A

- ➢ **aARCA index** ≡ *aggregated Additive Revealed Comparative Advantage index* → activity index
- ➢ **Absolute Country Counting** → bibliometric indices for countries
- ➢ **absolute score** → publication scores
- ➢ **ACA** ≡ *Author Co-citation Analysis* → citation networks
- ➢ **academic age** → academic age-based indices

❑ academic age-based indices

These indices are → *time-dependent bibliometric indices* which, unlike the → *paper age-based indices*, take into account the whole career of an author, i.e., the academic age of the author.

The **academic age** (Y_{aa}) is defined as the interval, expressed in years, from the present to the year of the first publication of an author:

$$Y_{aa} = Y_p - Y_f + 1$$

where Y_f is the year of the first publication and Y_p is the current year.

The simplest index was proposed [Hirsch, 2005] by relating the → *h-index* to the academic age and derived by the consideration that, for a given scientist, one can expect that the h-index would increase approximately linearly with time, i.e.,

$$h \approx m \cdot Y_{aa}$$

The slope m, called ***m*-quotient** (also called ***h*-rate** or ***m*-ratio index**), of this linear relationship was assumed as an empirical index of the impact of a scientist in time:

$$m \equiv h^N = \frac{h}{Y_{aa}}$$

This index was also called **age-normalized *h*-index** (denoted as h^N) [Sidiropoulos, Katsaros *et al.*, 2007] or **Carbon_*h*-factor** [Carbon, 2011]. Typical values were found between 1 and 3 [Hirsch, 2005]; according to Hirsch, a value $m \simeq 1$ characterizes a successful scientist; a value $m \simeq 2$ is indicative for outstanding scientists, and a value $m \simeq 3$ a truly unique scientist. The h-rate was suggested as a useful predictor for the future publication success of an author from her/his previous publication records [Hönekopp and Khan, 2012].

Handbook of Bibliometric Indicators: Quantitative Tools for Studying and Evaluating Research, First Edition.
Roberto Todeschini and Alberto Baccini.

Burrell distinguished two ways to evaluate the h-rate [Burrell, 2007a], i.e., the raw h-rate as given by h/Y_{aa} and the **least squares *h*-rate** (***LS h*-rate**) as given by the slope of the regression line passing through the origin of the author's h-sequence at time Y. This more sophisticated index requires the knowledge of the author's h-sequence, i.e., the h-index of each year along the career length of an author. Plotting the h-sequences versus the career length, different trends can be observed: (i) a linear trend, indicating that a constant increase of the h-index and the corresponding slope value is the appropriate least squares h-rate; (ii) a broken bilinear trend, where two slopes can be derived indicating two distinct periods of the author's h-index increasing (or decreasing); and (iii) an asymptotic trend, indicating that the author's h-index is still increasing; other special trends should be accurately evaluated indicating specific characteristics of the author's behavior.

The **time-scaled *h*-index** was proposed as a variant of the m-quotient [Mannella and Rossi, 2013], defined as

$$h^{TS} = \frac{h}{\sqrt{Y_{aa}}}$$

Another variant is the **$\boldsymbol{\alpha}$-index** (previously called ***a*-index**), where the h-index is divided by the number of decades calculated since the first published paper [Abt, 2012; Burrell, 2012; Sangwal, 2012b]:

$$\alpha = \frac{h}{Y_D} \quad y_D \geq 1$$

where Y_D is the number of decades, calculated as

$$Y_D = \text{int}\left(\frac{Y_{aa}}{10}\right)$$

Y_{aa} being the academic age and Y_D rounded to the upper value.

Still based on decades are → *cpd index* and the corresponding Hirsch-type index → *hpd index*.

From Figure A-1, it can be noted as the weighting scheme proposed by Hirsch [Hirsch, 2005] and Sidiropoulos [Sidiropoulos, Katsaros *et al.*, 2007], i.e., $1/Y$ is the most severe among the three compared weighting schemes, that is, it strongly penalizes papers published since 5/6 years or before.

Two other indices scaled on the academic age are the **time-scaled number of papers** P^{TS} and the **time-scaled citation index** C^{TS}:

$$P^{TS} = \frac{P}{Y_{aa}} \quad \text{and} \quad C^{TS} = \frac{C_T}{Y_{aa}}$$

where P is the total number of papers and C_T the total number of citations of a scientist.

The **annual *h*-index**, denoted as **hIa-index**, was defined with the aim to take into account both the number of coauthors and the author's academic age Y_{aa} [Harzing, Alakangas *et al.*, 2014] as

$$\text{hIa} = \frac{\text{hI, norm}}{Y_{aa}}$$

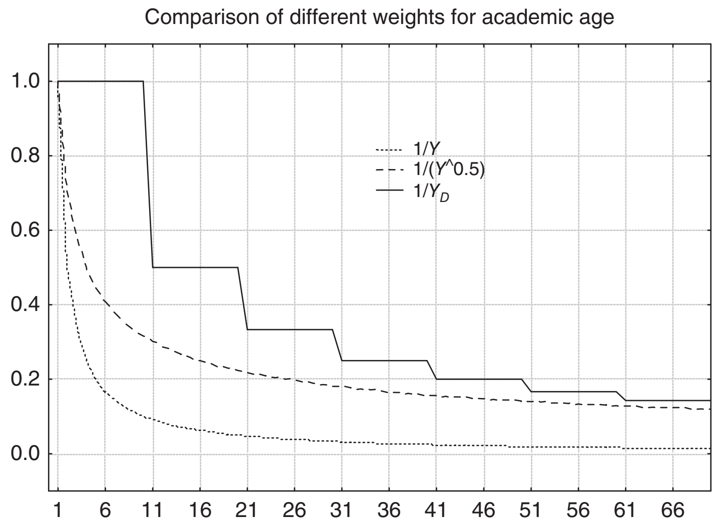

Figure A-1 Plot of three different age weighting schemes for ages between 1 and 70.

where → *hI,norm index* is the *h*-index calculated on normalized citations, that is, the number of citations of each paper is divided by the number of coauthors of that paper.

Example A-1

Table A-1 collects the citations *C* received by a hypothetical author for 10 papers, the number *A* of coauthors, and the year *Y* of publication. The actual year is assumed to be 2009 (Y_p) and the first paper was published in 1997 (Y_f).

Table A-1 Data of 10 hypothetical papers with their ordered citations, number of coauthors, publication year, and normalized citations *C/A*.

Rank	*C*	*A*	*y*	*C/A*
1	120	3	2002	40
2	110	1	2001	110
3	70	2	1998	35
4	60	5	2005	12
5	25	5	2003	5
6	15	2	2004	7.5
7	10	1	1997	10
8	6	1	2007	6
9	5	3	2009	1.7
10	0	2	2007	0

The academic age of the author is $Y_{aa} = 2009 - 1997 + 1 = 13$; the number of decades is $Y_D = 2$; the h-index is $h = 7$. The hIa-index is derived from the hI,norm index which is calculated as the h-index on the ordered C/A values:

$$m = \frac{7}{13} = 0.538 \quad h^{TS} = \frac{7}{\sqrt{13}} = 1.941 \quad P^{TS} = \frac{10}{13} = 0.769$$

$$C^{TS} = \frac{406}{13} = 31.231 \quad \alpha = \frac{7}{2} = 3.5 \quad \text{hI, norm} = 6 \quad \text{hIa} = \frac{6}{13} = 0.462$$

[Kyvik, 1990; Hu, Hou *et al.*, 2013]

➢ **academic journal** ≡ *journal*
➢ **academic publication** ≡ *scientific publication*
➢ **Academic Ranking of World Universities** → university rankings
➢ **ACCA** ≡ *Aggregated Citations of Cited Articles* → journal impact indicators
➢ **ACI** ≡ *articles coauthored internationally* → internationalization measures
➢ **ACS** ≡ *Maximum Corrected Scores* → coauthorship-weighted indices
➢ **active reference** → time window

activity index (AI)

Among the → *bibliometric indices for countries*, this index was proposed by Frame [Frame, 1977], and it is based on the same structure of the **revealed comparative advantage index** [Balassa, 1965] (or simply **RCA index**), usually used by economists to analyze a country's degree of specialization in production with respect to other countries or to the whole world. As such in scientometrics, it is used as an indicator of the degree of relative specialization of a country N in a research field F. The degree of research specialization of a country in a given field is calculated in reference to research production by considering data on → *research outputs*. In this case the activity index (AI) is defined as [Schubert and Braun, 1986; Schubert, Glänzel *et al.*, 1987; Rousseau and Yang, 2012]

$$AI(N,F) = \frac{\text{the } N \text{ country's share in the world's publication output in the field } F}{\text{the } N \text{ country's share in the world's publication output in all fields}} = \frac{P(N,F)/P(F)}{P(N)/P(W)}$$

A value of $AI > 1$ indicates that the country has a relative specialization in a given field, that is, it produces a share of world publication in that field greater than its share on the world research production.

Alternatively, the index can be defined as

$$AI(N,F) = \frac{\text{the given } F \text{ field's share in the } N \text{ country's publication output}}{\text{the given } F \text{ field's share in the world's publication output}} = \frac{P(N,F)/P(N)}{P(F)/P(W)}$$

where a value of $AI > 1$ indicates that the country has a concentration of research outputs in a given field greater than the share of this field on the total world output.

The notation adopted in the two equations is a revised version of the one originally adopted by Rousseau and Yang [Rousseau and Yang, 2012]:

$P(N, F)$	The total number of publications of country N in field F
$P(N)$	The total number of publications of country N
$P(F)$	The total number of publications in the field F
$P(W)$	The total number of publications in the world over all the fields

If a country is not active in the field, its corresponding AI value is equal to 0; a value equal to 1 indicates that the relative research effort in that field of the N country is the same as that dedicated in all the world. Given the terms $P(F)$ and $P(W)$ in the first equation, the maximum AI value is reached when N is the only country doing research in that field, i.e.,

$$\text{if } P(N,F) = P(F) \text{ then } AI(N,F) = \frac{P(W)}{P(N)}$$

Moreover, if there is only one field in which N is active,

$$\text{if } P(N,F) = P(N), \text{ then } AI(N,F) = \frac{P(W)}{P(F)}$$

If degenerate cases are not considered, the two following relationships hold [Rousseau and Yang, 2012]:

$$0 < P(N,F) < P(N) < P(W) \quad \text{and} \quad 0 < P(N,F) < P(F) < P(W)$$

It can be also noted that the term $P(W)$ which refers to the total number of publications in the world can be substituted by the total number of publications in some reference countries [Hoen and Oosterhaven, 2006].

The **attractivity index** (AAI) characterizes the relative impact of a country's publications in a given field as reflected in the citations they attract [Schubert and Braun, 1986], i.e.,

$$AAI(N,F) = \frac{\text{the } N \text{ country's share in citations attracted by publications in the field } F}{\text{the } N \text{ country's share in citations attracted by publications in all fields}} = \frac{C(N,F)/C(F)}{C(N)/C(W)}$$

or, alternatively,

$$AII(N,F) = \frac{\text{the given } F \text{ field's share in citations attracted by the } N \text{ country's publication output}}{\text{the given } F \text{ field's share in citations attracted by the world's publication output}} = \frac{C(N,F)/C(N)}{C(F)/C(W)}$$

As shown before, the notation adopted in the two equations is a revised version of the one originally introduced by Rousseau and Yang [Rousseau and Yang, 2012]:

$C(N, F)$	The number of citations received from country N in field F
$C(N)$	The total number of citations received from country N
$C(F)$	The total number of citations received in the field F
$C(W)$	The total number of citations in the world in all the fields

A value of AAI equal to 1 indicates that the citation impact of the country N in the field F corresponds to the world average; AAI values greater than 1 reflect citation impact greater than average, while values lower than 1 citation impact lower than average.

Note that the AI and the AAI are relative indices giving relative ranking with respect to a reference, but they cannot give information about the absolute research level reached by the country in the considered field [Hu and Rousseau, 2009].

The **Additive Revealed Comparative Advantage index** (**ARCA index**) is defined as the *activity index*, but the ratio is replaced by the difference [Balassa, 1965; Hoen and Oosterhaven, 2006] as

$$ARCA(N,F) = \frac{P(N,F)}{P(N)} - \frac{P(F)}{P(W)}$$

This index is 0 if the ratio related to the country N is equal to that of the world.

A generalized index of the country N's publication output is the **aggregated Additive Revealed Comparative Advantage index** (**aggregated ARCA index**, ***aARCA* index**), defined as [Hoen and Oosterhaven, 2006; Rousseau and Yang, 2012]

$$aARCA(N) = \frac{1}{2} \cdot \sum_F \left| \frac{P(N,F)}{P(N)} - \frac{P(F)}{P(W)} \right| \qquad 0 \le aARCA(N) \le 1$$

where the summation runs on all the research fields.

🕮 [Braun, Glänzel *et al.*, 1995; Zitt, Ramanana-Rahary *et al.*, 2005; Liang and Rousseau, 2007]

- **Activity Indices in Citation Classes** → quantile measures
- **actors** ≡ *vertices* → graphs
- **adaptive pure *h*-index** → coauthorship-weighted indices
- **Additive Revealed Comparative Advantage index** → activity index
- ***ADF*** ≡ *average indifference factor* → journal impact indicators
- ***ADJ*** ≡ *adjusted counting* → coauthorship-weighted indices
- **adjacencies** → graphs
- **adjusted counting** → coauthorship-weighted indices
- **adjusted immediacy index** → journal impact indicators
- **adjusted impact factor** → journal impact indicators
- ***AF*** ≡ audience factor → journal impact indicators
- **affinity index** → internationalization measures
- **AFI** ≡ *affinity index* → internationalization measures
- **age-normalized *h*-index** ≡ *m-quotient* → academic age-based indices
- **age of publication of the papers** → paper age-based indices
- **age of a paper** ≡ *paper age* → time-dependent bibliometric indices
- **aggregated Additive Revealed Comparative Advantage index** → activity index
- **aggregated bibliometric indicators** ≡ *composite bibliometric indicators*
- **Aggregated Citations of Cited Articles** → journal impact indicators
- **Aggregate Performance Indicator** → production indices

➢ **aggregation level** → bibliometric indices
➢ **AHCI** ≡ *Arts and Humanities Citation Index* → bibliographic databases
➢ **AIC indices** ≡ *Activity Indices in Citation Classes* → quantile measures
➢ **AICC indices** → quantile measures
➢ **AIF** ≡ *adjusted impact factor* → journal impact indicators
➢ ***AIF*** ≡ *alternative impact factor* → publication-citation matrix
➢ ***AIF*** ≡ *average impact factor* → journal impact indicators
➢ ***AII*** ≡ *adjusted immediacy index* → journal impact indicators
➢ ***a*-index** ≡ *A-index* → *h*-index
➢ ***A*-index** → *h*-index
➢ **A_g-index**→ *h*-index
➢ ***AIR*** ≡ *annual impact rate* → journal impact indicators
➢ **alternative impact factor** → publication-citation matrix
➢ **alternative metric indicators** ≡ *altmetrics indicators* → altmetrics
➢ **altmetric indicators** → altmetrics

altmetrics

It is short for **alternative metrics**. The term has a double meaning: (i) it describes indicators able to capture the diffusion of a single research product in online tools and environments (e.g., scholarly and general audience blogs, scholarly social networks as *ResearchGate* or *Academia.edu*, social networking services like *Twitter* or *Facebook*, online reference managers like *CiteULike*, *Mendeley*, and *Zotero*, postpublication peer reviews), and (ii) it indicates also the study and use of scholarly impact web-based measures [Priem, Piwowar *et al.*, 2012].

According to the Altmetrics Manifesto [Priem, Taraborelli *et al.*, 2010], “Altmetrics expand our view of what impact looks like, but also of what’s making the impact,” permitting to grasp nontraditional ways to diffuse scholarly works. In fact, altmetrics track the impact of papers self-published by authors in blog, the diffusion of articles self-archived in online repository such as *arXiv*, and the impact in social networks such as Twitter. Altmetrics estimate impact outside the academy, impact of influential but uncited work, and impact from sources that are not peer reviewed. Unlike bibliometric indicators as the → *journal impact indicators* and → *h-index*, altmetrics refer uniquely to article-level metrics, that is, to the impact of a single research work, nor to researchers or journals.

Altmetric indicators, that is, **alternative metric indicators**, are usually simple counts. The counts refer to different online activities about a single article:

- The number of times that users store an article in their archive.
- The number of times that users download an article.
- The number of web links and/or bookmarks pointing to the article.
- The number of times that the article is the object of a conversation in a social network environment.
- The number of times an article is mentioned on the web; the mention of a published article on the web was called a **web citation** [Vaughan and Shaw, 2003;

2008]; and the number of mentions received is called the **Web Visibility Rate** (**WVR**) of an article [Kretschmer and Aguillo, 2004; Kretschmer, Kretschmer *et al.*, 2007].

Consider, for example, Impactstory (*www.impactstory.org*), an open-source web-based tool calculating the impact of journal articles and other nontraditional → *research outputs*. For each article it presents four count indicators headed under the following label:

1. Viewed: The number of times the considered item has been viewed by readers
2. Cited: The number of citations received in → *Scopus*
3. Saved: The number of times that the article is saved in an online reference manager
4. Discussed: The number of times the article is discussed in social media

These indicators are compared with the distribution for articles published in the same year. An article labeled, for example, as "highly discussed" is an article with a number of mentions in social networks larger than 95% of the items.

The main advantages of altmetrics over traditional impact indicators are [Bornmann, 2014]:

1. The rapidity: Social media mentions, as, for example, tweets or Facebook mentions, are immediately available and offer a just-in-time assessment of impact, while traditional citation count is available only with a long delay after publication [Shema, Bar-Ilan *et al.*, 2014].
2. The broadness, that is, the capability to proxy the research impact beyond academic community.
3. The diversity, that is, the possibility to evaluate a greater diversity of → *research outputs* and not only publications.

The disadvantages of altmetrics are also discussed:

1. The question of manipulation of altmetrics score is controversial: some scholars underline the possibility to manipulate tweets [Shema, Bar-Ilan *et al.*, 2014]; others consider altmetrics more robust than citations "leveraging the diversity of altmetrics and statistical power of big data to algorithmically detect and correct for fraudulent activity" [Priem, Taraborelli *et al.*, 2010].
2. The bias toward more recent papers as they are strongly influenced by the increase of social media use [Shema, Bar-Ilan *et al.*, 2014]; moreover, for recent papers, the citation window is also too small to obtain reliable information [Haustein, Thelwall *et al.*, 2013b].
3. The dependence of altmetrics count from commercial social media is also considered as a potential problem [Bornmann, 2014].

Main research issues arising from the diffusion of altmetrics involve the distribution of altmetrics scores across publication years, the presence of these for publications registered by *Web of Science* or *Scopus*, the correlation of altmetrics scores with citations of articles, and the impact measures of journals where they are published [Costas, Zahedi *et al.*, 2014; Shema, Bar-Ilan *et al.*, 2014].

🕮 [Bollacker, Lawrence *et al.*, 2000; Eysenbach, 2011; Bar-Ilan *et al.*, 2012; Li, Thelwall *et al.*, 2012; Li and Thelwall, 2012; Priem, Piwowar *et al.*, 2012; Shuai, Pepe *et al.*, 2012; Thelwall, Haustein *et al.*, 2013; Haustein, Peters *et al.*, 2013a]

➢ **amplitude** → *h*-index
➢ **annual *h*-index** → academic age-based indices
➢ **Annual Impact Factor** → journal impact indicators
➢ **Annual Impact Rate** → journal impact indicators
➢ **annual T-indicator** → group of authors
➢ **API** ≡ *Aggregate Performance Indicator* → production indices
➢ **applied research** → research output
➢ **ARCA index** ≡ *Additive Revealed Comparative Advantage index* → activity index
➢ **ARC index** → graphs

☐ archetypal analysis

Aimed to describe and categorize researchers, it is a → *multivariate analysis of bibliometric indices* based on the alternating least squares algorithm, performed on a data matrix constituted by n researchers (the rows), each described by a set of m bibliometric indices (the columns), such as works, citations, downloads, and so on [Seiler and Wohlrabe, 2013].

For a given number of k archetypes, the algorithm finds the matrix $\mathbf{Z}$ by minimizing the residual sum of squares RSS of the model:

$$RSS = \|\mathbf{X} - \alpha \mathbf{Z}\|$$

where $\mathbf{X}$ is the data matrix $(n \times m)$ and α the numerical coefficients of the archetypes of dimension $(n \times k)$. The previous equation is minimized under the constraints:

$$\alpha_{ij} \geq 0 \;\; \wedge \;\; \sum_{j=1}^{k} \alpha_{ij} = 1$$

It differs from Principal Component Analysis (PCA) because archetypal analysis allows to extract more archetypes than dimension of the data and the number k of archetypes is evaluated by analyzing the residual sum of squares. The archetypes are detected by the extreme observations, not necessarily observed, of the generated convex hulls for each archetype dimension. On the data analyzed by Seiler and Wohlrabe, the best solution was found with $k = 3$, that is, three archetypes which are constituted by seven indicators, summarized by the following four blocks:

- Published work (number of distinct works and number of distinct works weighted by simple impact factor), which also includes working papers, books, software codes, and chapters
- Number of citations (number of overall citations, unweighted and weighted by the simple impact factor), which represents the impact of an author
- Number of pages (unweighted and weighted by the simple impact factor), which accounts for the published articles
- Access statistics (number of downloads).

➢ **ArCo index** → composite bibliometric indicators
➢ **AtCoTI** ≡ *ArCo index* → composite bibliometric indicators
➢ **arcs** → graphs
➢ ***AR*-index** → paper age-based indices
➢ ***AR*^{2}-index** → paper age-based indices
➢ **AR$_1^2$-index**Z → paper age-based indices
➢ **arithmetic counting** ≡ *proportional counting* → coauthorship-weighted indices
➢ **arithmetic *g*-index** → *g*-index
➢ **Arts and Humanities Citation Index** → bibliographic databases
➢ **article comparisons** ≡ *paper comparisons*
➢ **article degree** → paper similarity
➢ **article efficiency** → paper age-based indices
➢ **Article Influence Score** → Eigenfactor Score
➢ **Article Impact Index** → citations
➢ **article-level classifications** → research fields
➢ **articles** ≡ *papers* → research products
➢ **ARWU** ≡ *Academic Ranking of World Universities* → university rankings
➢ **Atkinson measure** → concentration measures
➢ **attractivity index** → activity index
➢ **audience factor** → journal impact indicators

author

The person who originates or gives existence to a → *research output*. A research output can have multiple authors, usually called the **coauthors**, and whose number is the **number of coauthors**. The names of the authors usually appear in the **byline**, that is, the line containing the names of the writers contributing to articles, books, and so on. The author of a research output is credited for the new results and the new knowledge contained in it. From the late 1600s until about 1920, the rule was one author per research output [Greene, 2007]; since then the average number of coauthors is growing rapidly. It is documented that research is increasingly done in teams across all fields [Wuchty, Jones *et al.*, 2007]: from 1960 to

2000 the average size of teams coauthoring papers doubled not only in science and engineering (from <2 to near 4 coauthors) but also in social sciences (from 1.5 to near 3), remaining stable about one in arts and humanities. According to Kennedy, "that's partly because labs are bigger, problems are more complicated and more different subspecialties are needed. But it's also because […] government agencies […] have started to promote team science" [Kennedy, 2003]. Surveys about multiauthorship are [Harsanyi, 1993; Speck, Johnson *et al.*, 1999].

The so-called demise of the lone author originates an open discussion in order to distinguish not only the specific contribution of each author and credit her/him for this but also how to credit each of the authors for the citations received by their article [Liu and Fang, 2012]. "The ruling convention of multiple authorship is that all authors shared in the work more or less equally and, if the first author or two takes the role of 'first among equals', all listed authors take full credit for the contents of the paper. This is easy enough to swallow where three or four authors are concerned, harder when there are 8 to 10 authors, and almost impossible with 20 or 50 – let alone hundreds, as in some sequencing papers" [Greene, 2007]. The separation of a single contribution in a paper is in reality a subjective and quite often arbitrary evaluation, although some journals have started to require coauthors to specify the contribution of each author as a percentage or through a summary description of the activities done by each. For bibliometric purposes, several approaches were proposed to make a partition of the credits to assign to each author present in the byline of a paper (→ *coauthorship-weighted indices*). Indeed, for several bibliometric indices, variants have been developed to take into account the existence of coauthors by normalizing, in one way or another, the number of citations received by each publication. Information contained in the byline of articles is also the main source for studying the collaboration degree among the authors (→ *collaboration measures*), the → *internationalization degree* of authors, institutions, and countries, and for → *coauthorship network analysis*.

From a legal point of view the author of the original expression in a work is its author. The author is the owner of the copyright of her/his original works of authorship; the copyright grants to her/him the exclusive right for a given period of time to reproduce and distribute the work. The author can assign the copyright to other persons or entities through a written agreement. Copyright laws protect the rights of the copyright owner, as → *patents* laws protect the rights of an inventor. The usual way through which an author diffuses her/his work is by signing a copyright agreement assigning to a publisher or a journal the right to publish and diffuse her/his work. The publisher or journal uses the acquired copyright for requiring a payment to readers. Journals usually request an annual subscription for hard copies and/or online access [European Commission, 2006]. The development of → *open-access* literature challenged the traditional model: the author can decide to diffuse her/his work in digital form, free of charge, and free of most copyright and licensing restrictions.

[Merton, 1969; Braun, Gémez *et al.*, 1992; White, 2001; Glänzel and Thijs, 2004a; Birnholtz, 2006; Uddin, Hossain *et al.*, 2012; Ausloos, 2013]

- **Author Cocitation Analysis** → citation networks
- **authorship domesticity** → internationalization measures
- **author *h*-core** → *h*-index
- **author's impact factor** → journal impact indicators
- **author order** → coauthorship-weighted indices
- **author positional weights** → coauthorship-weighted indices
- **author self-cited rate** → citations
- **author self-citing rate** → citations
- **author weighting scheme** → coauthorship-weighted indices
- **autocitations** ≡ *self-citations* → citations
- **autoscaling** → composite bibliometric indicators
- **average activity** → t_h index
- **average Canberra distance** → similarity/diversity measures
- **average citations per article** → fractional citation counts
- **average impact factor** → journal impact indicators
- **average indifference factor** → journal impact indicators
- **average information content** ≡ *Shannon entropy* → entropy measures
- **average indicators** → bibliometric indices
- **average interactivity** → interactivity measures
- **average of indirect *H*-indices** → indirect *H*-indices
- **average of ratios** → bibliometric indices
- **average quality** → fractional citation counts
- **average relatedness factor** → interactivity measures

axiomatic approaches to bibliometric indicators

Properties of bibliometric indicators are analyzed also by adopting axiomatic approaches [Marchant, 2009a; Waltman and van Eck, 2009, 2012b; Bouyssou and Marchant, 2010, 2011a, 2011b; Rousseau and Ye, 2012b], some of them specifically dedicated to the → *h-index* [Rousseau, 2008c; Woeginger, 2008a, 2008c; Quesada, 2009, 2010, 2011a, 2011b].

Of particular interest is the so-called independence axiom or B – M independence axiom [Bouyssou and Marchant, 2011b], which can be formulated as follows.

Let S and T to scientists and B any bibliometric indicator; let $\mathsf{B}(S) \leq \mathsf{B}(T)$ where $\mathsf{B}(S)$ and $\mathsf{B}(T)$ denote the values of the indicator for the two scientists S and T, calculated on the base of the sets of publications written by S and T, respectively. Now, if a paper with C citations is added to both scientists, then the axiom requires that the relation $\mathsf{B}(S) \leq \mathsf{B}(T)$ must still hold. The set of articles can be restricted to a specific → *time window*.

For instance, neither the → *citations per publication* C/P nor the *h*-index satisfies this basic axiom.

The notion of basic steps in scientific career is introduced by distinguishing between [Rousseau and Ye, 2012b]

- step P, a basic publication step (P) occurs when a scientist publishes a new article with no citations, and
- step C, a basic step (C) occurs when a scientist receives one citation to an already existing publication.

Based on these two steps, a variant of the B – M independence axiom, the **basic independence axiom**, was proposed as if $B(S) \le B(T)$ and the same type of basic step occurs to the two scientists S and T, then $B(S) \le B(T)$.

Relatively to the step P, this axiom is fulfilled, for example, by the total number of papers and the total number of citations, as well as the h-index and the citations received by the most cited papers which remain unchanged, unlike the average number of citations and the median of citations which may contradict the axiom.

Relatively to the step C, this axiom is still fulfilled only by the total number of papers and the total number of citations but may be contradicted by the other previously considered indicators.

Example A-2

Some examples of the application of the independence axiom are given as follows:

$$\text{Example 1, step } P: \; C/P$$
$$S = \{3,3,2,1,1\} \to S' = \{3,2,2,1,1,0\} \Rightarrow C/P(S) = 2 \neq C/P(S') = 1.67$$
$$T = \{3,1\} \to T' = \{3,1,0\} \Rightarrow C/P(T) = 2 \neq C/P(T') = 1.33$$
$$C/P(S) = C/P(T) \Rightarrow C/P(S') > C/P(T')$$

$$\text{Example 2, step } C: \; h\text{-index}$$
$$S = \{2,1,0\} \to S' = \{2,2,0\} \Rightarrow h(S') = h(S) + 1 = 2$$
$$T = \{2,1,0\} \to T' = \{2,1,1\} \Rightarrow h(T') = h(T) = 1$$
$$h(S) = h(T) \Rightarrow h(S') > h(T')$$

In both previous cases, other indicators fulfill the requirement of the independence axiom, such as the number of papers (P) and the total number of citations (C_T):

$$\text{Example 1}$$
$$P(S) = 5 \quad P(S') = 6 \quad P(T) = 2 \quad P(T') = 3$$
$$\Rightarrow \quad P(S) > P(T) \text{ and } P(S') > P(T')$$
$$C_T(S) = 10 \quad C_T(S') = 10 \quad C_T(T) = 4 \quad C_T(T') = 4$$
$$\Rightarrow \quad C_T(S) > C_T(T) \text{ and } C_T(S') > C_T(T')$$

Example 2

$$P(S) = 3 \quad P(S') = 3 \quad P(T) = 3 \quad P(T') = 3$$
$$\Rightarrow \quad P(S) = P(T) \text{ and } P(S') = P(T')$$
$$C_T(S) = 3 \quad C_T(S') = 4 \quad C_T(T) = 3 \quad C_T(T') = 4$$
$$\Rightarrow \quad C_T(S) = C_T(T) \text{ and } C_T(S') = C_T(T')$$

📖 [Vannucci, 2010; Miroiu, 2013]