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The case of scientometricians with the “absolute relative” impact indicator

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ABSTRACT

The effect of two different calculation methods for obtaining relative impact indicators is modelled. Science policy considerations make it clear that evaluating the sets of publications, the “ratio of the sums” method should be preferred over the “mean of the ratios” method. Accordingly, determining the *relative total impact* against the *mean relative impact* of the publications of teams or institutes may be preferred. The special problem caused by relating the number of citations of an individual article to the Garfield (Impact) Factor (or mean citedness) of the publishing journal (or a set of journals selected as standard) lower than zero is demonstrated by examples. The possible effects of the different share of publications in different fields on the value of the “new crown” index are also modelled. The assessment methods using several appropriately weighted indicators which result in a composite index are recommended. The acronym “BMV” is suggested to term the relative impact indicators (e.g. *RCR*, CPP/JCS_m, CPP/FCS_m and *RW*) in scientometrics.

> “But the Emperor has nothing on at all!”
> H. Ch. Andersen:
> (The Emperor’s New Suit)

1. Introduction

The *bibliometric features* (*factors*) of the scientific fields are different. They can strongly influence the measure of the scientometric indicators. (As bibliometric factors the preference of certain types of publication channels, mean number of references given, aging rate of information, mean Garfield (Impact) Factor (*GF*) of journals, mean yearly number of journal papers published, etc. may be mentioned, see Vinkler, 2010a). Consequently, it would seem reasonable to apply *relative scientometric indicators* in comparative assessments. For evaluating the publication output of research teams we may compare similar data of the teams with similar activity or, we may use the data of all or majority of scientists active in the field worldwide as reference standards.

Several scientometricians are searching for but, some others are already happy to believe in having captured the blue bird or philosopher’s stone of scientometrics: the “*absolute relative impact indicator*”, which has been termed as “crown” (van Raan, 2004; van Raan, van Leeuwen, Visser, van Eck, & Waltman, 2010; Lundberg, 2007) or even “new crown” index (Waltman, van Eck, van Leeuwen, Visser, & van Raan, 2011a; Waltman, van Eck, van Leeuwen, Visser, & van Raan, 2011b). Having surveyed the recent literature (Bornmann, Mutz, Hug, & Daniel, 2011; Schreiber, 2008) and some already classic publications on scientometrics (Elkana, Lederberg, Merton, Thackray, & Zuckerman, 1977) however, I came to the conclusion

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that *no absolute indicator exists,* provided that "absolute" is meant in the sense that an absolute index could be applied for analyzing each scientometric system (independent e.g. of the type and size of the system), and this absolute index *alone* could appropriately characterize both short term and long term impact of the scientific publications comparatively, and this "absolute" index might be regarded as superior to all other indicators.

I am in the opinion that science and scientific research is multifaceted, and their impact cannot be approximated by a single index. In evaluating the publication production of persons, teams or laboratories we have to take into consideration the *publication strategy* (i.e. quality of the publication channels used), the *amount* and *impact* of the published information. The *impact* can be analyzed as the *total* impact or *mean* specific impact (e.g. by journal paper) of the total information published *and*, as the impact of a special (most influential) part of the total (e.g. ratio of highly cited papers, total citations to the papers in the "elite set", mean citedness of Hirsch-core papers, etc.). If science politicians want to have a single index, representing the eminence of a project applicant or a research laboratory, *composite* scientometric indices should be applied (Vinkler, 2006).

One special group of the impact indices is represented by the *relative impact indicators*. The most widely used relative impact indices were introduced and applied by three different groups of authors in the eighties, last century independently from each other (Braun, Glänzel, & Schubert, 1985; Moed, Burger, Frankfort, & van Raan, 1985a; Moed, Burger, Frankfort, & van Raan, 1985b; Schubert & Braun, 1986; Vinkler, 1986). There are also several earlier publications on relative indicators by each author mentioned, which are however either in national languages or in publications of limited publicity. The relative impact indicators suggested by the mentioned authors are referred to in this paper as: *BMV indices* (the acronym may represent the initials of the first authors of the first papers).

2. Calculating BMV type indices by the ratio of sums (*RS*) or mean of the ratios (*MR*) method

Recently, the way of calculating BMV type indices of journal papers is a frequently discussed question in the scientometric literature (Bornmann, 2010; Bornmann et al., 2011; Gingras & Larivière, 2011; Glänzel, Thijs, Schubert, & Debackere, 2009; Larivière & Gingras, 2011; Leydesdorff & Opthof, 2011; Opthof & Leydesdorff, 2010; Spaan, 2010), although Vinkler already in 1996 argued for the preference of one of the calculation methods (ratio of sums) (Eq. (1)) based on empirical model calculations. According to theoretical considerations of aggregating impact factors, Egghe and Rousseau (1996 and 2002/03) arrived at a similar conclusion, i.e. *the ratio of sums* method (*RS*, Eq. (1)) would be more appropriate for the scientometric practice than the indices calculated by the *mean of the ratios* (*MR*, Eq. (2)) method.

Ratio of the sums (*RS*)

$$\mathrm{BMV} = \frac{\sum_{i=1}^{P} c_i}{\sum_{i=1}^{P} GF_i} = \frac{\sum_{i=1}^{P} c_i}{P \cdot GF_m} \tag{1}$$

Mean of the ratios (*MR*)

$$\mathrm{BMV} = \frac{1}{P}\sum_{i=1}^{P}\frac{c_i}{GF_i} \tag{2}$$

where BMV is a relative impact indicator, P is the total number of papers assessed, c_i is the number of citations obtained to the i-th paper and GF_i is the Garfield (Impact) Factor of the i-th journal selected as reference standard, or in general: the mean citedness of the publications ($GF_m = (C/P)_m$) in any set selected as standard.

The first authors of the BMV type indicators mentioned before, suggested the *RS*-method in calculating the relative impact indices (Eqs. (3) and (4)). The terminology of the different teams was (and even is) different. (Here it is concentrated only on the essence of the indicators, the type of publications, method for delineating subfields or fields, using different publication and citation time-periods, weighting of the publications or citations are neglected).

Ratio of the sums (*RS*)

$$RCR = \frac{MOCR}{MECR} = \frac{CPP}{JCS_m} = \frac{JPC}{PS} = \frac{\sum_{i=1}^{P} c_i}{\sum_{i=1}^{P} GF_i} \tag{3}$$

$$RW = \frac{CPP}{FCS_m} = \frac{\sum_{i=1}^{P} c_i}{P \cdot GF_m} = \frac{C\%}{P\%} = SIC \tag{4}$$

where *RCR* is the Relative Citation Rate (Braun et al., 1985), *MOCR* is the Mean Observed Citation Rate (*C*/*P*) (i.e. Journal Paper Citedness, *JPC*), *MECR* is the Mean Expected Citation Rate (i.e. Publication Strategy, *PS*); *CPP* is the average number of citations per publication (i.e. *JPC*), JCS_m is the average citation rate of papers in the journals in which the papers evaluated were published (i.e. *PS*) (Moed et al., 1985a,b); *JPC* is the Journal Paper Citedness (i.e. *C*/*P*), *P* is the total number of papers evaluated, c_i is the number of citations to the i-th paper evaluated, GF_i is the *GF* of the journal publishing the i-th paper evaluated; *RW* is the Relative Subfield Citedness (Vinkler, 1986); FCS_m is the average citation rate of all papers (worldwide) published in all (or possibly all) journals of the field (van Raan, 2004); GF_m is the aggregate mean *GF* of the journals in the corresponding field (i.e. calculated by the sum of citations divided by the sum of journal papers); *C*% is the percentage share of the citations to the papers assessed within the total selected as standard, *P%* is the percentage share of the papers assessed within the total selected as standard, *SIC* is the Specific Impact Contribution index (Vinkler, 2004).

The Publication Strategy (*PS*) and *Relative Publication Strategy* (*RPS*) indicator can be calculated by Eqs. (6) and (7), respectively.

$$PS = \frac{\sum_{i=1}^{P} GF_i}{P} \tag{6}$$

$$RPS = \frac{PS}{GF_m} \tag{7}$$

where GF_i is the (weighted) Garfield (Impact) Factor of the journals where the authors assessed have published their papers, whereas GF_m is the (preferably weighted) mean *GF* of the journals dedicated to the field where the authors assessed are active.

It is relatively easy to conclude, if using commensurate time-periods for the measurement and appropriate reference standards, the following relation will exist (Vinkler, 2003):

$$RW = RPS \cdot RCR \tag{8}$$

Naturally, for the meta-journal of a field (i.e. containing all journals and papers dedicated to the field) it is valid:

$$RW = RCR = RPS = 1.00 \tag{9}$$

3. The "new crown" index

Waltman et al. (2011a,b) define the CPP/FCS_m indicator ("crown" index, van Raan, 2004) as follows:

$$\frac{CPP}{FCS_m} = \frac{\sum_{i=1}^{n} c_i}{\sum_{i=1}^{n} e_i} \tag{10}$$

where *n* is the total number of publications, c_i denotes the number of citations to the *i*-th publication and: "e_i is the expected number of citations of publication *i* given the field in which publication *i* has been published" (Waltman et al., 2011a,b). The denominator ("expected number of citations") represents the reference standard applied. This may be the *GF* of the corresponding journals (preferably weighted) or the mean citedness (*C*/*P*) of the set of papers selected as standard. Waltman et al. (2011a,b) define the *MNCS* indicator as:

Waltman et al. (2011a,b):

$$MNCS = \frac{1}{n}\sum_{i=1}^{n}\frac{c_i}{e_i} \tag{11}$$

whereas according to Vinkler (1996):

$$RPCR = \frac{\sum_{i=1}^{N} c_i/h_i}{N} \tag{12}$$

where *n*, c_i and e_i are as given to Eq. (10), whereas in Eq. (12) *N* is the total number of papers published, c_i is the number of citations obtained by the *i*-th paper and h_i is the impact factor of the journal where the *i*-th paper was published. Naturally, h_i corresponds to any [*C*/*P*] type index (like *GF* of a journal) which is used as standard. *MNCS* is an acronym for the mean normalized citation score, which has been coined by Waltman et al. (2011a,b) as the "new crown" indicator.

In my view, the *MNCS* index can be traced back either to the *RW* index (calculated by the ratio of the sums, *RS* method) (Vinkler, 1986) or to the Relative Paper Citation Rate (*RPCR*) index (Eq. (12)) obtained by the mean of the ratios (*MR*) method (Vinkler, 1996). Calculating the relative impact index of journal papers in a set, three types of the *MNCS* indicator may be obtained: indices of *RS* type, indices of *MR* type or indices of mixed/MX/type (Eqs. (13)–(16)).

- Let us assume first that all papers in the set evaluated would belong to the same discipline (f_1). Accordingly, the number of citations obtained by the individual papers is related to the same average citedness value, $FCS_m(f_1)$:

$$MNCS/RS/ = \frac{1}{P}\left[\frac{c_1(f_1)}{FCS_m(f_1)} + \frac{c_2(f_1)}{FCS_m(f_1)} + \frac{c_3(f_1)}{FCS_m(f_1)} + \cdots + \frac{c_P(f_1)}{FCS_m(f_1)}\right] = \frac{\sum_{i=1}^{P} c_i(f_1)}{P \cdot FCS_m(f_1)} \tag{13}$$

where *P* is the total number of papers analyzed, and $FCS_m(f_1)$ corresponds to GF_m in Eq. (1).

Eq. (13) indicates that the "new crown" index would correspond, in this case to the *RW* indicator (Eq. (4)).

- In the second case, we may assume that each paper in the set analyzed belongs to a different field.

$$MNCS/MR/ = \frac{1}{P}\left[\frac{c(f_1)}{FCS_m(f_1)} + \frac{c(f_2)}{FCS_m(f_2)} + \frac{c(f_3)}{FCS_m(f_3)} + \ldots + \frac{c(f_P)}{FCS_m(f_P)}\right] = \frac{1}{P}\sum_{i=1}^{P}\frac{c(i)}{FCS_m(i)} \quad (14)$$

where $FCS_m(i)$ is the mean *GF* (or citedness) of the journals (or the papers) in the *i*-th field selected as standard.

Eq. (14) indicates that in the case studied the "new crown" index (*MNCS*) would correspond to a BMV index of *MR* type which is similar to the Relative Paper Citation Rate (*RPCR*) index (Vinkler, 1996).

- The situation in the third (mixed) case can be demonstrated with the following example.

Let us evaluate a set consisting of 3 papers published in field (f_1), 2 papers in field (f_2) and one paper in field (f_3). Accordingly, the *MNCS* index for the whole set (*P* = 6):

$$MNCS/MX/ = \frac{1}{6}\left[\frac{c_1(f_1)}{FCS_m(f_1)} + \frac{c_2(f_1)}{FCS_m(f_1)} + \frac{c_3(f_1)}{FCS_m(f_1)} + \frac{c_1(f_2)}{FCS_m(f_2)} + \frac{c_2(f_2)}{FCS_m(f_2)} + \frac{c_1(f_3)}{FCS_m(f_3)}\right] \quad (15)$$

It follows:

$$MNCS = \frac{1}{6}\left[\frac{\sum_{i=1}^{3} c_i(f_1)}{FCS_m(f_1)} + \frac{\sum_{i=1}^{2} c_i(f_2)}{FCS_m(f_2)} + \frac{c_1(f_3)}{FCS_m(f_3)}\right] \quad (16)$$

From Eq. (16) it concludes that the normalization is made in each field separately and, the average of the normalized citedness of the whole set is calculated on the paper level. Within the individual fields the standard of the corresponding field is applied (see Eq. (13)).

In contrast to the *MNCS* index the *RW* index is preferably calculated *by the field*, *separately* (Vinkler, 2010a). Accordingly, in comparing the activity of a single team in two fields, *two RW* indicators should be calculated. Similarly, the comparison of the relative impact of two teams is possible by calculating the corresponding *RW* indices in each field, separately.

The *MNCS* index would offer a possibility for comparing, e.g. the relative impact of two teams each conducting researches in *several* fields. This feature seems to be advantageous but, the *share* of the individual activities within the total activity of the teams has great influence on the index. The different shares in the same field of the teams may distort the index significantly (see later). Therefore, I would prefer evaluating the publication activity (relative impact) of organizations working in several fields by the field, separately.

4. Calculating BMV type indices by science political or mathematical approximation

The different methods suggested to calculate the relative impact indices, may be traced back to the different views on the essence of evaluative scientometrics (Vinkler, 1996, 2010a). In my opinion, one of the most important goals of evaluative scientometrics is to construct and use indicators for assessing publications of persons, teams, institutes, and countries by determining their impact on science both quantitatively and qualitatively. The scientometric assessment methods should take into account the *aim* of the evaluation and *specificities* of the scientometric system analyzed, primarily (Moravcsik, 1988).

To select relevant relative impact indicators, we may use a *science political* approximation (*SPA*) or a *mathematical* (theoretical) approximation (*MTA*).

Through *SPA* we may characterize the *relative gross impact* of the information in publications of the organization assessed, as a whole. In contrast, according to *MTA* we may analyze the *mean relative impact* of the publications of the team. (This would refer to the mean relative impact by *journal paper*.)

The different approximations may result in different methods which may yield *different results*. Through the *SPA* method the *total number of citations* obtained by the journal papers analyzed is related to the standard. (The total number of citations is supposed to reflect the gross impact of information published.) The applied standard may be derived from the citations to articles in the journals where the assessed publications were published (standard for *RCR* and CPP/JCS_m) or from the citations to all articles in the journals devoted to the field where the team assessed is active (standard for *RW* and CPP/FCS_m). Eq. (1) (i.e. ratio of the sums) may correspond to *SPA*, whereas Eq. (2) (i.e. mean of the ratios) may correspond to *MTA*.

The calculation based on the "mean of the ratios" method (Eq. (2)) corresponds to the *MTA* approximation. It may be traced back to the classic, although improper understanding of the Garfield (Impact) Factor (*GF*) of journals. Namely, *GF* is regarded as the mean citedness of papers (or citedness of the "mean paper") in the journal. The bibliometric features of the fields are different, consequently the definition implies that the *GF* of a journal may be a valid index in the corresponding field, only. It can be easily proved however that the *GF* represents the mean citations by paper in the journal only formally, and it may be assumed rather as the *specific impact contribution of the whole journal to the total impact of the journals dedicated to the corresponding field* (Eq. (4); Vinkler, 2004, 2010a, 2011a).

According to some authors (e.g. Gingras & Larivière, 2011; Spaan, 2010) the method for obtaining the *RCR* or *RW* index (Eqs. (3) and (4)) calculated as the ratio of sums, would be *inappropriate*, whereas other authors (e.g. Moed, 2010) are of different opinion.

The main disadvantages of using the “mean of the ratios (*MR*)” method in calculating relative impact indicators are as follows:

- The index obtained by the *MR* method may prefer the publication in journals with relatively low *GF*. Accordingly, a disadvantageous publication strategy would be favoured.
- The *MR*-type indices will be uncertain if there are citedness values (*C*/*P*, or *GF* of journals) lower than unity among the reference standards applied (i.e. the (*C*/*P*) or *GF* value of the standard is lower than unity in the denominator).

The main disadvantages of the “new crown” index may be given as follows:

- The value of the index strongly depends on share of the publications in the individual fields analyzed. Accordingly, the relative impact index (*MNCS*) would involve also quantitative aspects.
- The index will be uncertain if the citations obtained to the papers in a field are related to a citedness value (standard) in the denominator, which is lower than unity (e.g. $GF_m = FCS_m < 1$), (see e.g. Eqs. (2) and (11)–(16)).

5. The BMV-model

Before analyzing the BMV-model in Table 1, the following prerequisites of the scientometric evaluation should be accepted:

- the citation may be regarded as the scientometric *unit* of the scientific *impact*,
- the journal paper (all types included) may be regarded as the scientometric *unit* of scientific *information*,
- the impact is a linear function of citations,
- increasing the number of citations to papers in journals with higher *GF*, it should not decrease the impact index applied.

Naturally, for other models different conditions may be applied. (E.g., the impact is a logarithmic function of the number of citations.) The Garfield (Impact) Factor of journals may be assumed as chances for being cited (Vinkler, 2004). Accordingly, publishing in a journal with high *GF*, it offers a greater chance to obtain relatively more citations than publishing in low *GF* journals. Nevertheless, it is a chance, only (see the Invitation Paradox: ‘For many are called, but few are chosen’, Vinkler, 2010a). It is well-known that the distribution of citations among the papers is generally skewed. Nevertheless, I would not recommend using weighting the citations received according to the eminence of the citing journal (e.g. *GF*) (or citedness of the citing publication) in an evaluation process. The discrepancies in citedness of publications in different fields, caused by the different bibliometric factors would be unfavorably increased by the weighting (Vinkler, 2010a).

The last precondition mentioned above needs further explanation. It refers to the distribution of citations among the papers, and it does not allow the decrease of the relative impact index because of obtaining relatively more citations to papers in higher impact journals, whereas the total number of citations is kept constant. Relating the number of citations obtained by a paper to the *GF* of the publishing journal as reference standard, it may yield a relative impact index (RI) of BMV type (Eqs. (1) and (2)). Let us assume that paper P_1 was published in a journal with $GF = 1.00$ and obtained 10 citations whereas paper P_2 was published in a journal with $GF = 2.00$ and obtained 5 citations. Accordingly, $\text{RI}(P_1) = 10/1 = 10$ and $\text{RI}(P_2) = 5/2 = 2.5$. The mean of RI of P_1 and P_2 is: $(10 + 2.5)/2 = 6.25$. Let us change the number of citations obtained by the papers: $\text{RI}(P_1) = 5/1 = 5$ and $\text{RI}(P_2) = 10/2 = 5$. The mean $\text{RI} = (5 + 5)/2 = 5.00$. Naturally, the number of citations is kept constant ($C = 15$) within the system analyzed. We can realize that the increased number of citations ($5 \rightarrow 10$) to the paper is the journal with higher *GF* (2.00) and the decreased number of citations ($10 \rightarrow 5$) to the journal with lower *GF* (1.00) would result in the decrease of the mean RI value ($6.25 \rightarrow 5.00$). The method used for the calculation of the aggregate citedness index by the above method does not seem to be reasonable. The mean RI as calculated here represents a BMV/*MR* type index (Eq. (2)). In contrast, the *RCR* index which is a BMV/*RS* type indicator (Eq. (1)) would be identical in both cases ($RCR = 15/3 = 5.00$).

One of the problems of the relative indices is caused by the fact that the “citation” is a quantized measure accordingly, the number of citations obtained by a document may be zero or a *positive integer* (1, 2, 3...). This is a consequence of the action of referencing which may be described by a binary code: referencing or not referencing, accordingly cited or not cited. The value of the *citation rate* (citedness, i.e. citations per paper) of a *single* document (*C*/*P*; where $P = 1$) may be similarly only zero or a positive integer (e.g. the journal paper of author *A* and *B* in Scientometrics published in 2005 obtained 17 and zero citations, respectively up to the present).

In contrast, the *mean* value of the citation rate (citedness) of *several or many* documents may be zero, a positive integer or a positive *fraction*. (e.g. the journal papers of author *A* and *B* with $P = 11$ and 10, respectively obtained $C = 123$ and 8 citations, respectively. Accordingly, $C/P = 123/11 = 11.18$, and $C/P = 8/10 = 0.80$, respectively).

The *denominators* in Eq. (2) representing the *mean* of citations by paper in the corresponding journals (i.e. *GF* of the journals applied as standard) are not integer numbers (generally), and they may be lower or higher than unity. This way zero or a positive integer (number of citations) referring to a *single* item (i.e. the paper to be assessed) is related to a *mean* representing *many* items (from a couple up to about more thousand articles in the respective publishing journal or journals

Table 1
The BMV-model for calculating relative impact indices of papers published in journals (J_1, J_2, etc.) with different Garfield (Impact) Factor (*GF*).

	Journal						Indicator				
	J_1	J_2	J_3	J_4	J_5	Total	*JPC*	*RCR*	*RW*	*RW′*	*RPCR*
									Standard		
									GF_m (1.35)	GF'_m (2.70)	
									Method		
p_i	1	1	1	1	1	5	*RS*	*RS*	*RS*		*MR*
GF_i	0.2	0.8	1.0	2.0	5.0	9.0					
c_i											
c_i(a)	0	1	1	2	5	9	1.80	1.00	1.33	0.67	0.85
c_i(b)	1	1	1	2	5	10	2.00	1.11	1.48	0.74	1.85
c_i(c)	0	2	1	2	5	10	2.00	1.11	1.48	0.74	1.10
c_i(d)	0	1	2	2	5	10	2.00	1.11	1.48	0.74	1.05
c_i(e)	0	1	1	3	5	10	2.00	1.11	1.48	0.74	0.95
c_i(f)	0	1	1	2	6	10	2.00	1.11	1.48	0.74	0.89

MR: mean of the ratios. *RS*: ratio of the sums. GF_m and GF'_m: mean of the *GF* of journals in the field.

Publication strategy: $PS = \frac{1}{P}\sum_{i=1}^{5} GF_i = \frac{9.0}{5} = 1.80$ Journal paper citedness: $JPC = \frac{\sum_{i=1}^{5} c_i}{5}$

(a): $JPC = \frac{9}{5} = 1.80$
(b)–(f): $JPC = \frac{10}{5} = 2.00$

p_i: number of papers published in the *i*-th journal; c_i: number of citations obtained to the paper in the *i*-th journal; *P*: total number of papers; *C*: total number of citations.

Remarks to Table 1
Calculating the indicators of the BMV-Model
Relative Paper Citation Rate (RPCR) indicator (see *MNCS/MR/*, Eq. (14))

(a) $RPCR = \frac{1}{5}\left[\frac{0}{0.2} + \frac{1}{0.8} + \frac{1}{1.0} + \frac{2}{2.0} + \frac{5}{5.0}\right] = \frac{4.25}{5} = 0.85$

(b) $RPCR = \frac{1}{5}\left[\frac{1}{0.2} + \frac{1}{0.8} + \frac{1}{1.0} + \frac{2}{2.0} + \frac{5}{5.0}\right] = \frac{9.25}{5} = 1.85$

(c) $RPCR = \frac{1}{5}\left[\frac{0}{0.2} + \frac{2}{0.8} + \frac{1}{1.0} + \frac{2}{2.0} + \frac{5}{5.0}\right] = \frac{5.50}{5} = 1.10$

(d) $RPCR = \frac{1}{5}\left[\frac{0}{0.2} + \frac{1}{0.8} + \frac{2}{1.0} + \frac{2}{2.0} + \frac{5}{5.0}\right] = \frac{5.25}{5} = 1.05$

(e) $RPCR = \frac{1}{5}\left[\frac{0}{0.2} + \frac{1}{0.8} + \frac{1}{1.0} + \frac{3}{2.0} + \frac{5}{5.0}\right] = \frac{4.75}{5} = 0.95$
(f) $RPCR = \frac{1}{5}\left[\frac{0}{0.2} + \frac{1}{0.8} + \frac{1}{1.0} + \frac{2}{2.0} + \frac{6}{5.0}\right] = \frac{4.45}{5} = 0.89$

Relative Citation Rate (RCR) (Standard: $\sum_{i=1}^{5} GF_i$)

(a): $\sum_{i=1}^{5} GF_i = 9$
$RCR = \frac{\sum_{i=1}^{P} c_i}{\sum_{i=1}^{P} GF_i} = \frac{9}{9} = 1.00$
(b)–(f): $RCR = \frac{10}{9} = 1.11$

Calculating the Relative Subfield Citedness (RW) by different reference standards
Calculating the mean *GF* (GF_m) of the journals in field *A* (10 journals, J_1–J_{10} devoted to the field with the *GF* as given below)
GF
$J_1 = 0.2$; $J_2 = 0.8$; $J_3 = 1.0$; $J_4 = 2.0$; $J_5 = 5.0$; $J_6 = 0.1$; $J_7 = 0.4$; $J_8 = 0.5$; $J_9 = 1.0$; $J_{10} = 2.5$

$$GF_m : \frac{1}{10}\sum_{i=1}^{10} GF_i = \frac{13.5}{10} = 1.35$$

RW (calculated with the GF_m standard)

(a): $RW = \frac{C}{P \cdot GF_m} = \frac{C}{5 \cdot 1.35} = \frac{9}{6.75} = 1.33$
(b)–(f): $RW = \frac{10}{6.75} = 1.48$

Calculating the mean *GF* (GF'_m) of the journals in field *B* (10 journals, $J'_1 - J'_{10}$ devoted to the field with the *GF′* as given)
GF′
$J'_1 = 0.2$; $J'_2 = 0.8$; $J'_3 = 1.0$; $J'_4 = 2.0$; $J'_5 = 5.0$; $J'_6 = 0.4$; $J'_7 = 1.6$; $J'_8 = 2.0$; $J'_9 = 4.0$; $J'_{10} = 10.0$

$$GF'_m = \frac{1}{10}\sum_{i=1}^{10} GF_i^i = \frac{27}{10} = 2.70$$

RW′ (calculated with the GF'_m standard)

(a): $RW' = \frac{C}{P \cdot GF'_m} = \frac{C}{5 \cdot 2.70} = \frac{9}{13.50} = 0.67$
(b)–(f): $RW' = \frac{10}{5 \cdot 2.70} = \frac{10}{13.50} = 0.74$

of the field used as standard). We often refer to the statistical nature of scientometric methods. The uncertainty of the numerator, i.e. the number of citations to a *single* publication (the number of citations determined from different sources may be different, citations in books are neglected, self-citations are included, or not, the aging rate of information is different in different fields, etc.), makes this type of calculations (Eq. (2)) questionable both from statistical and also from science political reasons.

If the standard, i.e. *GF* of a journal or mean *GF* of the corresponding reference journals is lower than unity, the item to item comparison (*MR*, Eq. (2)) does not seem to be correct. E.g., let us assume three papers each with a single citation. The *GF* of the publishing journals let be, e.g., 0.121, 0.432, and 0.823. Accordingly, the CPP/JCS_m index will be equal to 8.26, 2.31 or 1.22 depending *reversely on the quality* (*GF*) of the journal. It seems to be hardly acceptable from any evaluation points to prefer publishing in relatively lower quality journals. It should be added that a single citation, e.g. a self-citation may be made very easily.

The BMV-model in Table 1 shows a set consisting of 5 journal papers published in journals (J_1–J_5) with different Garfield (Impact) Factor (*GF*). It is supposed first that the papers studied received a total of 9 citations, c_i(a) which is equal to the sum of *GF* of the publishing journals. It is assumed further that the paper in J_1 (*GF* = 0.2) obtained no citation, whereas that in J_2 (*GF* = 0.8) received a single citation ($GF_1 + GF_2 = 1.0$), the other papers obtained as many citations as the "mean" paper in the journal (i.e. *GF*). Accordingly, the Relative Citation Rate indicator (Eq. (3)) is equal to unity, *RCR* = 1.00. The Relative Subfield Citedness (*RW*) indicator (Eq. (4)) may be higher (*RW* = 1.33) or lower (*RW′* = 0.67) than *RCR* = 1.00, depending on the field average applied (1.35 or 2.70, resp.) (see also Remarks ad Table 1).

For the sets c_i(b)–c_i(f) the *JPC* index calculated as aggregate (or globalized) indices, show similar values. This observation is valid also for *RCR* and *RW* (Table 1). It follows, the value of the indices is *independent of the distribution* of citations among the journal papers. The value of the indices depends only on the total number of citations obtained, number of papers published and sum of *GF* of the journals used as standard.

The reference standard of the *RCR* index is the *Publication Strategy* (*PS*, Eq. (6)) of the researchers (individuals, teams, authors of laboratories, etc.) studied. Therefore, the *RCR* index may be strongly influenced by a low number of citations obtained to papers in journals of low *GF*. The papers of e.g. Russia, India and China show a significantly higher Relative Citation Rate (*RCR*) than Relative Subfield Citedness index (*RW*), which uses the *mean citedness of the corresponding field* as reference standard (Eq. (4)) (Vinkler, 2010a). This is because the scientists in the mentioned countries are publishing many papers in national journals with relatively low *GF*, and by obtaining a similarly low number of citations to those papers they may arrive at relatively higher *RCR* index.

The value of the *RW* indicator strongly depends on the reference standard applied. Provided the reference standard (GF_m = 1.35) is lower than the Publication Strategy (*PS* = 1.80), the *RW* index will be higher than unity (a: *RW* = 1.33; b–f: *RW* = 1.48). If however the value of the reference standard is higher than the Publication Strategy (*PS*): $GF'_m = 2.70 > PS = 1.80$, the Relative Subfield Citedness (*RW*) index will be lower than *RCR* = 1.00 (a: *RW′* = 0.67; b–f: *RW′* = 0.74) (see also Remarks ad Table 1).

The *RCR* and *RW* index may show great differences also because of discrepancies in the sample. Let us take an example. A team working in physical chemistry published altogether 30 papers in two years included a single paper in Nature (*GF* = 34.48 in 2009). The paper in Nature is on results attained in cooperation with another team in physiology. Let us suppose that the mean *GF* of the journals in physical chemistry is: GF_m = 2.35, and the team obtained altogether 71 citations in the proceeding year. Generally, the total number of citations obtained by 30 papers in physical chemistry would be: $\sum_{i=1}^{30}(30 \cdot 2.35) = 70.5$, which number may be used as standard. Accordingly, *RW* = 71/70.5 = 1.01. But the team published 29 papers in journals with *GF* = 2.35 in average, and a single paper in Nature with *GF* = 34.48, consequently the total number of "*expected*" citations would be: $\left[\sum_{i=1}^{29}(29 \cdot 2.35)\right] + 34.48 = 102.63$. Accordingly, the *RCR* index: 71/102.63 = 0.69. Naturally, the Nature paper may obtain significantly higher number of citations than the publications in the physical chemical journals. Accordingly, the *RCR* index may be higher than 0.69. Nevertheless, the single paper published in Nature cannot be characteristic of the activity of the team. Therefore, it would not be correct to calculate also with "outliers" in analyzing the scientific impact of teams.

In performing comparative evaluations on low hierarchical levels the assessment processes require personal (subjective) decisions from the evaluators to arrive at relevant results. The correct solution to the problem would be to calculate with only a part (e.g. 75%) of total publications of the teams or laboratories assessed. This way only those part of information will be assessed which clearly represents the majority of the activity of the team (the 75% of the papers may be taken into account by ranking the publishing journals according to the decreasing frequency of publications of the corresponding team in them, Vinkler, 2006). Assessments on team or personal level always need science political decisions.

In several cases, it seems to be difficult to find an appropriate standard to assess the papers of a team. We may select the set of journals as standard where the corresponding publications were appeared (i.e. Publication Strategy, Eq. (6)). This method is easily acceptable by the scientists evaluated at low hierarchical (e.g. team) level (Vinkler, 2002). The application of the method is relatively easy also at higher levels. Nevertheless, the advantage for teams or countries publishing primarily in relatively low *GF* journals is obvious.

The disadvantage of the *RW* index is clear at lower hierarchical level (Vinkler, 2002) because of the difficulties in obtaining appropriate standards (e.g. the team is involved in researches covering different fields, publications in multidisciplinary journals, difficulties in delineating the journals by field, etc.). But, on country level, primarily on the level of disciplines we may preferably select this index.

It should not be forgotten that the "global" or aggregate specific indicators (e.g. number of papers by scientist, Publication Strategy or citations by publication, etc.) which refer to the total number of publications of persons, teams, laboratories or countries within the set studied, depend also on the *share* of the *individual activities* (distribution of the publications by field and subfield). The BMV/*RS* type indicators (with appropriate standards) may mostly eliminate this effect.

From Table 1 it concludes that increasing the total number of citations to the set (consisting of 5 papers) by unity (c_i(b) = 10 vs. c_i(a) = 9) with obtaining a single citation to the paper in the journal with the lowest impact (J_1, *GF* = 0.2), it will enhance the value of the *RPCR* index calculated by the *MR* method from 0.85 to 1.85 (Δ = 118%). The increase of the index is *the lower* (1.85 → 1.05 → 0.89, resp.) *the higher* the *GF* of the publishing journal: J_1(0.2) → J_3 (1.0) → J_5 (5.0) in which the paper with the increased citedness was published. The total number of citations is kept at the same level (*C* = 10). It would seem that obtaining more citations to papers in more influential journals would be penalized by the index. In contrast, the increase of the *RW* indicator is only of 11.3% (1.33 → 1.48) or 10.4% (0.67 → 0.74), depending on the standard applied. And, the increase does not depend on the distribution of citations among the papers.

6. The "new crown" (*MNCS*) index model

The model in Table 2 may demonstrate the effect of different number of papers by the field on the value of the "new crown" (*MNCS*) index.

It is assumed first that the whole set of papers analyzed contains publications which may be attributed to three different fields (f_1; f_2; f_3), and each publication in the same field would obtain the same number of citations as the "mean paper" in the field (i.e. FCS_m). Accordingly, the *MNCS* index which refers to the whole set (consisting of 6 papers) equals to unity (see example *A*/1). This would mean that the impact of the set evaluated corresponds to the level of the reference standard. If the papers in field f_1 obtain citations two times more (24) than that of the standard (3·4 = 12), the *MNCS* index of the set will be equal to 1.50 (see example *A*/2). It is because 3 (50%) of 6 papers evaluated obtain citations two times more than "expected". If however the publications in field f_2 would obtain citations two times more (8) than the standard (i.e. 2·2 = 4) (example *A*/3) whereas the papers in the other fields would receive the same number of citations as the corresponding standard, the *MNCS* index of the set will be only 1.33. Increasing the citedness of the single paper in field f_3 (*A*/4) by unity, the increase of *MNCS* would take only about 17% related to *A*/1.

The model presented shows that the *MNCS* index strongly depends on the eminence of the activities in different fields. The share and conditions of the individual activities of universities or research laboratories depend on several inside and outside factors. Nevertheless, to connect the assessment, namely the calculation of the mean relative scientific *impact* of the organization with the *share* of the individual activities conducted by the organization, it does not seem to be reasonable from science political viewpoints. The determination of the share of activities in different fields is in most cases beyond the control of the team, laboratory or institute evaluated.

Table 3 shows several further model examples for calculating the "new crown" index. The distribution of the journal papers among the different fields (f_1; f_2; f_3) is given as follows: f_1: 3; f_2: 2; f_3: 1. Among the fields f_3 is supposed to figure with an average citedness value lower than unity (FCS_m = 0.5).

The citation is a quantized measure. Consequently, a paper may obtain zero citation or any positive integer number of citations. If the paper in field f_3 obtained no citations at al (*B*/1), the *MNCS* index of the set would be 0.83. If the same paper (f_3) received, however, a single citation (*B*/2), the *MNCS* index would increase of about 41% to 1.17. Consequently, the standard, $FCS_m(f_3)$ seems to be *uncertain* in this case, because the a paper published in this field should receive (1·0.5) = "0.5" citation to be equivalent with the field standard. By receiving only a single citation, the performance will be however significantly higher (1.17) than unity. Naturally, this uncertainty may be eliminated through applying 10 *GF* as the reference standard

Table 2
Model for investigating the dependence of the "new crown" index (*MNCS*) on the share of publications of different excellence in different fields.

Number of papers in different fields				Total citations	Weighted average of the citedness (*C*/*P* or *GF*) of the journals dedicated to the field (reference standard)		
A	f_1	f_2	f_3				
	3	2	1		$FCS_m(f_1)$	$FCS_m(f_2)$	$FCS_m(f_3)$
Sum of the citations obtained					4.0	2.0	1.0
Example	$\sum_{i=1}^{3} c_i(f_1)$	$\sum_{i=1}^{2} c_i(f_2)$	$c_1(f_3)$				
A/1	12	4	1	17	*MNCS* = (12/4 + 4/2 + 1/1)/6 = 1.00		
A/2	24	4	1	29	*MNCS* = (24/4 + 4/2 + 1/1)/6 = 1.50		
A/3	12	8	1	21	*MNCS* = (12/4 + 8/2 + 1/1)/6 = 1.33		
A/4	12	4	2	18	*MNCS* = (12/4 + 4/2 + 2/1)/6 = 1.17		

"Required" number of citations (reference standard) by the field:
A/Reference standards: f_1: 3 $FCS_m(f_1)$ = (3·4.0) = 12; f_2: 2 $FCS_m(f_2)$ = (2·2.0) = 4; f_3: $FCS_m(f_3)$ = (1·1.0) = 1.
Total number of publications: 6.

Table 3
Model for investigating the impact of the weighted average citedness value (FCS_m) lower than unity.

Number of papers in different fields				Total citations	Weighted average of the citedness (*C/P* or *GF*) of the journals dedicated to the field (reference standard)		
B	f_1	f_2	f_3				
	3	2	1		$FCS_m(f_1)$	$FCS_m(f_2)$	$FCS_m(f_3)$
Sum of the citations obtained							
Example	$\sum_{i=1}^{3} c_i(f_1)$	$\sum_{i=1}^{2} c_i(f_2)$	$c_1(f_3)$		2.0	1.0	0.5
B/1	6	2	0	8	$MNCS = (6/2+2/1+0/0.5)/6 = 0.83$		
B/2	6	2	1	9	$MNCS = (6/2+2/1+1/0.5)/6 = 1.17$		
B/3	6	2	2	10	$MNCS = (6/2+2/1+2/0.5)/6 = 1.50$		
C	f_1'	f_2'	f_3'	Total citations obtained	f_1'	f_2'	f_3'
Example	$\sum_{i=1}^{3} c_i(f_1)'$	$\sum_{i=1}^{2} c_i(f_2)'$	$c_1(f_3)'$		$FCS_m(f_1)'$	$FCS_m(f_2)'$	$FCS_m(f_3)'$
					0.5	1.0	2.0
C/1	0	2	2	4	$MNCS' = (0/0.5+2/1+2/2)/6 = 0.50$		
C/2	1	2	2	5	$MNCS' = (1/0.5+2/1+2/2)/6 = 0.83$		
C/3	2	2	2	6	$MNCS' = (2/0.5+2/1+2/2)/6 = 1.17$		
C/4	3	2	2	7	$MNCS' = (3/0.5+2/1+2/2)/6 = 1.50$		

"Required" number of citations (reference standard) by the field:
B/Reference standards: f_1: 3 $FCS_m(f_1) = (3{\cdot}2.0) = 6$; f_2: 2 $FCS_m(f_2) = (2{\cdot}1.0) = 2$; f_3: $FCS_m(f_3) = (1{\cdot}0.5) = 0.5$.
C/Reference standards: f_1': 3 $FCS_m(f_1)' = (3{\cdot}0.5) = 1.5$; f_2': 2 $FCS_m(f_2)' = (2{\cdot}1.0) = 2$; f_3': $FCS_m(f_3)' = (1{\cdot}2.0) = 2$.
Total number of publications: 6.

and 10 times the number of citations obtained in the numerator as the ratio of the original values remains. Increasing the number of citations of the paper in field f_3 by two (*B*/3), the *MNCS* index will increase to 1.50 although the total number of citations increased only from 8 to 10 (25%).

Let us change the average citedness (FCS_m) of the fields. Accordingly, the *required* number of citations would change from *B* = 6, 2 and 0.5 to *C* = 1.5, 2 and 2 in field f_1, f_2 and f_3, respectively (see Table 3). If the papers in field f_1' obtain zero citation, the *MNCS* index will decrease, $MNCS' = 0.50$ (*C*/1). The decrease of the total number of citations is significantly greater ($8 \rightarrow 4$) than the decrease of the index ($0.83 \rightarrow 0.50$) (see *B*/1 vs *C*/1). If the number of citations to papers in f_1' increases from zero to unity (*C*/2), the *MNCS'* index will show a similar value as for *B*/1 which again indicates a significant influence of the number of papers in the individual fields on the value of the index. The *MNCS* index is the same (1.50) for both *C*/4 and *B*/3 (which feature is similar to *C*/3 and *B*/2, where *MNCS* = 1.17), although the values of the total number of citations significantly differ (7 vs 10 and 6 vs 9, respectively).

For the *MNCS* index neither in *B* nor in *C* cases would it be possible to calculate a value of unity indicating a similar impact of the papers studied as the average of the field. This is because the value of the *reference standard is lower than unity*.

Analyzing the results obtained by the above model, it may be concluded, if one of the fields involved shows an FCS_m index lower than unity, by applying the "new crown" (*MNCS*) index no reliable relative impact index could be obtained. This concern may be relevant primarily in analyzing relatively low number of papers.

7. Conclusions

One of the important functions of the evaluative scientometric indicators is that they may *orientate* the future activity of researchers. One of the important goals of heads of laboratories and directors of research institutes is to enhance the level of the publication channels used for publishing the results attained in the laboratory or institute. Calculating relative impact indices by the "mean of the ratios" method (Eq. (2)), it seems to work against this desirable trend. Accordingly, by receiving a single citation or a couple of citations to articles in journals with *GF* < 1.00, the "mean of the ratios" (*MR*) method may significantly distort the value of the BMV type indicators.

The *RPCR* index and *MNCS* index strongly depend on the *distribution of citations* among the articles in different journals or fields, respectively. The application of the *RPCR* calculation method (mean of the ratios, *MR*) may praise or dispraise especially individuals (e.g. junior scientists) or teams with relatively low number of papers and citations. The effect of the distribution of citations among the papers in different fields, the number of papers by field, and the number of fields taken into account were found to strongly influence the *MNCS* index. The higher the *number of fields* in evaluating by the *MNCS* index, the closer the situation to that described for the *RPCR* calculation (see Eq. (14)). Because of the above facts, the calculation method ("mean of the ratios") cannot be recommended to apply in scientometric evaluations neither on journal paper nor on field level. Nevertheless, it should be acknowledged that the "ratio of the sums" method (for obtaining *RCR* or CPP/JCS_m and *RW* or CPP/FCS_m indices) gives any preference to the citations to papers in high impact journals neither. But, the value of these indices does not increase (or decrease) at least, only because of the increasing number of citations to journal papers in lower *GF* journals.

A good scientometric indicator should work appropriately both at low and high hierarchical level according to the selected criteria of the corresponding assessment. Nevertheless, each index has its own advantages and drawbacks.

In selecting appropriate indicators for assessing different scientometric systems, reasonable scientometric methods conform to the corresponding science policy goals should be preferred. It is obvious that the relative impact indicators are useful indices in evaluating the aggregate influence of information on science, comparatively. Nevertheless, using only the indicators studied here, we cannot characterize all relevant aspects of the impact of publications on science. Although the application of the classic scientometric indicators is widely acknowledged, it is highly advisable to apply also some other normalization methods and indicators of different type. Such indices may be the following: h-index (Hirsch, 2005), g-index (Egghe, 2006), *h*-type indices (Bornmann, Mutz, Neuhaus, & Daniel, 2008; Bornmann et al., 2011; Schreiber, 2008), π-index and π_v-index (Vinkler, 2009, 2010b), highly cited papers (Aksnes, 2003; Aksnes & Taxt, 2004; Plomp, 1990), the percentile approach included most highly cited papers (Bornmann & Mutz, 2011; Leydesdorff & Opthof, 2011), and Citation Distribution Score (CDS) and Citation Distribution Rate (CDR) (Vinkler, 2011b) etc.

The difference between the BMV-indices calculated by the ratio of sums (*RS*) or mean of ratios (*MR*) method or by the new crown index may be relatively low in analyzing the data of many laboratories or many teams (van Raan et al., 2010; Waltman et al., 2011a,b). Nevertheless, studies on a relatively small set of papers of small number of teams or individuals may show rather great differences in the value of the mentioned indices. It is well-known that the reliability of the publication assessments decreases at lower hierarchical levels, i.e. with lower number of journal papers. Consequently, the application of the BMV indicators on lower hierarchical levels needs extreme care. The delineation of fields by journal, primarily delineation of interdisciplinary and multidisciplinary journals or papers can be made with great uncertainty only. Low number of papers in a special field, whereas high number of publications in another field may strongly influence the value of the BMV indices, if the excellence (measured as citedness) of the corresponding papers differs. Therefore the BMV/*MR* type indicators cannot be recommended, at least at team or individual level.

There are no absolute methods and no absolute indicators in scientometrics. Nevertheless, scientometricians, science officers, scientists, and science politicians have frequently the task to assess grant applications or activity of R&D organizations. The application of assessment methods seems to be inevitable, especially in circumstances of economic recession and decreasing grants. In my view, scientometricians have to strive to find correct assessment methods with the possible lowest error. And, the persons elaborating, suggesting and using scientometric indices should be in aware of all the advantages and disadvantages of the indicators.

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