading back into 'obscurity' as fresh results and publications become more important.

The precise duration of the phases depends heavily on the discipline and topic.

'Sleeping beauties' are academic publications that for years and decades are cited little – if at all – until one day they are 'awoken'. This can be down to a reignited interest in the topic, the time not being 'ripe' for the paper at the point of publication or the topic having been thrust back into the limelight via political decisions.

A typical citation course also exists for high potentials, namely outstanding scientists: After the (usual) delay, the publication is cited at a high (or not very high) level, but the citation frequency does not wane for many years.

Another form of resonance analysis involves tracking patents and patent citations. Patents are often ignored as they are not important for all disciplines, and the relevant bibliometric databases do not display patents or patent citations.

In many academic disciplines, however, patents are actually highly significant as research output and their citations constitute an interesting yardstick for the importance of the individual patents and their creators.

Therefore, any number of questions, which can all be subsumed under the term bibliometrics, can be asked of publications; for example, the length of the articles, the linguistic characteristics, the titles and the common occurrence of keywords (co-word analysis) can be analysed.

The imagination (or rather the academic curiosity) virtually knows no bounds here.

By analysing certain key terms in publications, for instance, themes can be identified and trends projected. However, this kind of analysis is less suitable for determining the performance of people or institutions; instead, it is the object of the general 'science of science'.

3.2.2 The Hirsch Index

For a long time, the citation rate or impact factor (which was completely unsuitable for that purpose) was primarily used to evaluate a person's academic performance. Only a few years ago, an indicator was devised by the American physicist Jorge E. Hirsch that enabled a more accurate, more objective and thus more readily comparable evaluation basis for the academic significance of individual people [2].

After all, the traditional bibliometric indicators are not entirely suitable for evaluating the academic achievements of individual people. These indicators are either insignificant [3] or too complicated to ascertain due to technical or methodological difficulties [1]. Especially in the case of evaluating individual scientists, the call 'for a simple, objective indicator that ideally can be ascertained by the scientists themselves' [4] grew louder. In light of this, Hirsch developed an indicator in 2005 that was easy to ascertain but tailored to the individual performance of a scientist. He called it the H-index. Since its introduction, this indicator has attracted much attention in both the scientific community [1] and among the general public.

Like the citation rate, the H-index (also known as the Hirsch factor or Hirsch indicator) is initially a combination of the number of publications and the citation frequency.

It is determined by sorting all the publications by a person in the descending order of their citation frequency. The value where the sequential number of the publication tallies with the citation frequency denotes the Hirsch factor.

Fig. 3.1 shows an example of determining the Hirsch index.

As the example reveals, the Hirsch factor takes into account publications with an above-average low-citation frequency and those with an above-average high-citation frequency less than a paper that is cited at an average frequency. This means that extremes are disregarded in favour of the 'broadest' possible performance record.

> *It is a simple single number incorporating both publication (quantity) and citation (quality or visibility) scores and hence has an advantage over these single separate measures […] [6]*

Therefore, in determining the H-index, not only is the publication quantity factored in, but also the citation quantity. Consequently, the H-index says something about both the productivity and the influence of a scientist.

A scientist has published eight papers. If these are listed in descending order of how often they have been cited, the size of the Hirsch index can be inferred directly:

	Number of citations
1	32
2	25
3	21
4	13
5	7
6	5
7	4
8	1

Six publications have achieved at least five citations. The Hirsch index for the research in question is therefore five.

Fig. 3.1 Example of determining the Hirsch index [5].

As a result, a scientist who publishes little but has written a single paper with a very high citation frequency, for instance, does not achieve a disproportionately high Hirsch index. The citation rate alone would increase considerably thanks to this one, single paper.

However, a scientist's H-index is influenced by the length of his or her career, not the publication or citation quantity. It is presumed that the H-index and the duration of a career are proportionate to each other [1]. The size of the discipline and the fundamental or applied orientation of the subject in question also affect the H-index.

Hirsch expects the H-score to rise linearly in the course of a career [7]. He posits the following guidelines: A scientist who has an H-score of 20 after 20 years can be regarded as a successful scientist; those with H-scores of approximately 40 after a 20-year career are found at elite universities or renowned research centres; only a handful of outstanding scientists achieve an H-score of 60 after two decades in science.

Since its introduction in 2005, the Hirsch index has been used highly successfully and become the standard indicator in many appointment procedures. As with all bibliometric indicators, a variety of statistical variations on the Hirsch factor now exists.

Table 3.1 Hirsch Factors of Selected Scientists From Different Disciplines [8]

Scientist	Subject	H-Index	Year
Philip W. Anderson	Physics	91	2005
George M. Whitesides	Chemistry	169	2011
Wolfgang Holzgreve	Medicine	41	2013
Solomon H. Snyder	Biology	191	2005

As a so-called robust factor that eliminates the negative and positive peaks, the Hirsch index has established itself as an indicator for the evaluation of people's publication output that is simple to calculate and understand, and meanwhile can also be generated automatically on all relevant bibliometric databases.

As the H-index depends on the timeframe examined, the period considered always ought to be indicated when used, or – and this is standard – determine the H-Index for the researcher's entire career as a matter of principle.

Table 3.1 shows the H-score for scientists from different disciplines.

One of the biggest weaknesses of the H-Index is the fact that only rough statements can be made about the academic significance of two scientists with similar H-scores but different publication quantities and citation frequencies. If both scientists boast a similar number of publications and citations with different H-scores, however, the one with the higher H-score can be regarded as the more influential scientist.

Although the Hirsch Index is a simple, generally more comprehensible bibliometric indicator that is easier to determine, it should explicitly be pointed out that there is no ‘superindicator' which, reduced to a number, could provide an objective picture of the output and perception of academic publications. The Crown Indicator [9] developed at the University of Leiden also only provides an interdisciplinary comparability of key figures standardised across all subjects, just like the J-Factor devised by the Central Library at Jülich Research Centre [10].

It is undisputed among (serious) bibliometrists that only an extensive, heterogeneous set of indicators, but not a single key figure can paint a realistic picture of the performance of people and institutions.

3.2.3 The Impact Factor

Virtually everyone knows the Impact Factor. And it is used for virtually everything. This is the crux of the problem – and where the misunderstandings regarding an indicator that only describes the citation rate of articles in a journal in relation to the number of articles in this journal in a particular time begin. But one thing at a time:

Today more than ever, the journal is regarded as a fundamental medium of academic communication and is one of the most frequently used sources in bibliometric studies.

A journal's decisive parameters offer a glimpse into the development and influence of individual disciplines and fields and the journal's influence on its academic environment. The journal functions as an official medium that registers academic findings publicly; a medium for the propagation of information and a social institution that renders the contribution, the prestige and the recognition of authors, institutions, editors, countries and disciplines visible.

Consequently, it stood to reason to also make academic journals and their contents the object of bibliometric analyses.

This is precisely what Eugene Garfield, the legendary founder of mass bibliometrics, did in the 1950s when he developed an indicator to determine the significance of journals based on the citation frequency of their individual papers. And as was so often the case in the early days of bibliometrics, the indicator was intended to make it easier for librarians to make holding management decisions; that is, the subscription to key journals with a high impact factor should not be halted whereas those with a low impact factor could be dispensed with more readily in the library holdings.

The impact factor is one of the indicators that falls in the early years of Garfield's Institute for Scientific Information. A chemist involved in specialist information, Garfield wanted to find out how good academic journals could be distinguished from ones that were not as good. And so he developed and implemented the Journal Impact Factor, to use its correct name.

The impact factor is determined by the number of articles in a journal and the number of citations that each article receives. Here, the total number of citations is divided by the number of articles. As citations can only ever be measured with a delay of around 2 years, the Journal Impact Factor is defined as the total citations divided by all the articles in a journal in the previous 2 years.

The fact that a 2-year period was selected instead of 5 or 10 years was a coincidence: Garfield did not have more years of the journals he was examining at his disposal.

A journal's impact factor for 2014, for instance, is the number of citations for all the articles in this journal in 2014 divided by the total number of articles in the journal between 2012 and 2013.

The quality of a journal therefore tends to be described based on the impact factor. The basis here is the ratio between the number of articles and the sum of the citations of these articles. If a journal has a high impact factor, it is commonly assumed to be a better one as it is cited frequently. By the same token, if the impact factor is low, the interest among scientists seems minor and the quality of the journal not as good.

Like all cross-sectional factors (statistical averages), however, the impact factor does not say anything about the quality of individual articles. As a result, it is possible for a journal to owe its high impact factor and therefore good image solely to a handful of highly cited papers, while the remaining articles are noted less (if at all).

Consequently, it soon becomes clear that a scientist's performance cannot be assessed with the aid of the impact factor. Nevertheless, the impact factor is still misused as a benchmark for the academic excellence of individuals.

Scientists frequently determine their ‘cumulative impact factor’ by multiplying the impact factors of the journals in which they have published by the number of their papers in the respective journals and totting them up.

The inflationary use of the impact factor implies the assumption that it no longer matters what is published, just where.

If we trace the usage frequency of the impact factor and believe the scientists who use it so readily as their own performance index, the impact factor is a veritable miracle index and all-rounder. It is used to document the importance and quality of journals and, at the same time, it is still the number-one evaluation standard in the majority of contract negotiations for academic staff. Quite wrongly, as an analysis of the factor can easily reveal.

Naturally, it is a certain statistical probability that a scientist's article in a journal with a high impact factor is also cited more frequently than articles in a journal with a low impact factor.

On the other hand, the scientist can only be the ‘profiteer’ of good and frequently cited papers by other scientists in the same journal.

The correlation between the impact of an individual work and the Journal Impact Factor of the publishing journal is usually low [11]

Unfortunately, the use of this indicator as an evaluation standard by individuals in academic practice is extremely difficult to eradicate, even though the H-Index meanwhile offers a far better indicator for the assessment of individual people.

Despite (or perhaps even because of) its widespread usage, the Journal Impact Factor is not without its critics as it influences decisions on the journal in which a paper is published, is used for the performance-oriented allocation of funding and is even consulted to grant salary bonuses among scientists. However, the data basis used is dubious as it is not rendered transparent and therefore open to scrutiny [12].

The impact factor is and remains a benchmark for assessing journal quality and is unsuitable for making statements about the perception of individual academic articles and their authors.

Optof summarises the basic features of the impact factor as follows [8]:

- The impact factor is a tool for determining journal quality.
- The impact factor is *not* a tool for determining the quality of an individual article.
- The impact factor is *not* a tool for assessing the quality of an individual scientist.
- The impact factor is *not* a tool for assessing the quality of a research group if it has published fewer than 100 papers in 2 years.
- The quality of an article, scientist or group of researchers is measurable via citation analyses.
- There does not necessarily have to be a correlation between citation analyses and the assessment of the reviewers.
- The citation analysis can be used later as a success indicator for a particular ‘science policy’.

The impact factor is determined and published in the Journal Citation Reports (JCR), a former Thomson Reuters database (in 2016 the Intellectual Property & Science Business was sold to Onex and Baring Asia. In the following, all Services former belonging to Thomson Reuters are referenced as ‘Onex and Baring Asia’). The JCR only contains a limited selection of journals and ignores web publications, monographs and grey literature in the evaluation [13].

Moreover, it is unclear which articles are included: evidently also ones that are generally not cited, such as editorials, letters or brief reviews.

Another point of criticism is the (randomly) set evaluation timeframe of 2 years. For many disciplines, especially those where the 'knowledge half-life' is considerably higher, this is not a reasonable timespan. Marx and Bornmann provide a good overview of the weaknesses of the impact factor [14].

After all, the Journal Impact Factor depends heavily on the individual academic discipline. Consequently, the Journal Citation Reports now offer a 5-year impact factor.

In 1987 Hirst introduced the Discipline Impact Factor, which determines the number of all citations of articles in core journals in a particular subject.

Table 3.2 features examples of the Journal Impact Factor for a few selected journals. Table 3.3, on the other hand, indicates the average impact factor for selected disciplines (Aggregate Impact Factor) and the average citation rate (Aggregate Immediacy Index) in these subjects. Moreover, the impact factor is easy to manipulate if citation circles become active.

Table 3.2 The Journal Impact Factor Depends Heavily on the Discipline

Discipline	Journal	JIF (2013)
Psychology	Psychological Bulletin	14.392
Physics	Nature Materials	36.452
Genetics	Genomics	2.793
Chemistry	Annual Review of Analytical Chemistry	7.814
Biology	PLoS Biology	11.771

The JIF for selected journals in different disciplines [8].

Table 3.3 Average Journal Impact Factors and Citation Rates in Selected Disciplines [15]

Discipline	Ø JIF(2013)	Ø Citation Rate(2013)
Geosciences	2.241	0.524
Life Sciences	3.167	0.669
Chemistry	3.222	0.652
Physics	2.415	0.545
Formal Sciences (Mathematics, Computer Science, Systems Science)	1.446	0.278
Engineering	1.924	0.362
Medicine and Health Sciences	2.881	0.638
Applied Sciences	1.755	0.353

The Immediacy Index is an extension of the impact factor. It is a gauge of the speed at which the articles in a journal are cited, and is determined by dividing the number of citations on articles in a journal within a year by the number of articles published in the same year. If a journal published 100 articles in 2014 that received 1000 citations in the same year, the Immediacy Index for the journal in 2014 is 10.

Like most bibliometric indicators, the Immediacy Index only makes sense if placed in an academic context. This begs the question as to the importance of the speed of citations for the content of the publications or the progress of the scientific findings. Again, the importance is bound to be highly discipline specific and much more important for assessing the rate of spread and the reception of information in academia (the 'science of science') than assessing the quality of a journal. And naturally, the Immediacy Index is no more suitable for inferring the academic performance of individual authors than the impact factor.

The inverse factor to the Immediacy Index is the citing half-life. While the Immediacy Index describes the reception rate of knowledge in the scientific community, the citing half-life is an indicator to determine the currentness of the references in a journal. The citing half-life is the number of previous years from which half the references in articles in the journal for the current year stem. A journal's citing half-life for 2014, for instance, is three if 50% of all the references in the journal's articles stem from the years 2012, 2013 and 2014.

This makes the indicator a statement on the citation behaviour of the authors in this journal.

Once again, the interpretation of the citing half-life depends extremely heavily on the disciplines and even the individual research field.

The quality of the statements that this indicator furnishes is questionable: What does it ultimately mean for the academic quality of a journal and its contributors if the references are recent and therefore current, and the citing half-life score is low? Is this a positive statement ('the authors only use the latest sources') or to be regarded with a more critical eye ('the authors only see a small temporal horizon')?

Besides the *citing* half-life, the *cited* half-life is also determined on the database Journal Citation Reports. Whereas, as we have seen, the citing half-life concerns the currentness of the articles cited in a journal, the cited half-life involves the recent use of articles from a journal in other articles. The cited half-life is the number of years after which 50% of all the references from the journal in question stem. If a journal's cited half-life is five, this means that 50% of all the articles in this journal are still being cited after 5 years. If the cited half-life is 10, however, then half of the articles are still being cited after twice as long (10 years), which suggests an enduring perception of the articles in this journal and longer sustainability in the scientific community.

Most publishers use the impact factors of their journals as an adverting chip and the now established open access journals still prove their relevance and competitive edge over commercial journals with the impact factor.

As with many other factors in bibliometrics, the impact factor has been refined in a large number of variations and is also still very much present as a journal benchmark in bibliometric research and practice [16].

It is not possible to go into all of these refinements here.

Besides the refinements and statistical variations of the JIF, there is a whole series of alternatives to the impact factor [17–20].

This already leads us to the chapter on alternative metrics, or ‘altmetrics’.

3.3 THE LEADER BOARDS: RANKINGS AND BENCHMARKING BASED ON BIBLIOMETRICS

The use of bibliometric analyses only makes the most sense by comparison; absolute figures on academic output and citation frequencies without a benchmark are virtually meaningless. Only a direct comparison with people, institutions, groups, regions or countries renders positions visible and open to interpretation (Figs 3.2A,B, 3.3 and 3.4).

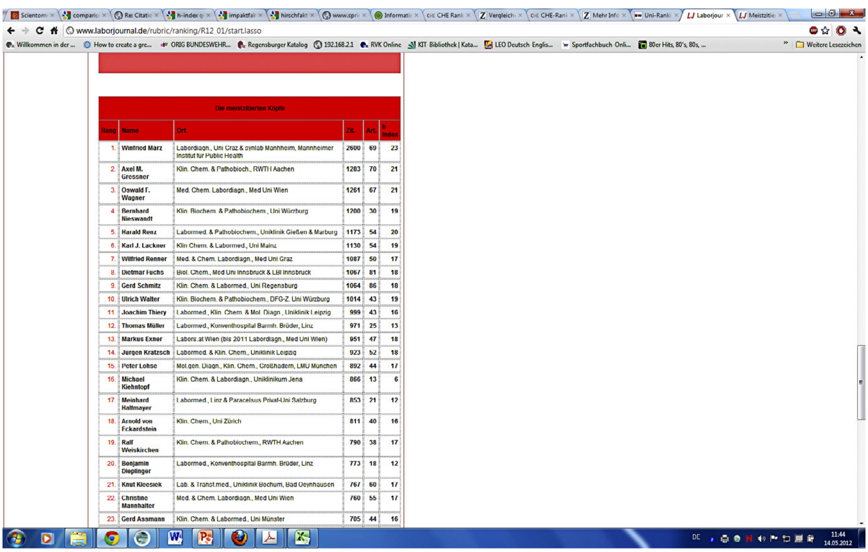
However, the use of bibliometric analyses in a ranking is one of the main challenges that bibliometrics faces. After all, to be able to make a comparison the partners need to be comparable. This already pinpoints one of the most important parameters for a bibliometric ranking.

It is necessary to find a ‘comparable’ partner, that is, when ranking scientists, knowledge of which fields the researchers each work in. Comparing a biologist directly with a chemist is just as futile as comparing an experimental physicist with a theoretical one. Even for a comparison in these heavily related disciplines, the publication habits and consideration or non-consideration on international databases are too different. A direct comparison between a philologist and a physician or a law scholar and a sociologist is practically impossible.

At this point, it already becomes clear just how much effort needs to be made to elevate bibliometric rankings from meaningless numbers games.

Meanwhile, however, statisticians have also developed methods in bibliometrics that facilitate a transdisciplinary comparison. For example, the relative position of scientists or institutions within a specialist community can be determined, whereby interdisciplinary comparisons are possible again [24].

If the academic performance of the Institute of Romance Studies is to be compared with that of the Institute of Genetics, for instance, the Institute of Romance Studies' position in the ranking can be determined bibliometrically compared to all institutes of romance studies at German (European, worldwide) universities and is ranked fifth out of fifty, for example. The same is carried out for the Institute of Genetics, which comes twelfth out



www.laborjournal.de/rubric/ranking/R12_01/start.lasso

Die meistzitierten Köpfe

Rang	Name	Ort	Zit.	Art.	h Index
1.	Winfried März	Labordiagn., Uni Graz & synlab Mannheim, Mannheimer Institut für Public Health	2600	69	23
2.	Axel M. Gressner	Klin. Chem. & Pathobioch., RWTH Aachen	1283	70	21
3.	Oswald F. Wagner	Med. Chem. Labordiagn., Med Uni Wien	1261	67	21
4.	Bernhard Nieswandt	Klin. Biochem. & Pathobiochem., Uni Würzburg	1200	30	19
5.	Harald Renz	Labormed. & Pathobiochem., Uniklinik Gießen & Marburg	1173	54	20
6.	Karl J. Lackner	Klin Chem. & Labormed., Uni Mainz	1130	54	19
7.	Wilfried Renner	Med. & Chem. Labordiagn., Med Uni Graz	1087	50	17
8.	Dietmar Fuchs	Biol. Chem., Med Uni Innsbruck & LBI Innsbruck	1067	81	18
9.	Gerd Schmitz	Klin. Chem. & Labormed., Uni Regensburg	1064	86	18
10.	Ulrich Walter	Klin. Biochem. & Pathobiochem., DFG-Z. Uni Würzburg	1014	43	19
11.	Joachim Thiery	Labormed., Klin. Chem. & Mol. Diagn., Uniklinik Leipzig	999	43	16
12.	Thomas Müller	Labormed., Konventhospital Barmh. Brüder, Linz	971	25	13
13.	Markus Exner	Labors.at Wien (bis 2011 Labordiagn., Med Uni Wien)	951	47	18
14.	Jürgen Kratzsch	Labormed. & Klin. Chem., Uniklinik Leipzig	923	52	18
15.	Peter Lohse	Mol.gen. Diagn., Klin. Chem., Großhadern, LMU München	892	44	17
16.	Michael Kiehntopf	Klin. Chem. & Labordiagn., Uniklinikum Jena	866	13	6
17.	Meinhard Haltmayer	Labormed., Linz & Paracelsus Privat-Uni Salzburg	853	21	12
18.	Arnold von Eckardstein	Klin. Chem., Uni Zürich	811	40	16
19.	Ralf Weiskirchen	Klin. Chem. & Pathobiochem., RWTH Aachen	790	38	17
20.	Benjamin Dieplinger	Labormed., Konventhospital Barmh. Brüder, Linz	773	18	12
21.	Knut Kleesiek	Lab. & Transf.med., Uniklinik Bochum, Bad Oeynhausen	767	60	17
22.	Christine Mannhalter	Med. & Chem. Labordiagn., Med Uni Wien	760	55	17
23.	Gerd Assmann	Klin. Chem. & Labormed., Uni Münster	705	44	16

(A)

Fig. 3.2 (A) Ranking of the most cited physicians in Germany in the medical journal Laborjournal*: Publikationsanalyse 2005–08: Klinische Chemie & Labormedizin (publication analysis 2005–08: clinical chemistry & laboratory medicine) by Lara Winckler,* Laborjournal *01/2012 [21a].*

(Continued)

1612 Highly Cited Researchers (h>100) according to their Google Scholar Citations public profiles

Sixth Edition

The data for this edition was collected during the **second week of February 2017** of a **BETA** list of the public profiles of the most highly cited researchers (h-index larger than 100) according to their declared presence in the **Google Scholar Citations** database.

The list, that includes both living and deceased authors, is ranked first by h-index in decreasing order and when ties appear, then by the total number of citations as a secondary criteria.

This ranking is far of being complete, as many scientists have no developed a GSC public profile yet, that it is a very easy and free task and with a surprisingly large coverage of both contributions and citations. It is also probably we overlooked a few profiles, so please contact us with any information regarding gaps, missing profiles or the full project. Our editor is available from this email address Isidro F. Aguillo (isidro.aguillo@csic.es), but we strongly suggest to read **Methodology** in advance.

This ranking has been funded by the **Project ACUMEN** European Commission 7th Framework Programme, Capacities, Science in Society 2010. Grant Agreement 266632 and the CSIC Intramural 201310E040

Powered by Google scholar

IMPORTANT!: All scientists with duplicated profiles (marked # in the rankings) will be removed in future editions unless they delete their extra entries

RANK	NAME	ORGANIZATION	H-INDEX	CITATIONS
1	Sigmund Freud	University of Vienna	269	488396
2	Graham Colditz	Washington University in St Louis	264	256415
3	Eugene Braunwald	Brigham and Women's Hospital; Harvard Medical School	246	290831
4	Ronald C Kessler	Harvard University	245	263006
5	Pierre Bourdieu	Centre de Sociologie Européenne; Collège de France	242	528228
7	Solomon H Snyder	Johns Hopkins University	240	216313
6	Michel Foucault	Collège de France	237	690001
8	Robert Langer	Massachusetts Institute of Technology MIT	232	216122
9	Bert Vogelstein	Johns Hopkins University	230	315600
10	Eric Lander	Broad Institute Harvard MIT	225	294683
11	Michael Karin	University of California San Diego	223	210430
12	Gordon Guyatt	McMaster University	217	187432
13	Michael Graetzel	Ecole Polytechnique Fédérale de Lausanne	216	235390

(B)

Fig. 3.2, Cont'd (B) 1612 Highly Cited Researchers (h > 100) according to their Google Scholar Citations public profile [21b].

of sixty institutes. In the direct comparison, it is evident that the Institute of Romance Studies has performed slightly better than the Institute of Genetics. Nevertheless, these analyses are complex and require a painstaking approach to render the results comparable. The extremely different and specific directions of the two institutes alone in one country relativise this benchmark's statement.

Fig. 3.3 How universities are ranked: the top universities in the world in the World University Rankings [22].

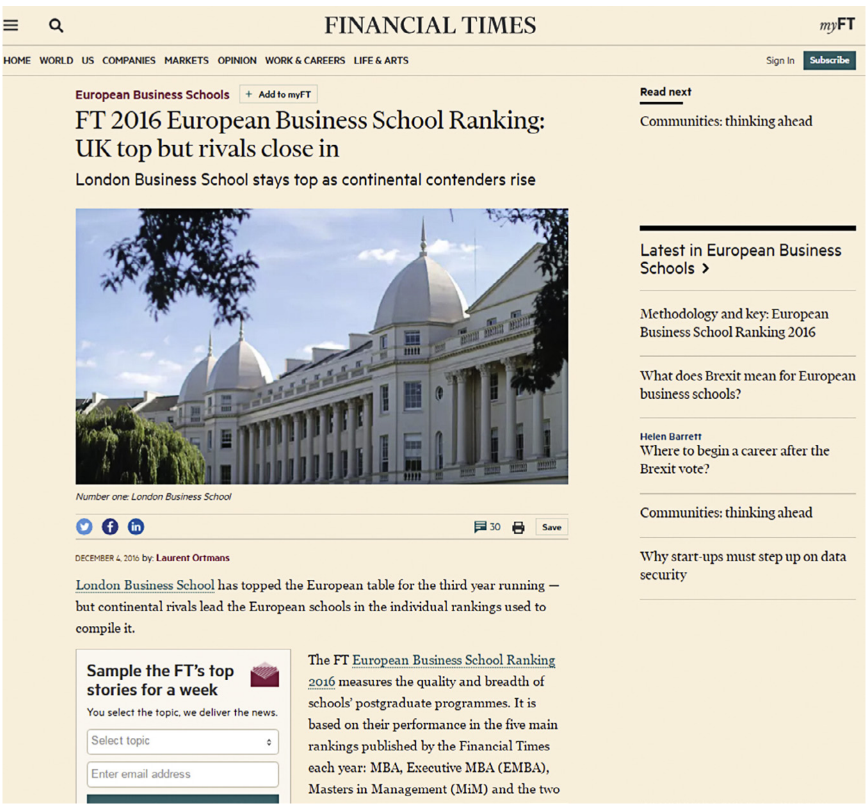


Fig. 3.4 Already reached the daily press: Business School Ranking, here from the newspaper Financial Times *(screenshot from December 4, 2016) [23].*

Comparative analyses are therefore always a task for bibliometric specialists and, besides precise knowledge of the parameters, demand as extensive a number and indicator base and the use of as many different bibliometric methods as possible. Overhasty comparative analyses using the quick-and-dirty method not only produce (valid) reservations regarding bibliometrics overall; they can also cause considerable harm if strategic, personnel or monetary decisions are made based on the results.

Advisory committees and research promotion institutions have also examined academic rankings and issued recommendations as to how rankings might be shaped within and between universities. The German Rectors' Conference, for instance, highlights seven points for compiling a ranking:

- "University and non-university institutions that conduct research in questionable subjects are included fully and equally.
- The funding does not take place through the institutions affected and, besides the central costs, also encompasses the local costs in full.
- A standardised 'core research dataset' is to be implemented across the board beforehand as a systematic basis to minimise effort and costs.
- Different subjects and subject cultures each undergo specific rating procedures. According to the method's design, interdisciplinary comparisons are systematically inappropriate.
- In the political acknowledgement of the rating results, the financial and legal starting point of the institutions is also to be taken into consideration.
- A sufficient number of reviewers are available without jeopardising other evaluation tasks.
- The German Council of Science and the Humanities permanently retains responsibility for the research rating. The universities are not involved in the commercial rating process" [25].

Bibliometric methods also lend themselves to the selection of suitable comparative partners (whether they be people or institutions). A thematic analysis can be used to quickly determine which possible comparative partners work in a similar field. The analysis of coauthors of academic publications also provides indications of which institutes or people work on similar issues. This leads to another method that bibliometrics uses to create trend analyses.

3.4 BIBLIOMETRICS AS A TREND SCOUT: TREND ANALYSES AND FORECASTS

Bibliometric methods can also be used to ascertain academic or content-related trends. In the thematic focusing and concentration of relevant publications, it soon becomes clear where possible trends are evident.

Every year, the publishers of the international database Web of Science (WoS) and the IP & Science division at Onex and Baring Asia predict the Nobel Prize winners with the aid of bibliometric methods – with a remarkable success rate [26]. Besides the number of citations, the international networking and sustainability of citations (high level over a longer period of time) are also taken into account. Trend analyses are conducted in a very similar way: If particular topics are present in (international) publications at a high level over a longer period, this is indicative of a trend theme. Conversely, flagging citation rates reveal a declining interest in the topic and thus a downtrend.

Nonetheless, there are so-called 'sleeping beauties', namely topics that are ignored (from a citation perspective) for a long time before fresh interest in the subject is awakened due to changed (usually external) parameters. This can frequently be observed in politically influenced or fuelled topics, such as in environmental or energy policy. Academic insights into a particular subject rapidly become uninteresting if they are not supported politically or therefore financially. The citation frequencies of such projects are often very low over the years, which is not down to the quality of the publications here. If fresh (political) interest in the topic is aroused, however, sleeping-beauty publications are quickly roused from their 'deep sleep' and increasingly received and cited.

Trend analyses that make predictions on academic and socially relevant topics are especially used for strategic decisions by academic managers and policy-makers. Bibliometrics can therefore also support the political process involved in the focus and establishment of new research promotion areas complete with a new infrastructure.

Fig. 3.5 Tag cloud of bibliometric indicators.

3.5 NEW AND ALTERNATIVE BIBLIOMETRIC METHODS: ALTMETRICS

> *There's no greater source for creating competitive data advantages than the web. Web intelligence gives us a more timely, geographically specific, and contextually precise view than we've ever had before [27]*
>
> ***(OREN FALKOWITZ, Former Chief Data Scientist, United States Cyber Command)***

In principle, the number of bibliometric variations is unlimited (Fig. 3.5). As is usual in statistics, new statements also emerge through new combinations and relations in bibliometrics. Here, a distinction needs to be drawn between the mere change, alteration and refinement of existing basic indicators and their bibliometric variations and the establishment of qualitatively new measurement parameters, which, for their part, also facilitate qualitatively new statements about the academic performance of people, institutions, regions and countries. Besides the refinement and optimisation of existing bibliometric methods, their indicators and the resulting bibliometric variations, bibliometrics has also received a boost with the digital media transition and the change in academic communication.

Thanks to the (mass and straightforward) availability of contents on the internet, academic publications and their importance have taken on an entirely new dimension both in their determinability and their evaluation. Webometrics is a branch of altmetrics, for instance.

Webometrics describes quantitative methods that help analyse web structures, links and contents, and interrelate them. If it examines academic online publications, it is part of bibliometrics. The term *webometrics* was already defined by Almind and Ingwersen in 1997, according to which webometrics constitutes the use of informetric methods on the World Wide Web [28].

In the internet age, the citation referenced will not be the sole benchmark to deduce the significance of a publication directly for much longer.

Until now, this assessment has been coupled with the assumption that frequently cited publications are more important and thus also represent a better academic achievement. The reception of publications is not determined through pure citation, however. In many humanities disciplines, for instance, it is usual to consider other texts extensively, comment on their content, add to them, reject them or devotedly refer to them. Such a reception generally assumes that the author has scrutinised the text. If an author merely cites another publication, the assumption is that he or she has examined it. However, the pure citation does not prove this. In the bibliometric follow-up to his 1988 book, Andrew Abbot reveals that the majority of citations contain literature that has not even been read [29].

Bibliometrics therefore fails to (and even cannot) demonstrate whether scientists have actually perceived the cited texts by their colleagues.

Even if the new metrics in the age of the internet are unable to provide this definitive proof, they still add another step to classic bibliometrics and its measurement of citation frequency. The availability of digital publications on the web and the emergence of a vast variety of different online academic activities such as blogs, communication on social networks and flipboards enable the measurement of access figures, the time spent, links and download figures, as well as providing (indirect) indications of the importance of the work in question and the scientist's productivity and networking.

Although, naturally, this does not prove that the work has been read (and understood!), a download potentially displays a greater interest than pure citation. Moreover, gauging the duration of the online use of documents enables a more advanced inference regarding the interest in an academic work, as recently made possible by the academic social network Mendeley [30]. In the not too distant future, the evaluation of the usage data of electronic publications via library catalogues will also open up another possibility to make statements on usage habits.

These new possibilities are based on a new fundamental understanding of the development of academic insights over time. The notion that truth is constituted through concrete stages of knowledge is largely linked to the individual medium. Publications – and therefore actual statements of the progress of knowledge – can only follow a distinct step in the analogue, paper-based world. Therefore, it needs to seem as if the increase in knowledge is progressing as the acquisition of knowledge in stable, step-by-step knowledge levels. Evidently, this notion is contingent on the underlying medium. In the digital environment, however, a continual cognitive process is possible for the first time. This not only topples firmly held truths of clear knowledge levels, but also their simple evidence of the citation of the publication in question.

> *In the West, for thousands of years, we imagined knowledge as a system of stable and consistent truths. Might it be that this tells us more about the limitations of knowledge media than about knowledge itself? If knowledge is communicated and conserved by committing it to paper in ink, then knowledge is precisely what makes it through institutional filters and does not change. The new medium of knowledge, however, is less a system for the publication of essays or book than a networked audience… It is never really stable, never written down in full and never entirely complete [31].*

The development of a digital academic environment is far more than the use of a new medium to transport old contents; it is a revolution in the system of knowledge acquisition, its communication and its references.

The pursuit of the digital footprint that all users leave on the web will thus facilitate more detailed statements about the use and usage intensity of online publications than was the case with paper-based publications. A large number of so-called alternative metrics already exist, the use of which goes beyond gauging the classic citation frequency of academic publications. Ascertaining the number of (online) readers, the number of comments, tags, bookmarks or the entry of blogs or tweets indicates the potential of webometrics with alternative metrics. However, these alternative metrics are still a far cry from the systematic usability and coverage of academic contents and disciplines. On the website altmetrics.org, a whole series of ‘alternative’ tools that can be used to measure the impact are listed [32].

> *Altmetrics cover not just citation counts, but also other aspects of the impact of a work, such as how many data and knowledge bases refer to it, article views, downloads, or mentions in social media and news media [1].*

The article by Mike Thelwall et al. [33] provides an insight into the history of webometrics, which dates back to 1997. The major problem of webometric studies is that a large number of diverse documents, redundancies, spam and other things appear on the internet together with high-quality information. A link analysis, for instance, yields very unsatisfactory results here. Nonetheless, the article illustrates how useful networks between various academic information and relevant websites can be created by analysing web links.

A study by Paul Wouters and Rodrigo Costas from CWTS Leiden, on the other hand, provides a comprehensive and well-readable summary of current alternative metrics [34].

Mike Thelwall and Pardeep Sud explain three different ways of conducting webometrics [35]. The central three basic forms of webometrics are link counting, web name counting and the citation of URLs. In the process, information from Yahoo and Bing on the distribution, citation and linking of organisations in the academic environment are used.

While these technologies make other bibliometric variants possible, webometrics is unable to overcome the principal limitation of bibliometrics – namely that it only indicates the quality and significance of academic publications indirectly – although it utilises the diverse measurement possibilities of the digital world. Nonetheless, it is a step ahead for the purposes of the succession line: The proven use of a publication is worth more than its mere citation.

The transformation from the printed word to digital texts also carries major advantages for citations: The reader can 'click through' online resources seamlessly and consult and check references directly. However, this only works as long as the link is active. Accurate citations do not help if the link does not work. Then references no longer perform their original function and counteract the basis of modern academic discourse. Even though it has largely been neglected thus far, the topic of 'link rot' is therefore a particularly important subject for bibliometrics in a digital environment [36].

Digital online documents put what for centuries was tradition into reverse. The majority of highly specialised academic books could not be produced at any publishing house without costing the author a fortune. Now, conversely, gauging the costs per download can provide an indication of how important an academic article or reference book really is.

For decades, bibliometric analyses have been conducted based on the only database available to date, the Science Citation Index (SCI). Nowadays, at least there is also a commercial competitor product, Scopus. Today, alternatives to this classic principle of counting publications and tracing their citation in other publications (citation-based metrics) exist [37].

However, the SCI was the only available system to also provide statistically relevant critical masses of bibliometric resonance data with (mechanical) mass evaluation. Although the development and market launch of another mechanically processed and evaluated database with bibliometric data, the Scopus database by Elsevier, triggered a competition with the rival products by Thomson Reuters, it did not principally spawn a new kind of data selection and assessment.

Only the mass availability of freely accessible publication data and, where applicable, their resonance values has made the emergence of such alternative metrics, or 'altmetrics' for short, possible of late. As the internet ultimately permits this kind of alternative metrics, it is often also referred to as *webmetrics* or, alluding to the term bibliometrics, *webometrics*.

Levitt and Thelwall describe altmetrics as the natural extension of classic bibliometrics [38].

The alternatives exist in the new key figures that are distinct from the classic ones recorded for more than 50 years on the one hand and in the attempt to develop alternatives to the aforementioned (commercial) databases introduced (SCI and Scopus) on the other. However, they are based absolutely crucially on new forms of academic communication, which has changed dramatically in the course of the last two decades. Besides classic publications in journals, conference volumes and as books, a whole series of other, internet-based publication forms have emerged that cannot be evaluated on the known databases with the established indicator canon on the one hand, but signify a valuable new form of measurable output from scientists on the other.

Bar-Ilan, Haustein et al. argue that altmetrics has uncovered previously unknown paths of academic impact and facilitates the visibility of science on the web as citations alone are not academically adequate and can only have recourse to a very slow and formal path of academic communication [39].

The free availability of other academic content on the web, even beyond classic completed documents, leads to a large number of considerations and approaches as to how academic activities might be measured and evaluated. Besides the familiar linear academic documents and treatises, these include video and audio files, but also academic contents that are provided or simply 'crop up' within the scope of the wealth of social media, such as Facebook, Twitter and blog systems, which are as yet not fully ascertained or ascertainable. These Web 2.0 applications have not only rendered the academic discussion 'web-suitable', they also offer a platform for lasting academic statements that can no longer be neglected when assessing the overall picture of people and institutions.

Altmetrics becomes possible once many academic results in all their forms have been made available as open data. Using altmetric methods, these forms of academic output can first be available swiftly (we do not have to wait for a paper to be published or a book to printed and delivered) and second can be determined without any major methodological effort, such as a citation database.

Here are some examples of possible formats for this internet-based academic output [40]:

- PDF downloads and viewed (clicked-on) HTML files
- Academic comments on blogs, Wikipedia, Twitter, Facebook and other social media
- Links saved in systems such as Mendeley or CiteULike
- Recommendations via systems such as F1000Prime
- Alternative citations such as ImpactStory, where the indicators available in the classic databases are not used

While systems such as SCImago Journal Rank (SJR), Eigenfactor or the Source-Normalized Impact per Paper (SNIP) index do not yet constitute real alternatives, they are just the ticket to enrich and broaden the thinking on key figures and the data basis used [41–43].

On the website eigenfactor.org [41], for instance, the impact of academic journals and the article significance are considered based on a 5-year citation history. Moreover, a cost-benefit factor determines the ratio between journal impact and journal price [42].

The SNIP, on the other hand, interprets the ratio of the citation rate of an article to the average citation rate of an article from the same year and discipline as a benchmark. The data basis is the database Scopus [44].

On the SCImago website, a whole series of statistical values on journals and their usage is processed. The data is based on the Elsevier database Scopus [43].

Webometric Analyst finds online contents, evaluates their impact and processes their usage graphically [45].

Ever-increasing amounts of relevant academic information are also provided freely on the net for the scientific community in the form of talks and presentations (Slideshare [46]) or academic software (GitHub [47]). The ascertainment and measurement of these forms of academic output also permit statements about the activity, quality and quantity of a scientist's research.

Disciplines that are supposedly remote from the internet, such as the history of archaeology, already use Web 2.0 technologies to make relevant statements and trigger academically recognised discourses on the web (e.g. the *Wissenschafts-Blog der Historiker* [48]).

To gauge alternative metrics, a whole series of established services already exists that determines alternative indicators, each with a different alignment, to quantify academic output. These include systems such as impactstory.org, sciencecard.org, altmetrics.com or readermeter.org.

It rapidly becomes clear that bibliometrics can be rethought here: Way beyond the first steps of bibliometric succession, such as measuring the output quantity and determining the citations as (thus far) the sole benchmark for the resonance of a publication, the opportunity now arises to get closer to finding proof of the actual use of a publication.

Moreover, it has long been necessary to also include so-called alternative academic performances based on the scientist's internet activities in the evaluation.

However, altmetrics measurements should also be called into question: First, the data quality is primarily criticised, as well as the randomness of the selection of parameters. There is no sign here yet of a standardised method as is known and applied for the classic citation databases. Systems such as NISO [49] or ORCHID [50] could help. ORCHID is an unequivocal author ID that clearly determines the author and is supposed to rule out mix-ups. NISO, on the other hand, is an American standardisation organisation that develops exchange formats between libraries and publishing houses. Nevertheless, the standardisation of altmetric indicators and their data basis harbours the risk of lapsing into classic database patterns and a strictly specified data selection, thereby returning to the classic bibliometric databases.

Another criticism of evaluating academic contributions on social networks concerns the issues of resonance. It is presumed that the academic quality of the works is often less responsible for their good proliferation than a quirky title or even an unusually popular object of research.

Moreover, there are not yet any reference values that exist for the evaluation of statistics on social media: The social impact is difficult to gauge and without a benchmark, 465 retweets say just as little as 234 citations. Systems such as Social Crawlytics, which help find competitors and compare oneself on the social web, could help here [51].

Therefore, altmetrics has two faces: Although download figures and reader metrics are unable to substitute for citations, they can probably be a useful supplement to them [52]. Moreover, altmetrics means the recognition of new and modern forms of academic communication beyond journal papers and books. At the same time, it heralds a democratisation of the evaluation of academia through the emancipation of commercial, monopolistic citation databases on the market.

3.6 FROM CAUSALITY TO CORRELATION: BIG DATA IN BIBLIOMETRICS

Bibliometrics means the quantification of academic output and the inference of the perception and quality of publications. It is therefore part of the quantification of the entire lifeworld that has been in full swing for a few decades.

With big data, this quantification reaches a new level: In future, truth will be based on correlations and no longer solely on causality, which also has huge consequences for bibliometrics.

Until now, bibliometrics has predominantly been based on the tradition of relational databases and clear datasets.

It was unquestionable that only the causal relationship between the public perception of a work through citations or usage and the importance of the work and its author yielded a correct statement. But in this logic, statistical probability had already come to the fore instead of pure causality. It is known that a paper's high profile is either achieved through a good and outstanding performance or particular errors, which are then refuted and produce high citation rates.

Statistically, however, a high citation rate is far more likely to signify a particularly good work than an exceptional error.

The extreme accuracy of processing the data upon which bibliometric analyses are based is thus in peculiar contrast with the statistic probabilities to be deduced from them. After all, they cannot be used to produce purely causal relationships.

Nonetheless, the diligence with which the parameters of the individual publications and their authors (such as complex author IDs [53]) are determined is in keeping with the classic mindset of data cleanliness and data precision from the age of relational databases of the 1980s.

For a few years, however, there has been a new approach towards establishing truth and connections that are neither based exclusively on nor demand the cleanliness of the individual data. Big data describes a phenomenon that generates statements based on an enormous amount of data that neither mean nor call for any causality. Pure correlations emerge that permit statements, the veracity of which increases with the amount of underlying data evaluated.

> *The transition into the world of big data demands a change in thinking on our part with regard to the advantages of precision… As already mentioned, the insistence on accuracy is a relic of the analogue era… Back then, every single data point was important, which is why great pains were taken to rule out any mistake in the recording [53].*

This is how medicine succeeds in extrapolating therapeutic recommendations from pure correlation analyses based on a very large comparative quantity of symptoms. A useful statement on treatment and its success or therapy for individual patients can then be deduced.

In other words, if hundreds of thousands or millions of patients with the same or similar symptoms have been treated successfully with a course of therapy, it is highly likely that a new patient can be treated successfully with the same therapeutic approach, without having to make a diagnosis based on causal correlations.

The therapeutic recommendation then follows the algorithm and no longer the art of medicine; the patient is effectively treated by a computer and no longer by the doctor. This is the epistemic basis for what physicians describe as evidence-based medicine and will be able to achieve ever better results in the (machine-aided) age of big data.

If, however, correlations can crop up in lieu of causality in many other areas (and not just in humanly sensitive medicine) in future, and the results become better for it, not worse, that is a victory for algorithms over expertise; a victory of empiricism over specialism.

> *Many decision-makers have recognised that big data is no longer a pure IT topic. Instead, big data is blossoming into a movement that encompasses the interplay between modern internet technologies and analysis methods, which enables the acquisition, storage and evaluation of big and expandable, primarily differently structured data [54].*

For bibliometrics, a clear agenda emerges: The cleanliness of the data is no longer as important as it used to be. If the amount of data available is only big enough, the error becomes increasingly small, and the quality of the statement improves with every new piece of data available on the web.

What this means in concrete terms: The more data on scientists and their output there is available in a wide variety of forms this side of the paywall, the more statements about the importance of publications and their copyright holders can be made automatically with the aid of algorithms. Besides, the fuzziness in terms of the kind of publications has ballooned to such an extent that it is virtually impossible to define a publication exactly these days.

Algorithmic systems will then be able to conjure true statements from the enormous quantities of data on the web – without the aid of specialists. They develop without anyone having painstakingly extracted, structured or stored any data beforehand; they develop without relational databases being filled with them and specific categories having been created to sort them out again.

> *The ethos of inaccuracy is already forcing its way into an area that doesn't tolerate a lack of precision: databases. Traditional database engines need highly structured and precise data that has not only been stored, but also split into so-called 'records', which in turn were composed of fields…*
>
> *This approach towards storage and analysis, however, is becoming increasingly unrealistic… This has led to new database developments that reject old principles – the principles of datasets and predefined fields that reflect the precisely defined information hierarchies [55].*

The interpretation of connections will then no longer be important for the truth of the statements. There is no need to speculate or determine why a correlation developed.

The truth will then simply be there, and it will be a new truth that no longer needs to be based solely on causality.

If algorithms are able to provide useful therapeutic recommendations for treating people and soon it will not only be doctors who have to treat patients, algorithms will also be able to provide useful statements about the importance of academic publications and their authors.

In any case, a rapid increase in data about people and their statements and achievements can be observed on the web. The contents of websites, professional networks, social networks, blogs and chats, but also data from smartphones and other mobile terminal devices all the way to data from lifelogging systems also yield an increasingly sharp profile of the individual scientist, which permits conclusions regarding his or her academic importance.

The individual indicators that have painstakingly been determined within the scope of classic bibliometrics so far are therefore increasingly taking a back seat as general 'profiling' can paint a far more accurate and comprehensive picture of the performance and importance of a scientist and his or her work.

The notion of the transparent customer is well known; the transparent scientist soon will be. And without any negative connotations, either:

> *As a consequence, an increasing amount of data on every single one of us is available – including from areas of our private lives. The image of the transparent customer and transparent citizen is certainly no longer a vision of the future; it has become a reality [56].*

A score like the one that has long existed for the evaluation of scientific efficiency, especially in allocating grants, can then be transferred to academia.

The new H-index, which is supposed to determine the significance of a scientist's publications as a simple indicator, is obsolete and can be replaced by a digital 'scientist score': a value that considers and combines a scientist's complete data available online.

> *While membership of clans, the nobility or the upper class used to decide our opportunities in social and economic life, big data analysis per score value (…) now assumes this task of separating the wheat from the chaff [57].*

Whether we like it or not, the massive changes in the academic knowledge and work process also require a new perspective on the quantification of academic achievements: The future of academic evaluations will be data analysis as academic findings are increasingly manifesting themselves in data, and the internet already has an enormous amount of data by and about people ready for analysis.

> *Education has observed the reduction of teaching staff in disbelief ever since word got around that no learning effect is more reliable than that of the forefinger on a tablet computer that correlates databases, which then signal either their correctness or fallacy, or ideally the next challenge. . . . Academia is transforming into a cluster of data with impact factors which can be deposited without distinction through texts, authors, institutes or entire disciplines, and signalise nothing other than the amount of additional data that refers to the data mentioned first [58].*

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CHAPTER 4

Bibliometrics in the Humanities and Social Sciences: Special Forms and Methods

4.1 INTRODUCTION

> *Not everything that counts can be counted, and not everything that can be counted counts.*
>
> ***(Albert Einstein)***

Bibliometrics is the measurement and counting of publications. However, the Albert Einstein quote emphasises that there are areas where evidently not everything that counts can be expressed and measured in numbers. This especially goes for academic results in the humanities and social sciences. The usual and widespread use of bibliometrics is primarily successful in the natural sciences and medicine, where it is already part of the standard repertoire of performance evaluation.

We also find a certain spread and acceptance of bibliometrics in the social sciences, although virtually no standard bibliometric methods are used in the humanities. In this chapter, we aim to clarify the possible causes of this dichotomy in the use and distribution of bibliometrics.

Bibliometrics is primarily concerned with measuring and evaluating research achievements that appear in written form in a wide variety of media. Consequently, only academic output, its perception and therefore its impact history that can be proven in writing are gauged in classic bibliometrics. In itself, bibliometrics does not say anything about the quality of the individual academic research achievements; it merely indirectly infers the quality and importance of the respective written research achievement on account of its impact history. For the natural sciences and medicine, academic publications as research achievements primarily consist of journal and conference papers, as well as articles in academic books. Monographs and other major publications, however, are much rarer.

An Introduction to Bibliometrics. http://dx.doi.org/10.1016/B978-0-08-102150-7.00004-9

Table 4.1 Publication Cultures by Comparison: NSE (Natural Sciences, Engineering) and SSH (Social Sciences, Humanities)

	NSE	SSH
Citation behaviour	Constructive citation (rung ladder principle)	Citation as differentiation/rebuttal
Thematic orientation	International	Regional and national
Publication language	English	Often language of the country
Place of publication	International	Regional and national
Kind of publication	Journal papers dominate	Monographs and collected volumes dominate; also journal papers
Target group	International specialist audience	Specialist academia and audience
Individual vs. coauthorship	Coauthorship	Often individual authors

The scientific and humanities disciplines differ from each other on the strength of these different publication cultures alone (Table 4.1).

In order to test the applicability of bibliometrics to the humanities and social sciences, it is therefore necessary to work out the differences in publication cultures and to analyse which kind of research achievements are made in the humanities and social sciences besides classic publications and whether and how they can be taken into consideration in bibliometric analyses on the other.

Consequently, the following section will begin by providing a closer look at the publication and citation habits of selected humanities and social science disciplines before attempting to gain an overview of the kind of academic output in these fields and test the 'bibliometric operability' by analysing selected scientists [1]. In doing so, we will examine a historian, an archaeologist, a law scholar and a German philologist more closely.

4.2 PUBLICATION AND CITATION CULTURES IN THE HUMANITIES AND SOCIAL SCIENCES

The nature and kind of publications already differ between the natural sciences and medicine on the one hand and the humanities and social sciences on the other. The latter are dominated by monographs, collective volumes and conference volumes. With articles in academic journals taking a back seat, books still play a key role in academic communication here.

By contrast, science, medicine and technology predominantly publish their research results in journals and conference volumes, while classic monographs are a major exception.

As for the thematic orientation and research objects, the natural sciences, medicine and engineering have, for the most part, an international focus. The questions when researching photosynthesis or the treatment of heart failure are simply identical in Europe, the United States or Asia.

In the humanities and social sciences, on the other hand, regional or nationally relevant topics are frequently the subject of academic research. Moreover, the social sciences and especially the humanities are oriented far more strongly by the results of the national academic output.

This result also corresponds to the publication language. Science, technology and medicine predominantly publish in today's usual scientific language, English; in the arts, the language of the country is still frequently more suitable.

The major difference in the number of publications in English in the social and natural sciences can be attributed to the fact that the social sciences deal with phenomena that are specific to a geographical and social context. Therefore, such projects are not necessarily interesting for a broad international audience. There are also far fewer international journals (in English) in the social sciences. Moreover, publishing in international journals is less important for the appointment and reward system than in the natural sciences and technology.

These findings also reflect the places of publication, which are consistently internationally oriented for science, technology and medicine yet nationally or even regionally oriented in the humanities and social sciences.

Van Leeuwen et al. stress the importance of national journals in national languages for law or linguistics (especially when it comes to researching smaller languages and their literature) [2]. It is highly unlikely that a journal written in a more minor language will be represented or cited in the Onex and Baring Asia or Elsevier global citation databases. The same observation goes for journals that examine historical topics from smaller regions and are not interesting for the broader specialist community. In the natural sciences, such phenomena are far less common and usually limited to classic mapping projects in botany and zoology.

Although the arts and social sciences frequently reach a broad, interested (nonspecialist) audience, the vast majority of articles in science, technology and medicine are aimed at an international specialist audience.

As far as the number of authors is concerned, once again differences between the two groups can be observed. In the humanities and social sciences, it is still often single authors who pen sometimes quite extensive individual works (classic monographs) and take years to do so. The smaller journal papers in the natural sciences and medicine, on the other hand, are usually written by several authors, frequently whole groups of scientists who publish these works together.

With the exception of the humanities, cooperation has become the norm in academic work. It becomes visible through the organisation and foundation of new and larger centres of excellence or multidisciplinary research groups [3].

In the natural sciences and biomedicine, for instance, a rise in coauthored publications of around 80%–85% was detected between 1998 and 2000, compared to only 70% in technology, 45% in the social sciences and barely 15% in the humanities [4].

The natural assumption that publication behaviour and cultures are only fundamentally different between the natural sciences and humanities is actually incorrect. Even within the humanities and social sciences, sometimes significant differences appear between the various disciplines. Tables 4.2–4.4 highlight this in a comparison of the publication cultures between law, literary studies, classical history, archaeology and classic philology.

Online publications in law, for instance, have a lesser image than classic book or journal publications. In literary studies, however, a hesitant increase in the use of online publications can be observed. Online publications have only a low status in classical history, archaeology and philology.

Table 4.2 Publication Behaviour in Different Academic Disciplines [5]

	Law	**Literary Studies, Main Reference Point: German Studies**	**Class. History, Class. Archaeology, Class. Philology**
Prestigious publication forms	Monographs and treatises (postdoctoral thesis, dissertation)	Monographs (dissertation, postdoctoral thesis)	Monographs and congress volumes (postdoctoral thesis, dissertation)
Important publication forms	Major commentary vs. study commentary; course books vs. reference books	Collected volumes (workshops and conferences)	Major importance of the review system; journal papers
Quality control	Renowned publishers; peer review	Tendency towards peer review for specialist journals	Renowned publishers; double blind peer review
Orientation of specialist focuses	National and regional	Predominantly national	Specialisation in temporally and geographically limited areas

Table 4.3 Publication Behaviour in Different Academic Disciplines [5]

	Law	Literary Studies, Main Reference Point: German Studies	Class. History, Class. Archaeology, Class. Philology
Online publications	Enjoy less prestige than book and journal publications	Hesitant use of online publication; emergence of review organs, newsletters and second versions of essays in printed journals	Low prestige and limited appeal
Place of publication	National and regional orientation	Mostly national orientation	In accordance with the orientation of the subject-specific focuses
Publication language	Occasionally international	Language of the country	In accordance with the orientation of the subject-specific focuses

Table 4.4 Publication Behaviour in Different Academic Disciplines [5]

	Law	Literary Studies, Main Reference Point: German Studies	Class. History, Class. Archaeology, Class. Philology
Individual vs. coauthorship	Traditionally individual authorship	Increase in publications with several authors, but hardly any coauthorship	Individual authorship; also coauthors
Rankings	Since 2009: ranking of law journals	No recognised ranking	Ranking of humanities journals (ESF)
Subject-specific features	Reduction in academic work of 'leading professors'	Importance of specialist journals declined in the long term	Academic colloquium as evidence of research activity

There are also noticeable differences between the three aforementioned groups in terms of the place of publication and the publication language:

Law is primarily regionally and nationally based and very seldom internationally oriented. This also goes for literary studies, as well as history and archeaology, which are often bound by national research focuses.

In law and literary studies, the publication language is very often the national language.

If we compare the number of authors and the kind of publications, law is characterised by single authorship. Only very few legal papers by several authors exist. Coauthorship is also very scarce in literary studies, although the tendency is gradually on the increase.

4.2.1 Citation Cultures

In the natural sciences, citation behaviour takes place according to a cumulative rung ladder. Preceding papers are cited; the scientist works step by step on a temporal and content-related development line for the purposes of increasing knowledge and cites the preceding papers upon which his or her (partial) findings are based, builds his or her own hypotheses or uses (published) methods in his or her own experiments. In the humanities and social sciences, citations are often included to distinguish from or consciously refute other scientists' theories or hypotheses. A constructive citation that, purely methodically, entails a high citation rate for previous publications is not common here.

The sources cited in each case also differ significantly: Whereas only around half of all citations stem from journals in the humanities and social sciences, this figure is more than 80% in the natural sciences and medicine. The dominance of the journal culture is also evident here compared to the monograph culture in the humanities and social sciences (Fig. 4.1).

The majority of citations do not refer to journal papers here, but rather books, music libraries, works of art, etc. The citation dynamics also differ in this instance: It is not uncommon to encounter citation sources that are hundreds of years old in contemporary texts [7].

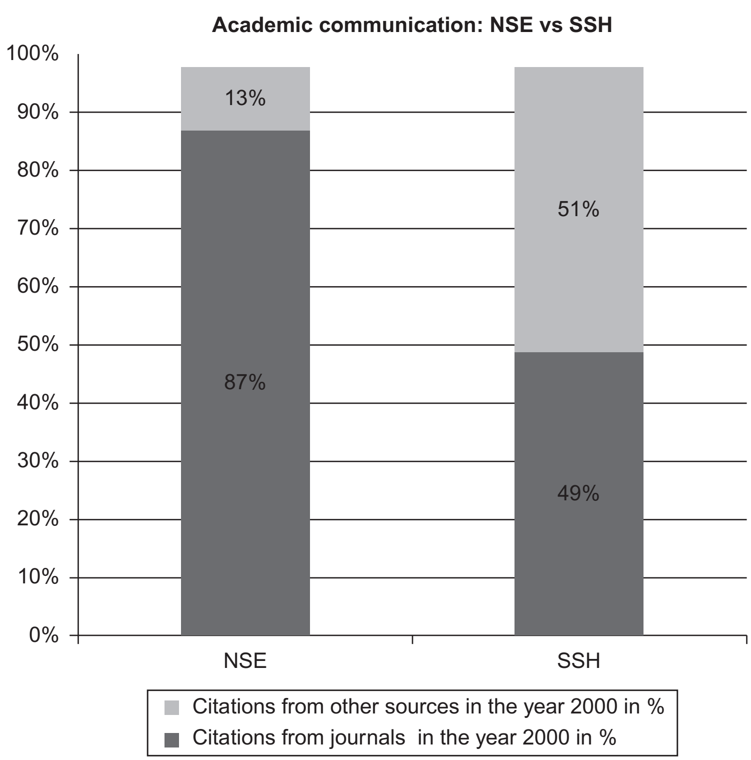

Fig. 4.1 The distribution of citations from different sources in NSE and SSH [6].

The number of self-citations also differs:

In the humanities and social sciences, the proportion tends to be low compared to other disciplines.

4.3 FORMS OF ACADEMIC OUTPUT IN SELECTED DISCIPLINES

Not every kind of academic output is bibliometrically suitable as a written publication. But the known citation mechanisms, their evaluation and the data basis are not usable for many disciplines. Therefore, special research for measuring performance and bibliometrics evolved in the humanities. There is evidently a whole series of specific characteristics in the humanities that make the use of familiar bibliometric methods seem inappropriate here. The Rectors' Conference of the Swiss Universities (CRUS), for instance, initiated its own large-scale project to develop quality criteria for research in the humanities [8].

In the aforementioned project, Ochsner et al. compiled and named a series of quality criteria for the humanities [9].

On his homepage, Professor Ulf Brunnbauer, a Regensburg historian and Eastern Europe researcher, provides a long list of extremely different academic achievements [10]. Interestingly, these are not predominantly written publications that would be bibliometrically suitable, but rather largely other achievements that completely defy evaluation via bibliometrics: congresses and conferences, seminars and colloquia, specialist collected editions, popular science publications, films, talks, exhibitions, recommendations for the preparation of exhibitions and a tourist trail on the collection of lost cultures.

In his projects on Bohemian-Bavarian cross-border relations, for instance, as a historian he collaborates with various regional partners, such as museums, organisations and initiatives.

This combination alone just goes to show that clearly only a very small proportion of his academic achievements exist in written form and is therefore bibliometrically suitable. In the case of congresses and conferences, whether a citable conference volume is available is key; seminars, colloquia, popular science publications, films, exhibitions, talks and museum activities cannot be recorded bibliometrically.

The Regensburg archaeologist Tobias Gärtner also only provides a small proportion of his findings in a bibliometrically suitable form [11]. The results of his excavations of ancient and mediaeval castles and their grounds are photos, films, models, plans and, naturally, a corresponding selection of publications. It is not possible to record photos, films, models and plans in any bibliometrical form, however.

A closer look at the researcher's publications also reveals that the majority of the journals in which he publishes, such as *Archäologie in Niedersachsen*, *Nachrichten aus Niedersachsens Urgeschichte* or *Schaumburger Studien*, are not featured on the major databases.

The archaeologist's achievements are therefore virtually bibliometrically unverifiable.

A large number of research results are also extremely difficult to capture bibliometrically in law.

Professor Thorsten Kingreen, a law scholar at the University of Regensburg, lists the following achievements on his homepage [12]:

monographs, editorships, annotations, articles in handbooks and textbooks, essays, didactic articles, reviews, talks, hearings and varia.

Of these, at best monographs are straightforward to record bibliometrically; editorships, articles in handbooks and textbooks, or didactic articles much less so.

Commentaries, which signify an extremely important academic contribution for jurists, and hearings, which constitute proof of quality for a good law scholar within the scope of legislative measures, for instance, completely fall through the bibliometric cracks.

In the case of a philologist, such as German philologist Professor Ursula Regener, we expect a highly book- and text-based academic performance [13]. Sure enough, the researcher references a wealth of publications on her website. However, she also consistently describes lectures, exercises and seminars as research achievements.

Even *Erläuterungen und Dokumente zu Joseph von Eichendorff Das Marmorbild*, which she published and highlighted as central, a handout published by the renowned publishing house Reclam for students that has since become a seminal work on the topic, falls through the bibliometric cracks: The author's name does not even appear in the key bibliographical information on the book. Evidently, the publisher and author neglected to apply the name to the work in such a way that it would be bibliometrically traceable.

Therefore, even distinct commercial publications fall through the bibliometric cracks and are lost for performance evaluations.

It is therefore clear that the application of established bibliometric methods and indicators across the board is still virtually impossible, especially in the humanities and social sciences. On the one hand, a whole series of bibliometrically unsuitable research achievements exists; on the other hand, no suitable data basis is available for these disciplines that would permit processing with classic bibliometric indicators.

Indicators that are supposed to be used to evaluate research achievements in the humanities and social sciences therefore still need to be developed in close collaboration with the individual disciplines and with due regard to the specific publication habits. The fact that there is currently not even a reliable data basis for automated bibliometric methods in the humanities does not make the matter any easier. Neither Web of Science nor the database Scopus factor in monographs sufficiently to render a bibliometric statement feasible.

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CHAPTER 5

The Data Basis

The success of bibliometrics depends on the data basis available. As bibliometrics makes a quantitative statement about publication events, bibliometric projects are based on the broadest possible data basis on the publication or its author or institution, etc., to be described and analysed.

For anyone looking to make statements about a publication, it is sufficient to have this publication to describe it. Collecting simple metadata on a publication, such as the author, institution, place of publication, year, scope or language, is already a simple bibliometric statement for the purposes of a description. In this sense, cataloguers in the world's libraries already work as bibliometrists.

If we want to make statements about a larger number of publications, however, such as the number of all the publications by an author, institution or country, or even analyse the perception of publications, it no longer suffices to have only one publication. It now becomes necessary to gather a data basis with metadata on the publications, which can be used to answer bibliometric questions.

In light of this deduction, it goes without saying that compiling one's own data basis for a bibliometric analysis is laborious and will scarcely produce any comparable bibliometric results. If the data basis is untransparent and the results are not comprehensible, however, they no longer correspond to the basic principle of scientificity and their statements are disputable.

Sure enough, in the early days of publication analyses bibliometrists collected the respective data basis themselves.

Even today, not all questions can be answered based on the databases available, and the analyst needs to gather the desired data from other sources.

Nevertheless, these days we have bibliometric databases that contain the majority of the (meta) data for bibliometric issues. And that is not all: Thanks to a concise, transparent and professional data acquisition and publication evaluation over a long period of time, efficient systems are available

An Introduction to Bibliometrics. http://dx.doi.org/10.1016/B978-0-08-102150-7.00005-0

that made bibliometrics possible on the high level we conduct today. Despite the sometimes justified criticism of the details, which will also be discussed later for the databases mentioned, the existence of commercial databases is vital for professional bibliometrics.

At the same time, alternative metrics in bibliometrics (altmetrics) require other basic data to use their indicators. Essentially, altmetrics is based on free data that is available on the web and evaluated with the aid of algorithms. This leads to established commercial databases feeling considerable competition, while classically structured databases, such as Web of Science or Scopus, are ousted in the long run due to the specifics of data evaluation as used in altmetric methods. In the transition to big data technology, bibliometrics is able to generate the majority of its findings from vast, free, unstructured data quantities.

5.1 WEB OF SCIENCE AND SCIENCE CITATION INDEX BY THOMSON REUTERS (NOW ONEX AND BARING ASIA)

The fact that the chemist Eugene Garfield began recording publications systematically and evaluating them statistically in 1955 can be regarded as a major stroke of fortune for bibliometrics. By collecting data in the Science Citation Index and later at the institution of the Institute of Scientific Information (ISI) he founded, Garfield already established the data basis for professional bibliometric analyses more than half a century ago (see also Chapter 2: Introduction and History). There is no need to recount the long history of this database in detail here [1].

The rather long period (compared to the history of the more recent natural sciences) in which publication and reception data was collected in a concise and comprehensible way is crucial for the scope and quality of the data. This proves to be a major competitive advantage.

Nowadays, the database is owned by Onex and Baring Asia and exists in an increasingly confusing deluge of commercial products and names, which nevertheless contain the database's ‘centrepiece’, the Science Citation Index, in the respective ‘packaging’ [2].

Web of Science, for instance, is a multidisciplinary platform with 46 million datasets, more than 12,000 journals and around 150,000 conference reports. The bibliographical information, abstracts (albeit only since 1991), citation information, cited references and all authors are evaluated.

The database is updated on a weekly basis. Fig. 5.1 features a screenshot of this product's current look.

Here, it is important to point out which content-related, structural development this database has undergone.

While only a limited number of academic journals was originally evaluated by Garfield, nowadays a colourful array of evaluated publications is available. In the Journal Citation Reports (JCR), the impact factor and its derivatives are ascertained based on citations of articles in individual journal titles. The JCR Science Edition contains roughly 8500 journals, the JCR Social Sciences Edition around 3000. Basic bibliographical information, such as the publisher, short title, language and ISSN, the subject classification in the JCR's roughly 230 academic categories, the Journal Impact Factor (JIF) and other bibliographical, bibliometric statistics, is determined. The beating heart of the multiple database sales package Web of Knowledge remains the Science Citation Index. It currently evaluates around 3800 journals from 1000 disciplines and is mainly limited to the natural sciences, medicine and engineering. Today, SCI-Expanded, which dates back to 1900, records more than 8800 journals from 150 subject areas in the natural sciences, medicine and engineering. Since there has been a mounting interest in and even a demand for bibliometric analyses in the arts and social sciences, the former Thomson Reuters also established the Social Science Citation Index (SSCI) in 1973, which presents contents until the year 1898

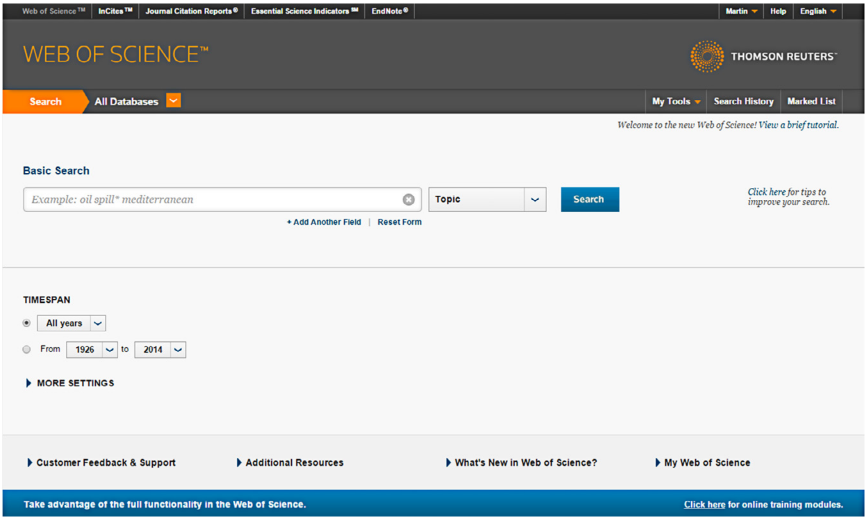

Fig. 5.1 Web of Science homepage (status 24.10.2014).

and currently contains around 4500 journals from the social sciences, but also roughly 3500 from the natural sciences and technology.

It was not until 1978 that the Arts and Humanities Citation Index (AHCI) was developed. It only falls back on literature since 1975 and currently evaluates around 2300 journals from the arts and humanities, as well as subject-relevant articles from around 6000 social science journals.

Around 150,000 conference reports are evaluated in the Conference Proceedings Citation Index, which only goes back as far as 1990.

Unfortunately, the coverage is still so low from a temporal and thematic perspective that reliable analyses are not yet really possible with this instrument. Here, it is clear just how valuable a data basis that has been built up over a long period of time is, but also the particularity of the respective publication cultures with regard to their evaluation and evaluability.

Besides the aforementioned citation indices, Onex and Baring Asia also issues the Conference Proceedings Citation Index, which emerged from the original ISI Proceedings and evaluates conference papers (see earlier mention).

The discussion on which media forms and units ought to be evaluated in citation databases will continue as long as the SCI exists. Very recently, for instance, the Book Citation Index was established as the result of increasingly vociferous calls among the academic community. Launched in 2011, for the first time it evaluates academic monographs. This plugs a gap that had long triggered criticism of the Science Citation Indices as publications in book form and their citations had been excluded from consideration.

These examples just go to show how closely the possibilities of bibliometrics are linked to the data basis available. Without the indispensable work of Eugene Garfield, bibliometrics would not be possible in this form today.

Fig. 5.2 reveals the coverage of different disciplines over the years in the SCI (proportions of academic publications from different disciplines in the total number of papers evaluated in the SCI from 1990 to 2014) [3]. It is clear that the central STM topics and covered with medicine, the life sciences and physics.

Many bibliometrists are uneasy about having to rely on data from a commercial enterprise in conducting their analyses which, until only recently, was roaming about on the market without any competitors. Anyone who

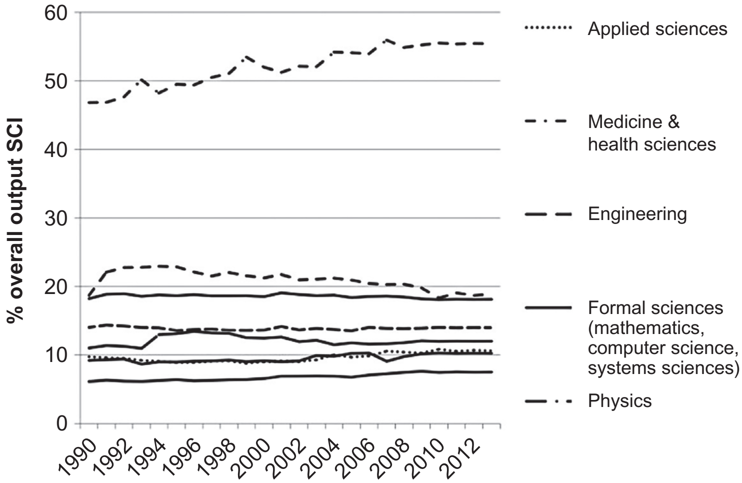

Fig. 5.2 Coverage of disciplines in the Science Citation Index over years.

cannot afford access to the (expensive) bibliometric databases on the market is virtually excluded from bibliometrics.

Another breakdown and specialisation of bibliometric databases was accomplished by Onex and Baring Asia with the development of regional bibliometric databases. This triggers a discussion that criticises the dominance of North American, European and Japanese science in English in the SCI. In addition, the rise of China as a relevant academic nation (which has turned the 'Big Three' into the 'Big Four' and whereby China has long since overtaken Japan in research output) prompted Onex and Baring Asia to not only launch a Chinese Citation Index, but also to compile an Arabic Citation Index in collaboration with the Regional Library in Shiraz (Iran) [4]. This should guarantee that relevant research output from other language and cultural spheres are considered in citation databases.

Naturally, this begs the question as to why indices for other language and country groups (e.g., a Spanish citation index to take into account the research output from all Spanish-speaking countries) should not also be established. The discussions on this matter continue.

The basic design of the WoS and the journals assessed there are geared towards the evaluations of the Journal Citation Reports. Only if a journal receives a particular impact factor over a longer period of time is it evaluated in the WoS and part of the journal set as the basis for the world's most well-known citation database.

On the other hand, this is the most commonly expressed criticism of the SCI's evaluation policy. Only around 5% of academic journals worldwide are found in the WoS. Publications in the remaining 95% of global academic journals are not taken into account. What is a quality criterion from the perspective of the WoS editorial team means that, for the critic, the majority of the global academic output is simply ignored.

5.2 SCOPUS BY ELSEVIER

For decades, the SCI was the only database on the market that made bibliometric analyses possible. In 2004 Elsevier, an international media company with extensive experience in the academic publishing business, became a competitor in the complex field of bibliometric analysis databases with its own database, Scopus [5]. Fig. 5.3 features a screenshot of its current look.

This step was received by the community with a mixture of scepticism and joy: the former because Elsevier had not previously developed any explicit expertise or collected any (resonance) data; the latter as the monopoly that the SCI had enjoyed thus far was not cemented for good. Nonetheless, besides the market-based assessment, there was also a whole series of

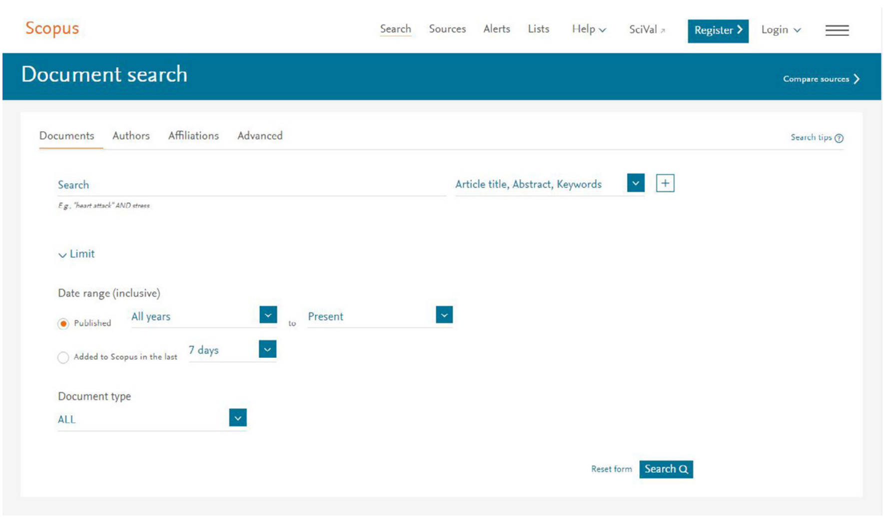

Fig. 5.3 Homepage of the Scopus database [6].

content-related grounds that spoke in favour of a diversification of the services for bibliometric databases. Consequently, the selection of the journals evaluated in the SCI according to the impact factor (see the previous mention) is just as contested as the focus of the publications listed in the SCI in the English language.

Scopus pursues another approach in these fields: A committee decides on the acceptance of journals and their evaluation. Journals with a lower impact factor therefore have a chance of being accepted on this database, and scientists and editors can propose interesting journals for acceptance. To put it in simple terms, the SCI approach is based on a quality-oriented, close selection of titles, while Scopus's unique selling point lies in the greatest possible variety and breadth.

What promises variety and the broadest possible coverage can rapidly become randomness and the loss of quality standards. The openness of the Scopus publishing committee to publications not written in English, however, therefore led to signs of a particular interest in the Scopus database outside the Anglo-American sphere.

The major competitive advantage of the longstanding coverage and great history of the SCI was exhausted relatively swiftly. The possibilities of mass digitisation enabled the makers of Scopus to feed in an enormous amount of content in a very short space of time and achieve a temporal coverage that is suitable and sufficient for reliable bibliometric analyses. The Scopus database is hosted by the platform SciVerse Scopus and contains around 49 million datasets, roughly 80% of which are provided with an abstract. Scopus is multidisciplinary and evaluates around 19,500 journals, trade journals, 360 book series and at least 5 million conference papers. The datasets evaluated have only contained cited references as well since 1996. Thanks to massive retrodigitisation, however, almost 50% of the contents of the Scopus database is literature dating back further than 1996. Bibliometric analysis tools are available.

In contrast to WoS, Scopus has a stronger European and Asian focus and is updated daily [7].

The market therefore has two commercial systems where the compilation and use of data at an extremely high automated and technical level facilitate professional bibliometric analyses.

5.3 GOOGLE SCHOLAR

The two commercially available databases with relevant bibliometric data have been described earlier. Moreover, there is an understandable desire to be able to conduct bibliometric analyses even without having to fall back on ‘payment information’. At the latest by the time the search engine giant Google expanded its database services to include the ‘Scholar’ sector, the community seemed to have found a new option. And sure enough, Google not only included academic publications in the system, but also citation data [8].

Fig. 5.4 shows a screenshot of the current look.

In Google Scholar it is also possible to at least find the number of citations of a publication and a person's H-index. And not only that, the citations are usually linked and direct access to the citing publications is possible.

Nevertheless, Google Scholar does not currently constitute a real alternative to Scopus and the SCI. It is absolutely unclear which publications are accepted or how the citations gauged come about. Unfortunately, one might say, Google – as with most of its other services – also clings to a high nontransparency of the data and its usage – which, at this point, is all the more unfortunate as we need to know the data basis and its composition for serious bibliometric analyses.

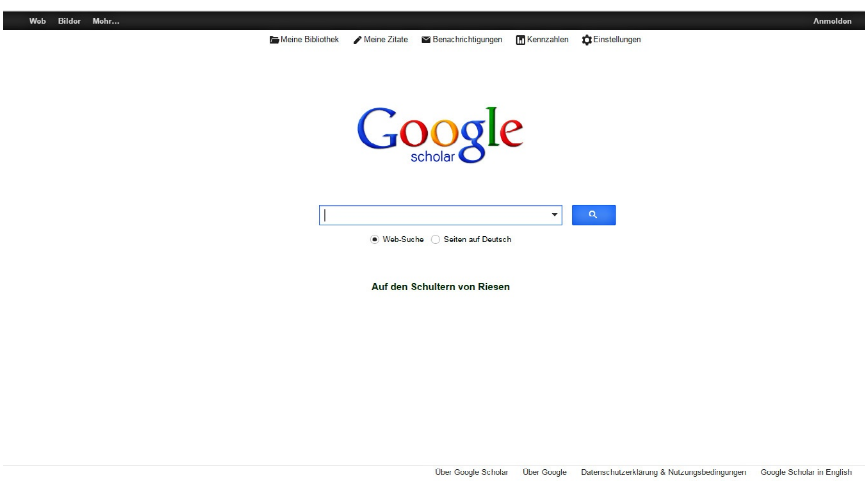

Fig. 5.4 The free alternative for bibliometric analyses. The Google Scholar homepage [9].

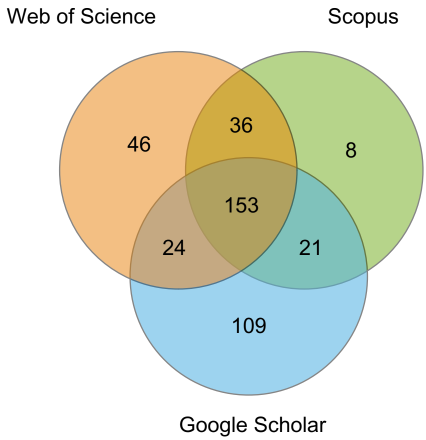

Fig. 5.5 The distribution of a book's citations among the three main bibliometric databases [10].

Google Scholar thus rules itself out for the use of bibliometric analyses. Citation figures and analysis results received are simply chance products and therefore virtually worthless.

This is all the more unfortunate as the amount of academic content freely available on the web is increasing dramatically and supplementing the classic publication forms significantly. The analysis of this data is also extremely important for a bibliometric 'overview' and shows the direction in which the journey of academic communication is heading in future. Not least the many altmetric (webometric) methods rely on the availability and traceability of free online publications. Google will be able to play its dominating role positively again here.

In any case, it is gradually becoming clear that something approximating a fair and objective performance assessment of academic output is only possible via a comprehensive picture using all the available data sources and analysis methods. Fig. 5.5 clearly illustrates that, as yet, one system alone is unable to offer a complete truth.

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CHAPTER 6

Summary and Outlook

Bibliometrics is the quantification of (written) academic output and its perception. The classification of the performances of people and institutions based on bibliometric indicators is often presented in rankings. The statistics yield indirect clues as to the quality of the academic performance of people, institutions and countries.

The basic indicators of bibliometrics are the number of papers and their reception by the community based on citations. An incalculable number of statistical variations are derived from these basic parameters and used.

The important thing is to always keep an eye on what statement an indicator actually makes and what conclusions are possible.

Changes in academic communication in the wake of the digitisation of other aspects of life are giving rise to many new possibilities to communicate and propagate findings in academia that increasingly depart from the classic concept of publishing.

Online publications, blog entries, forums, Twitter, Facebook and other social media, portals and liquid documents (content) demand novel metrics to determine academic achievements, output and the performance of people and institutions.

> *Social networks have blossomed into substantial source collections for mass statistical ascertainment. Their gigantic databases serve the systematic acquisition of information and are used to collect, evaluate and interpret socio-statistical data and information [1].*

Alternative bibliometric methods (altmetrics) with completely new indicators and based on free online content increasingly supplement bibliometrics based on the classic commercial databases.

Even though in the beginning bibliometrics was unquestionably intended to support library holding management, modern, contemporary bibliometrics has been based on large statistical databases and the old efficient systems of Web of Science since the second half of the 20th century.

An Introduction to Bibliometrics. http://dx.doi.org/10.1016/B978-0-08-102150-7.00006-2

However, this database is old and its structures stem from the 1960s. The approach back then was brilliant but simple: The data had to be very clean and clearly classifiable, the fields clearly indexed and labelled; the more fields the better, but clear fields and clear classifications, please. This is the mindset of relational databases, which emerged on large-scale computer systems and had their heyday in the 1980s.

For decades, this is how databases were compiled and the large electronic catalogues of the libraries worked. This is pure mainframe-computer bibliometrics—bibliometrics based on relational databases and cleaner, clearer data. Today, big data is an approach that now asks for correlations as opposed to causality. Giant quantities of (unstructured) data that are analysed with highly complex algorithms serve as the basis.

By applying such algorithms, the data to be analysed must not be 'clean' nor classified in any categories, as we still know it from relational databases. Only the amount of data to be evaluated must be sufficiently large for the results to be meaningful.

> *The transition into the world of big data requires a change of thinking on our part with regard to the advantages of accuracy… As already mentioned, the insistence on exactitude is a vestige of the analogue age… Back then, every single data point was important, which is why huge efforts were made to rule out errors in the record [2].*

Maintaining special, high-resolution databases and entering clear datasets is therefore become increasingly redundant. The end of the large and once so powerful databases that determined bibliometrics like a monopoly is thus also foreseeable if academia is to have deposited all its findings in the widest variety of forms on the web, unhampered by barriers and accessible round the clock in the sense of open data.

At the same time, however, this also calls for a departure from the 'classic database mindset' among bibliometric experts.

> *Traditional database engines need highly structured and precise data that were not just stored, but also split into so-called 'records', which in turn consisted of fields. This approach towards storage and analysis, however, is becoming increasingly unrealistic… Which has triggered new database developments that renounce the old principles – the principles of datasets and predefined fields that reflect strictly defined information hierarchies [3].*

Until then, the database providers of the major, established systems will keep working hard to prove that only relational databases and their clean data are able to facilitate meaningful bibliometric results.

But with free publication and information on the free web, the opportunities for big data applications in bibliometrics are becoming ever bigger.

The tendency towards all-encompassing data acquisition and its evaluation takes us a step further. Under the keyword 'analytics', it is increasingly possible to collect and analyse huge, vastly diverse quantities of data on the web. With big data, new connections are being uncovered that nobody had thought of or questioned in that way before.

Consequently, an increasing amount of data is available about each and every one of us – especially from areas of our private lives. The image of the transparent customer and the transparent citizen is certainly no longer a vision of the future; it has become a reality.

The transparent scientist is then also possible if a wide variety of data is evaluated, such as unencrypted emails; text messages; contributions on social network; personal profiles; search engine requests; internet searches; ordering, purchasing and payment processes; booking processes (travel, tickets); shipment tracking; all manner of downloads; data from educational portals; (location) data from apps, smartphones and all kinds of sensors; communication and contact information; navigational devices; vehicle data electronics/sensors; personal sensors; data in the cloud; data from the household infrastructure; networked PC infrastructure; payment methods/financial data such as EC (Eurocheque), discount and credit cards; credit bureaus; bank account data; data from registry offices and the Inland Revenue; and data from health insurance companies [4].

This kind of profiling is another trend that bibliometrics will greatly supplement. If vast amounts of (personal and institutional) information on scientists are available that can be compiled and evaluated via a search algorithm, before very long this data yields clues as to the achievements and performance of these people.

A series of analytical tools are already available on the market, such as PLUM Analytics [5] Figshare [6], InCites [7] or SciVal [8], which pursue an integrated management approach and prepare performance, financial, personal and publication data for decision-makers in academia and research.

Data from classic bibliometrics will then only be a small part of a comprehensive evaluation of data on people and institutions.

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GLOSSARY

A

Academic communication academic communication is used here to mean a scientist's communication within his or her own specialised discipline and community.

Algorithm an arithmetical procedure used to process data.

Alternative metrics see altmetrics.

Altmetrics an alternative method used to measure the impact of academic publications and other academic output based exclusively on web applications.

B

Bibliometrics bibliometrics is a quantitative analysis of the academic output of people, institutions, facilities, regions and countries, it uses statistical methods to make statements about the quantity, extent, frequency, significance and connections of publications.

Big Data Big Data is the processing of very large, usually unstructured, quantities of data with the aid of algorithms.

C

Citation a citation is a reference to another publication in an academic paper.

Citation analysis as a sub-area of bibliometrics, citation analysis examines the number, frequency and connections of citations in academic publications.

Citation rate the citation rate is a benchmark for the average frequency of the citation of a publication. It is determined by the number citations of a particular publication in relation to the number of publications in a fixed period.

Cluster analyses in a cluster analysis, different groups of documents and information that belong together are pooled and analysed.

Co-authors co-authors are scientists who publish an article jointly. The number of co-authors is theoretically unlimited. It depends on the discipline and the individual publication culture.

Co-word analysis analysis of special keywords that are used in different texts and appear frequently.

Cumulative impact factor it is the addition of the impact factors of papers in journals that are frequently used for the academic performance of individuals.

E

E-Science (enhanced science) E-Science means science that largely takes place in the digital sphere and uses electronic media and methods both to obtain and disseminate findings.

Eigenfactor a free academic website used to determine the impact factor of academic journals and as an alternative to the Journal Impact Factor by Onex and Baring Asia (formerly Thomson Reuters).

Emerging fields thematic areas characterised by particular interest and intensive academic processing.

G

Garfield, Eugene (1925–2017) he is the founder of modern bibliometrics and the Institute for Scientific Information that created the database Science Citation Index.

Google Scholar it is a special section of the search engine Google that exclusively features academic literature.

H

Hirsch Factor (H-Index, H-Factor) it is the popular bibliometric indicator that takes the number of publications, their citations and the course of the authors' academic careers into account.

I

Institute for Scientific Information (ISI) the facility founded by Eugene Garfield where the Science Citation Index was created.

Impact factor (also Journal Impact Factor) the impact factor describes the correlation between the number of publications that a journal publishes in two consecutive years and the number of citations of these articles the following year.

J

Journal Citation Reports (JCR) annually published database by Onex and Baring Asia (formerly Thomson Reuters) in which the Journal Impact Factor is determined.

L

Link analysis it is the quantitative, qualitative and, if necessary, bibliometric evaluation of outgoing and incoming internet links.

M

Multi-authorship (see also co-authorship) multi-authorship means that several authors co-publish an academic publication.

N

Normalisation it is the important methodical step in the conduction of bibliometric analyses and the comparison between people, institutions and facilities, and regions and countries by creating a uniform point of reference.

O

Open access open access describes the free-form access (free of charge) to information and literature in the academic sphere.

Open peer review it is the organisation of the peer review process with the aid of social media and that is publicly accessible.

Output (academic) academic output refers to publications and other forms of academic results that are published and thus broadly accessible.

Output analysis output analyses measure and evaluate the quantity, extent and frequency of the academic output of people, institutions, facilities, regions and countries.

P

Patent citations they are the citations of patents and patent publications in academic papers.

Peer review it is the academic review process for a submitted manuscript conducted by experts (peers) prior to publication.

Perception analysis see resonance analysis.

Pre-print it is the pre-publication of academic papers on an electronic server prior to the final publication at a publishing house or on an open access repository.

Publication culture publication culture refers to the specific framework conditions under which the various academic disciplines publish and cite. Publication cultures differ considerably between disciplines.

R

Rankings (bibliometric) rankings are leader boards for scientists, institutions, facilities, regions and countries based on key bibliometric figures.

Resonance analysis resonance analyses examine the impact of academic publications in the specialist community or on a general level.

S

Science 2.0 it is the term used to describe academia where findings are obtained and disseminated with the aid of social media and WEB 2.0 technology.

Science Citation Index (SCI) it is a multidisciplinary database created by the media company Onex and Baring Asia (formerly Thomson Reuters) containing bibliographical data and extensive citation information. The contents focus on the natural sciences and medicine.

SCOPUS SCOPUS is a multidisciplinary database created by the media company Elsevier which, like the Science Citation Index, combines bibliographical data with extensive citation analyses.

Self-citations a self-citation is a citation by an author who cites him or herself in a paper.

Sleeping beauties sleeping beauties are publications by scientists that are ignored for a long time without any bibliometric relevance until they become much-cited works due to thematic interests or changed political parameters.

T

Trend analyses trend analyses use bibliometric methods to determine thematic trends and tendencies.

W

Web of Science (WoS) it is a platform and portal of the media company Onex and Baring Asia (formerly Thomson Reuters) that hosts the central databases of the Science Citation Index.

Webometrics webometrics is the bibliometrics of academic web contents. Here, not only is the strict standard of a formal academic publication applied, but the totality of academic findings and the output provided on the web is taken into account as well.