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EM and $EM^{'}$-index sequence: Construction and application in scientific assessment of scholars

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Abstract Most of the scientometric indicators use only the total number of citations of an article and produce a single number for scientific assessment of scholars. Although this concept is very simple to compute, it fails to show the scientific productivity and impact of scholars during a time-span or in a year. To overcome this, several time series indicators have been proposed that consider the citations from the entire research career of a scholar. However, these indicators fail to give a comparative assessment of two scholars having same or very similar index value. To overcome this shortcoming, h-index sequence was proposed to assess the impact of scholars during a particular time-span and to compare multiple scholars at a similar stage in their careers. The h-index sequence is based on the h-index formulation. One of the main issues related to the h-index is that it completely ignores the excess citation in scientific assessment; h-index sequence also exhibits a similar behaviour. To overcome these limitations, in this article, we have discussed the EM and $EM^{'}$-index sequence, and performed an empirical study based on yearly citation count earned from all publications of 89 scholars' publication data. The element of the EM and $EM^{'}$-index sequence for a given year shows the impact of a scholar for that year. We conclude that the EM and $EM^{'}$-index sequence could be used as an alternative metrics to asses the impact of scholars.

Keywords h-index · EM-index · EM'-index · h-index sequneces · EM-index sequence · $EM^{'}$-index sequence

1 Introduction

The scientometrics and bibliometrics indicators play a key role in the scientific assessment of scholars and are also used in faculty promotion in colleges/universities, scientific award distribution and project funding etc. King (1987). One of the most influential scientometrics/bibliometrics indicator h-index, proposed by Hirsch (2005), considers productivity as well as impact of scholars. However, this indicator suffers with several drawbacks that restrict its use in comparing scholars having similar index values computed based on their entire research careers. Several studies have been done to overcome this drawback and increase the acceptability in the scientific assessment (Rousseau (2006); Bornmann et al. (2008); Rousseau and Leuven (2008); Alonso et al. (2009);

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Rosenberg (2014); Wildgaard et al. (2014)). Generally, most of the indicators produced only a single number to asses the scientific impact of the entire career of the scholars. However, instead of a single number, a set of indicators seem to be more justified in this case. In this context, first Liang (2006) proposed the h-index sequence. The h-index sequence is the set of h-index values computed from yearly citation counts, where the sequence elements were computed in the reverse chronological order of the academic careers of the scholars, i.e., recent publications being considered first. However, Egghe (2009) mentioned that the calculation of sequence in the forward direction of time is more precise than the reverse direction, and it is easy to understand as well. Liu and Rousseau (2008) defined 10 different types of time series h-index sequences. Fred and Rousseau (2008) discussed the relationship between the power law model and the h-index sequence using h_4 values (discussed in Egghe's sequences). Wu et al. (2011) performed an empirical study of *real career h-index sequence* based on h_3 values (discussed in Egghe's sequences). Liu and Yang (2014) performed an empirical study of h-index sequence based on yearly citation performance of cumulative publications using h_2 values obtained from Egghe's sequences. The authors proposed L-sequence obtained from h_2. However, all of the above h-index based sequences consider only the h^2 citation and completely ignore the importance of excess citation. Another issue is that they do not consider all the items in the computation of sequences, whereas the articles that are cited even once have significance in scientific assessment. To overcome this, Bihari and Tripathi (2017) proposed a new measure called EM-index and $EM^{'}$-index. The EM-index gives full credit to highly influential articles, whereas the $EM^{'}$-index considers all articles that are cited even once.

This article proposes the EM and $EM^{'}$-index sequence as an effective way to evaluate the scientific impact of scholars. The EM and $EM^{'}$-index sequence is the sum of the elements calculated using EM and $EM^{'}$-index formula respectively. In this article, first we discuss EM-index, $EM^{'}$-index and L-sequence (Sec. 2). Then we discuss the comparative empirical analysis of EM and $EM^{'}$-index sequence done on yearly citation count earned from all the articles in the dataset of 89 scholars used in Bihari and Tripathi (2018). The experimental results highlight the properties of EM and $EM^{'}$-index sequence that reflect the overall impact of scholars. Used this way, we show that EM and $EM^{'}$-index sequence provide an alternative superior way to evaluate the scientific impact of scholars.

2 Background

The h-index, as proposed in Hirsch (2005), is described as: "The h-index of a scholar is h if h of his/her publications have at least h citations each and the rest of the publications may have h or less citations."

This index attracted attention from the research community due to its characteristics, however, it has several limitations. In general, it seems that the most of the indicators give only a single number to show the scientific impact of scholars, but they do not differentiate between scholars having similar index values. Further, they do not take into account the career-duration of scholars. The primary limitation of h-index is that it completely ignores the excess citation (i.e., over and above h) of articles.

Example: Let 15 articles be published by scholar A with the following citation counts Cit={30, 30, 25, 22, 22, 21, 15, 15, 14, 10, 10, 10, 9, 8, 1 }. Let 15 articles be also published by scholar B with the following citation counts cit={10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 0, 0, 0, 0, 0}. In both the cases, the h-index value is 10, however, the scientific impact of scholar A is more than that of scholar B because scholar A has (i) more citation counts for each article and (ii) non-zero citation counts for h-tail articles when compared to scholar B who has zero citation count for h-tail articles. This shows that h-index may not be a good measure for comparative scientific assessment of scholars because it does not give any extra credit to excess citations and h-tail articles.

To overcome this shortcoming of h-index, the EM-index was proposed by Bihari and Tripathi (2017); and is defined as: "The EM-index of an author is the square root of the sum of the elements of the EM-index." Here, the elements of the EM-index of an author are the h-index values computed from the h-core article citation count at multiple levels. The first element of the EM-index is the original h-index and the subsequent elements are the h-index values from the excess citation count of the h-core articles. In the previous example, if we consider the citation count of author A, the components of EM-index are {10, 6, 5, 3, 2, 2, 2} and the EM-index is 5.48. Author B has only

one component of EM-index as {10} and the EM-index is 3.2. Clearly, the EM-index captures the significant difference in the scientific impact of these two authors.

The EM-index considers the impact of the excess citation count of the h-core articles, which is not considered in the h-index, but is helpful to differentiate between two different scholars having similar index values. However, the h-index and the EM-index do not consider the impact of all those articles that have been cited even once. If we look at the citation counts of author A, there are some articles having citation count equal to the h-index or less than that. However, both the h-index and the EM-index do not consider the impact of citation counts of such articles. To overcome this, a new indicator was proposed by Bihari and Tripathi (2017) named $EM^{'}$-index. This index is the multidimensional extension of the EM-index.

In spite of the progress so far, none of the above mentioned indices consider the career-duration of scholars, making it difficult to gauge the impact of a scholar at a particular stage of his/her career. Several articles have been published on this problem; Mahbuba and Rousseau (2013, 2016); Liu and Yang (2014) and Bihari and Tripathi (2018) are the recent ones among them. Mahbuba and Rousseau (2013, 2016) discussed the year based h-index that considers year wise impact of scholars based on (i) the total number of citations earned in a particular year, (ii) the total number of citations from all publications that are published in a particular year, and (iii) the total number of publications in a particular year. These year based indices still suffer with h-index limitations. To overcome the year based h-index excess citations problem, Bihari and Tripathi (2018) proposed year based EM and $EM^{'}$-index. The year based indicators cover the entire career of scholars, however they do not consider the year wise impact of scholars. To overcome this issue of year based indices, Liu and Yang (2014) studied the h-index sequence and proposed a new index called L-sequence. L-sequence considers the entire research career of a scholar to determine the scientific impact. To define L-sequence, consider a scholar who has published k articles in his/her career. Let the first publication year be y_1 and the current year be y_c. Then, the L-sequence of an author for n^{th} year, denoted L_n, is the h-index value computed on the basis of citation counts of all publications received in the n^{th} year. Thus, the L-sequence of the author is $L_{y_1}, L_{y_1+1}, ...L_{y_c}$.

The computation of L-sequence is based on h-index, but it does not account for the impact of excess citations and the h-tail items.

From the above discussion, it can be concluded that the scientific assessment of scholars is done with the help of citations earned by all articles, however, the career-duration of scholars is not considered, which is also significant in scientific assessment. To overcome this, we propose EM and $EM^{'}$-index sequence, which are described next

3 EM-index Sequence

As discussed in the previous section (sec: 2), the year based indices consider only the total number of citations earned by all publications in a particular year to produce a single number for scientific assessment. In this process, they ignore yearly impact of scholars. Instead of a single number, a set of numbers capturing the yearly impact of scholars will be more suited to evaluate and compare the performance of scholars. To this end, we introduce EM-index sequence based on yearly citations received by all publications.

Definition of EM-index Sequence

Let the research career of a scholar span n years, publishing k articles. Let y_1 be the year in which his/her first publication is published. Let the current year be y_c. The EM-index sequence element for the y^{th} year, denoted EM_y, is calculated from the citation count in y^{th} year using the EM-index formula given in Bihari and Tripathi (2017). Then, the EM-index sequence value is computed as the sum of all such EM-index sequence elements. Formally,

$$EM - index\ Sequence = \sum_{y=1}^{c} EM_y \tag{1}$$

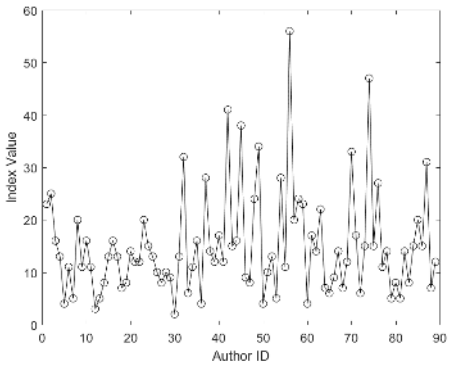
For example, consider the scientific research history and impact of author **Andrew D. Jackson** (Source: Web of Science) as shown in Table 1. The corresponding EM-index sequence elements are 2.24, 2.65, 3.16, 2.83, 2.24, 3.16, 3.74, 3, 3.32, 2.45 & 1.73 and the EM-index sequence value is 29.17.

Table 1: Publication history and year wise impact of Author Andrew D. Jackson

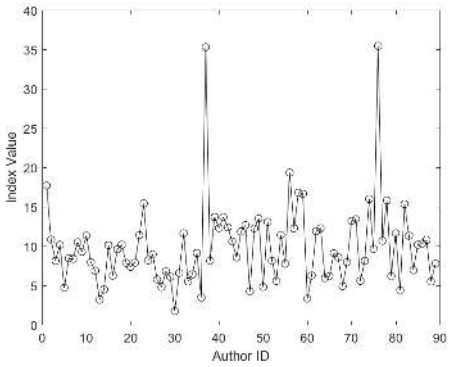
Publication Year ↓	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
2006	11	9	11	15	12	11	20	14	16	11	5
2007	4	6	9	8	5	10	13	8	4	2	0
2007	0	0	0	0	0	0	0	0	0	0	0
2008	0	1	10	4	4	5	7	6	4	5	1
2008	0	0	0	0	0	1	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	3	5	9	4	6	10	6	2
2009	0	0	0	0	0	2	0	1	0	0	0
2010	0	0	0	0	1	0	0	0	0	0	0
2011	0	0	0	0	1	3	3	4	2	1	0
2013	0	0	0	0	0	0	0	1	1	1	1
2013	0	0	0	0	0	0	0	0	1	0	0
2013	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	1	1	0
2015	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	1	0
2016	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0
EM-index	2.24	2.65	3.16	2.83	2.24	3.16	3.74	3	3.32	2.45	1.73

4 Empirical Study of EM-index-sequence

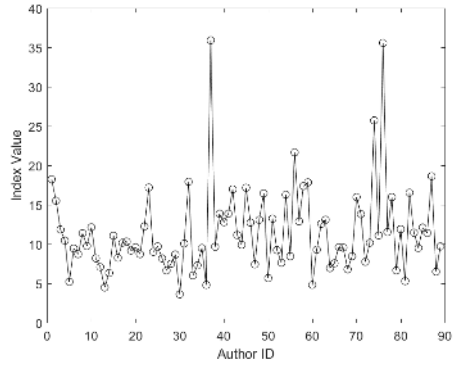
In this section, we present an empirical study of EM-index sequence over the h-index sequence, h-index, EM-index, $EM^{'}$-index and year based EM-index by citations. The study illustrates the merit of EM-index sequence in comparison to others. To do this, we have used the publication-data of 89 scholars from reference Bihari and Tripathi (2018). Among the 89 scholars, most of them are working in scientometric and biblometrics fields of research. The h-index, EM-index, $EM^{'}$-index, year based EM-index by citations, h-index sequence and EM-index sequence for all 89 scholars is shown in Figure 1. As can be seen, there is significant variation in the indices values of all scholars. Table 2 shows the corresponding EM-index sequence value for each of the 89 scholars.



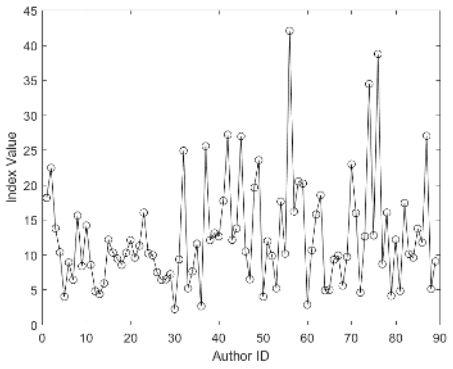
(a) The h-index of all Scholars



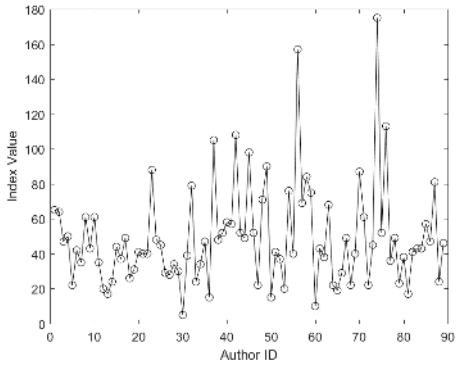
(b) The EM-index of all Scholars



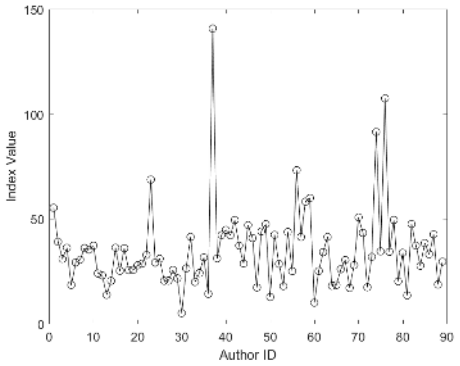
(c) The $EM^{'}$-index of all Scholars



(d) The Year based EM-index by citations of all Scholars



(c) The h-index sequence of all Scholars



(d) The EM-index sequence of all Scholars

Fig. 1: h-index, EM-index, $EM^{'}$-index, year based EM-index by citations, h-index sequence and EM-index sequence for the publication-data of 89 scholars from reference Bihari and Tripathi (2018)

Table 2: The EM-index sequence of all 89 scholars

ID	**Author**	**EM-index Sequence**	**ID**	**Author**	**EM-index Sequence**
1	Adamantios Diamantopoulos	55.24	46	Lokman Meho	40.81
2	Albert Zomaya	39.06	47	Luca Mastrogiacomo	17.26
3	Alireza Abbasi	30.85	48	Ludo Waltman	44.00
4	András Schubert	36.16	49	Lutz bornmann	47.42
5	András Telcs	18.39	50	Maisano, DA	12.70
6	Andreas Thor	29.17	51	Marek Kosmulski	42.35
7	Andrew D. Jackson	30.51	52	Maria Bordons	28.49
8	Anne-Wil	36.07	53	Mark Fine	17.89
9	Aric Hagberg	35.29	54	Mark Newman	43.74
10	Barry Bozeman	37.23	55	Mathieu Ouimet	25.01
11	Ben R Martin	23.98	56	Matjaž Perc	73.17
12	Benny Lautrup	23.00	57	Matthew O. Jackson	41.33
13	Berwin Turlach	13.73	58	Mauno Vihinen	58.17
14	Birger Larsen	20.44	59	Michael Jennions	59.89
15	Blaise Cronin	36.21	60	Michael L. Nelson	10.00
16	C Lee Giles	25.17	61	Miguel A.	25.07
17	Carlos Pecharroman	35.97	62	Morten Schmidt	34.08
18	Caroline S. Wagner	25.53	63	Nees Jan van Eck	41.35

Table 2: The EM-index sequence of all 89 scholars continued.....

ID	Author	EM-index Sequence	ID	Author	EM-index Sequence
19	Christoph Bartneck	25.64	64	Nils T. Hagen	17.99
20	Claes Wohlin	27.79	65	Olle Persson	18.39
21	Clint D. Kelly	28.62	66	Paul Wouters	25.96
22	Dimitrios Katsaros	32.75	67	Peter Jacso	30.36
23	Egghe Leo	68.69	68	Raf Guns	17.02
24	Elizabeth A. Corley	29.09	69	Raj Kumar Pan	27.83
25	Erhard Rahm	30.98	70	Richard S J Tol	50.67
26	Fiorenzo Franceschini	20.43	71	Roberto Todeschini	43.30
27	Fred Y.	20.50	72	Robin hankin	17.39
28	Gad Saad	25.56	73	Rodrigo Costas	31.87
29	Gangan Prathap	21.60	74	Ronald Rouseau	91.43
30	Gary M. Olson	5.00	75	Ruediger mutz	34.46
31	Gerhard Woeginger	26.38	76	Santo Fortunato	107.41
32	Guang-Hong Yang	41.37	77	Serge GALAM	34.26
33	Heidi Winklhofer	19.85	78	Sergio Alonso	49.48
34	Hendrik P. van Dalen	24.16	79	Steve Lawrence	20.16
35	Henk F. Moed	31.51	80	Sune Lehmann	33.80
36	Herbert Van de Sompel	14.20	81	Terttu Luukkonen	13.49
37	Hirsche	140.79	82	Vicenç	47.50
38	James Moody	31.10	83	Walter W (Woody) Powell	37.21
39	Jayant Vaidya	42.25	84	Werner Marx	27.58
40	Jerome Vanclay	44.69	85	Wolfgang Glänzel	38.37
41	Johan Bollen	42.13	86	Yannis Manolopoulos	33.06
42	JOHN IRVINE	49.43	87	Ying Ding	42.58
43	Judit Bar-Ilan	37.21	88	Yu-Hsin Liu	18.65
44	Kène Henkens	28.71	89	Yvonne Rogers	29.57
45	Loet Leydesdorff	46.97			

The EM-index sequence provides a more balanced and efficient way to assess the scientific impact of scholars. The EM-index sequence elements provide year wise scientific impact of a scholar that helps to compare the performance of scholars at a particular year of their career. In order to validate this, a comparative analysis has been made with h-index sequence as shown in Table 3.

Table 3: Comparison of h-index sequence with EM-index sequence

ID	Author	h-index Sequence	Rank	EM-index Sequence	Rank
1	Adamantios Diamantopoulos	65	18	55.24	8
2	Albert Zomaya	64	19	39.06	27
3	Alireza Abbasi	47	37	30.85	47
4	András Schubert	50	30	36.16	33
5	András Telcs	22	76	18.39	77
6	Andreas Thor	42	48	29.17	51
7	Andrew D. Jackson	35	62	30.51	48
8	Anne-Wil Harzing	61	20	36.07	34
9	Aric Hagberg	43	44	35.29	36
10	Barry Bozeman	61	21	37.23	29
11	Ben R Martin	35	63	23.98	68
12	Benny Lautrup	20	81	23.00	69

Table 3: Comparison of h-index sequence with EM-index sequence continued....

ID	Author	h-index Sequence	Rank	EM-index Sequence	Rank
13	Berwin Turlach	17	84	13.73	85
14	Birger Larsen	24	72	20.44	72
15	Blaise Cronin	44	43	36.21	32
16	C Lee Giles	37	59	25.17	64
17	Carlos Pecharroman	49	31	35.97	35
18	Caroline S. Wagner	26	71	25.53	63
19	Christoph Bartneck	31	66	25.64	61
20	Claes Wohlin	41	49	27.79	57
21	Clint D. Kelly	40	52	28.62	54
22	Dimitrios Katsaros	40	53	32.75	42
23	Egghe Leo	88	8	68.69	5
24	Elizabeth A. Corley	48	35	29.09	52
25	Erhard Rahm	45	41	30.98	46
26	Fiorenzo Franceschini	29	68	20.43	73
27	Fred Y. Ye	28	70	20.50	71
28	Gad Saad	34	64	25.56	62
29	Gangan Prathap	30	67	21.60	70
30	Gary M. Olson	5	89	5.00	89
31	Gerhard Woeginger	39	56	26.38	59
32	Guang-Hong Yang	79	12	41.37	23
33	Heidi Winklhofer	24	73	19.85	75
34	Hendrik P. van Dalen	34	65	24.16	67
35	Henk F. Moed	47	38	31.51	44
36	Herbert Van de Sompel	15	86	14.20	84
37	Hirsch J.E.	105	5	140.79	1
38	James Moody	48	36	31.10	45
39	Jayant Vaidya	52	26	42.25	21
40	Jerome Vanclay	58	23	44.69	15
41	Johan Bollen	57	24	42.13	22
42	John Irvine	108	4	49.43	11
43	Judit Bar-Ilan	52	27	37.21	30
44	Kène Henkens	49	32	28.71	53
45	Loet Leydesdorff	98	6	46.97	14
46	Lokman Meho	52	28	40.81	26
47	Luca Mastrogiacomo	22	77	17.26	82
48	Ludo Waltman	71	15	44.00	16
49	Lutz Bornmann	90	7	47.42	13
50	Maisano, Domenico A.	15	87	12.70	87
51	Marek Kosmulski	41	50	42.35	20
52	Maria Bordons	37	60	28.49	55
53	Mark Fine	20	82	17.89	80
54	Mark Newman	76	13	43.74	17
55	Mathieu Ouimet	40	54	25.01	66
56	Matjaž Perc	157	2	73.17	4
57	Matthew O. Jackson	69	16	41.33	25
58	Mauno Vihinen	84	10	58.17	7
59	Michael Jennions	75	14	59.89	6
60	Michael L. Nelson	10	88	10.00	88
61	Miguel A. García-Pérez	43	45	25.07	65
62	Morten Schmidt	38	57	34.08	39
63	Nees Jan van Eck	68	17	41.35	24
64	Nils T. Hagen	22	78	17.99	79
65	Olle Persson	19	83	18.39	78

Table 3: Comparison of h-index sequence with EM-index sequence continued....

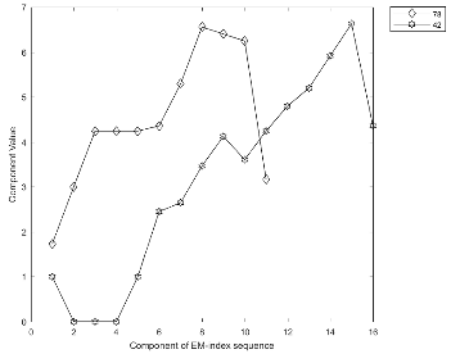
ID	Author	h-index Sequence	Rank	EM-index Sequence	Rank
66	Paul Wouters	29	69	25.96	60
67	Peter Jacso	49	33	30.36	49
68	Raf Guns	22	79	17.02	83
69	Raj Kumar Pan	40	55	27.83	56
70	Richard S. J. Tol	87	9	50.67	9
71	Roberto Todeschini	61	22	43.30	18
72	Robin Hankin	22	80	17.39	81
73	Rodrigo Costas	45	42	31.87	43
74	Ronald Rousseau	175	1	91.43	3
75	Ruediger mutz	52	29	34.46	37
76	Santo Fortunato	113	3	107.41	2
77	Serge Galam	36	61	34.26	38
78	Sergio Alonso	49	34	49.48	10
79	Steve Lawrence	23	75	20.16	74
80	Sune Lehmann	38	58	33.80	40
81	Terttu Luukkonen	17	85	13.49	86
82	Vicenç	41	51	47.50	12
83	Walter W (Woody) Powell	43	46	37.21	31
84	Werner Marx	43	47	27.58	58
85	Wolfgang Glänzel	57	25	38.37	28
86	Yannis Manolopoulos	47	39	33.06	41
87	Ying Ding	81	11	42.58	19
88	Yu-Hsin Liu	24	74	18.65	76
89	Yvonne Rogers	46	40	29.57	50

The comparative result of h-index sequence and EM-index sequence values shows that the excess citation of articles can increase the impact of scholars, improving their rank in the group. For example:

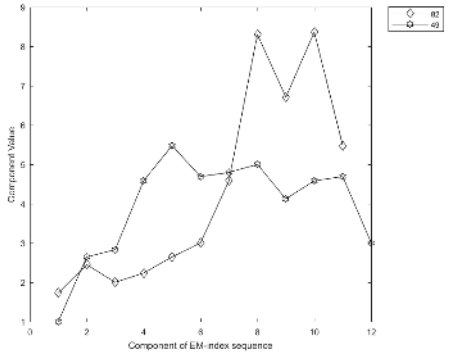
1. Author **Hirsch J.E.** (Author ID=37) is ranked 5 as per the corresponding h-index sequence value of 105. His rank improves to 1 when computed as per the corresponding EM-index sequence value of 140.79. This is because the h-index sequence did not account for 4122 excess citations that helped in improving the rank computed based on EM-index sequence.
2. On the other hand, Author **Ronald Rousseau** (Author ID=74) is ranked 1 as per the corresponding h-index sequence value of 175. His rank reduces to 3 when computed as per the corresponding EM-index sequence value of 91.43. This is because the excess citation count of Author **Ronald Rousseau**, which is 1774, does not match up to the very high h-index sequence value of 175, resulting in a little bit lowering of rank computed based on EM-index sequence.
3. As an extreme example, author **Marek Kosmulski** (Author ID=51) is ranked 50 based on h-index sequence value of 41, whereas his rank is 20 based on EM-index sequence value of 42.35. Here, a marginal difference in the two index values affects the corresponding ranks in a major way. Here, the author has 435 excess citations.

In general, the comparative analysis between scholars has been performed based on total index value. In this case, if two scholars get the same index value, then it is very difficult to discriminate the impact of scholars. Hence, instead of a single number, a set of numbers are more suited to compare the scientific impact of two scholars. Consider one such case: Figure 2 shows the EM-index sequence component analysis of scholars, where all have very similar EM-index sequence values. As shown in Figure 2(a), authors 78 and 42 have EM-index sequence values of 49.48 and 49.43 respectively; their career spans 12 and 18 years respectively. Even though both authors have similar EM-index sequence values, the scientific impact of author 78 is more than that of author 42 considering the latter's career so far, i.e., the first 12 years only. Figure 2(b) compares scholars 82 (EM-index sequence value: 47.50, career span: 13 years) and 49 (EM-index sequence value: 47.42, career span: 12 years). Here both authors have similar career spans, however, as evident from the plot, author 49 has a greater scientific impact during the first half of his career, i.e., the first seven

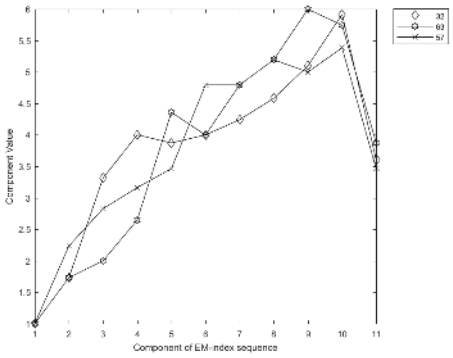
years, while scholar 82 has a greater scientific impact during the second half, i.e., the last four years. This is not evident by just looking at the EM-index sequence values of the two scholars. Figure 2(c) compares scholars 32 (EM-index sequence value: 41.37, career span: 12 years), 63 (EM-index sequence value: 41.35, career span: 12 years) and 57 (EM-index sequence value: 41.33, career span: 12 years). Here all scholars have similar career spans and their impacts are almost the same.



(a) The component analysis of EM-index sequence of Author ID- 78 & 42 with corresponding index value 49.48 & 49.43



(b) The component analysis of EM-index sequence of Author ID- 82 & 49 with corresponding index value 47.50 & 47.42



(c) The component analysis of EM-index sequence of Author ID- 32,63 & 57 with corresponding index value 41.37, 41.35 & 41.33

Fig. 2: The component analysis of EM-index sequence

From the above discussion, it is clear that the elements of EM-index sequence helps in comparing the scientific impacts of scholars having equal or very similar EM-index sequence values.

While EM-index sequence values are better than h-index sequence values with respect to the excess citations of h-core articles, both can be limited due to complete ignorance of the citations of h-tail articles. This is not good because some of the h-tail articles have citation count similar to the h-core articles. Such h-tail articles are obviously important, however, even the h-tail articles with lesser citations can be significant in assessing the impact of a scholar, and hence, should not be ignored. Motivated by this, reference García-Pérez (2009) proposed multidimensional h-index and Bihari and Tripathi (2017) proposed $EM^{'}$-index. Both the proposed indices consider all publications with non-zero citations. Next, we introduce $EM^{'}$-index sequence and discuss how it can be used (i) to better assess the scientific impact of a scholar, and (ii) to compare scholars with similar career spans or having equal number of publications.

5 $EM^{'}$-index sequence

Let the research career of a scholar span n years publishing k articles. Let y_1 be the first year of publications and y_c be the current year. The $EM^{'}$-index sequence element for the y^{th} year, denoted $EM_y^{'}$, is computed from the citation count in the y^{th} year using $EM^{'}$-index formula as given in Bihari and Tripathi (2017)). Then, the $EM^{'}$-index sequence is the sum of all such $EM^{'}$-index sequence elements. Formally, it is defined as:

$$EM^{'} - index\ Sequences = \sum_{y=1}^{c} EM_y^{'} \tag{2}$$

To demonstrate the effectiveness of $EM^{'}$-index sequence, consider the data of author **Andrew D. Jackson** from Table 1. The corresponding $EM^{'}$-index sequence values are shown in Table 4.

Table 4: Publication history and year wise impact of Author Andrew D. Jackson for $EM^{'}$-index sequence

Publication Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
2006	11	9	11	15	12	11	20	14	16	11	5
2007	4	6	9	8	5	10	13	8	4	2	0
2007	0	0	0	0	0	0	0	0	0	0	0
2008	0	1	10	4	4	5	7	6	4	5	1
2008	0	0	0	0	0	1	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	3	5	9	4	6	10	6	2
2009	0	0	0	0	0	2	0	1	0	0	0
2010	0	0	0	0	1	0	0	0	0	0	0
2011	0	0	0	0	1	3	3	4	2	1	0
2013	0	0	0	0	0	0	0	1	1	1	1
2013	0	0	0	0	0	0	0	0	1	0	0
2013	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	1	1	0
2015	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	1	0
2016	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0
$EM^{'}$	2.24	3.0	3.32	3.87	3.46	3.74	4.47	3.74	4	3.32	2.24

The elements of $EM^{'}$-index sequence are 2.24, 3.0, 3.32, 3.87, 3.46, 3.74, 4.47, 3.74, 4, 3.32 & 2.24 and the $EM^{'}-$index sequence value is 37.40, whereas the EM-index sequence value is 29.17. Looking at these values, one can clearly see that h-tail articles with at least one citation also have significance in assessing scientific impact of a scholar. Figure 3 shows the $EM^{'}$-index sequence values of all authors. Figure 4 compares $EM^{'}$-index sequence value, h-index sequence value and EM-index sequence value for all authors.

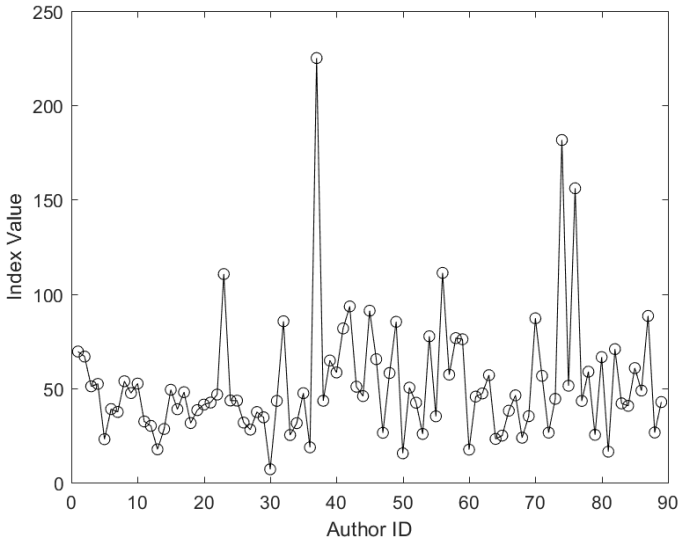


Fig. 3: The $EM^{'}$-index sequence of all Scholars

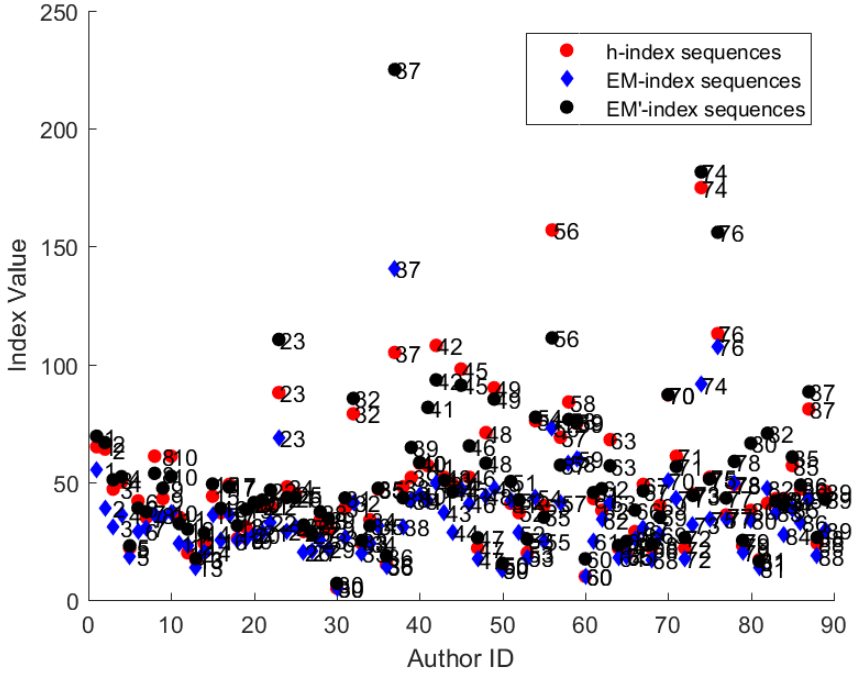


Fig. 4: Comparison of the h-index sequence, EM-index sequence and $EM^{'}$-index sequence of all Scholars

To demonstrate the impact of tail articles in the scientific assessment of scholars, we performed a component level analysis on top 4 authors based on $EM^{'}$-index sequence with reference of EM-index sequence as shown in Figure 5. Looking at Figure 5, it is clear that the $EM^{'}$-index sequence

gives better result than the EM-index sequence by appropriately capturing the impact of citation counts of tail articles. For example, consider Author ID-37 (see Figure 5(a)). The author's EM-index and $EM^{'}$ index sequence values are very much the same for the first 10 years – the same is corroborated by a very low number of citations of tail articles during these years. However, after the 10^{th} year, the citation count of tail articles increases significantly – making $EM^{'}$ sequence values significantly greater than EM-index sequence values.

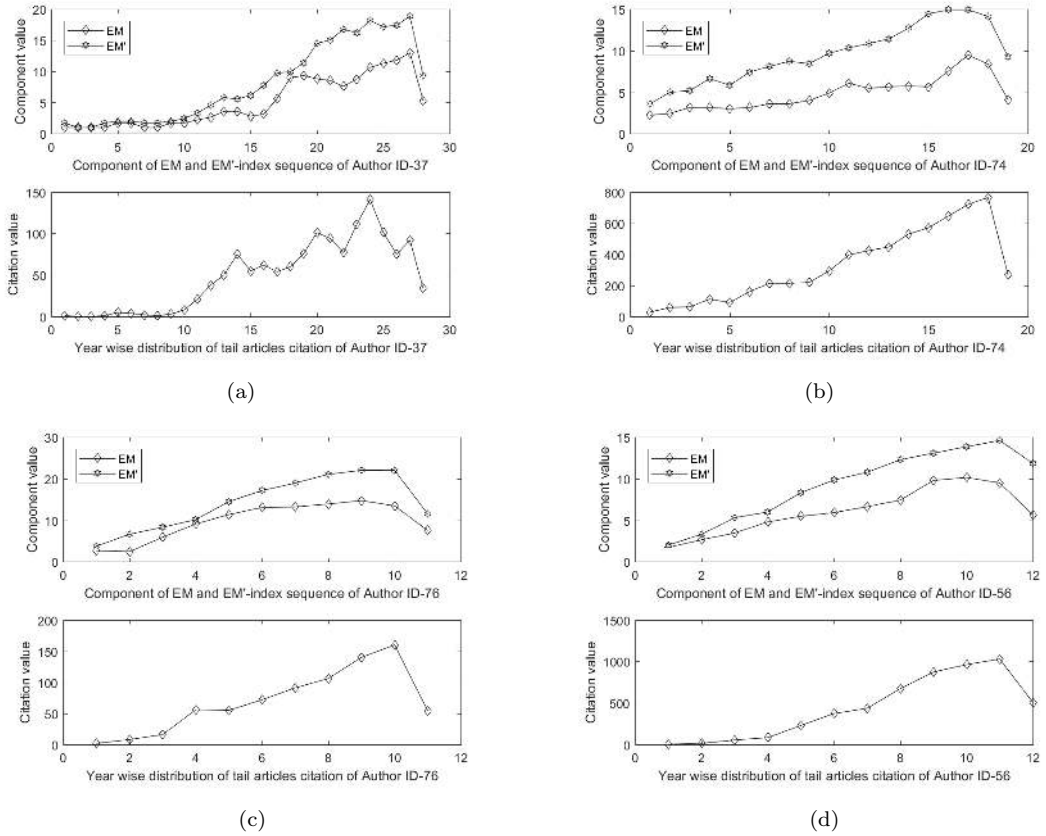


Fig. 5: Comparative result of EM-index sequences and $EM^{'}$-index sequence of top 4 authors with their tail articles citation distributions.

Another extreme analysis can be seen in Figure 6. In Figure 6, we performed a component level analysis of authors 78 and 42 with respect to EM and $EM^{'}$ sequences. As can be seen in Figure 6, authors 78 & 42 have similar EM-index sequence value, however the $EM^{'}$-index sequence values exhibit significant difference. These two component level analyses show the impact of tail articles in scientific assessment of scholars and could be used as an effective alternative.

Table 5 shows a rank-based comparison based on $EM^{'}$-index sequence value, h-index sequence value and EM-index sequence value. The comparative results show that the $EM^{'}$-index sequence gives better results than others and also one can clearly see that how the excess citation and tail articles citation count affect the scientific assessment of scholars. The result of the $EM^{'}$-index sequence shows the importance of tail publications' citation count. If we consider the impact of author id: 76, whose total citation count is 19841, h-core citation count: 12769, excess citation: 6312 and the h-tail citation is 760. The h-index sequence used only the h-core citation count and left a huge amount of citation count (7072), the EM-index sequence considers the h-core citation and excess citation count and left only few amount of citations (760), whereas the $EM^{'}$-index sequence considers overall citation count in scientific assessment. Finally, we can conclude that the excess citation of h-core and tail articles citations gives a fair contribution in scientific assessment of scholars.

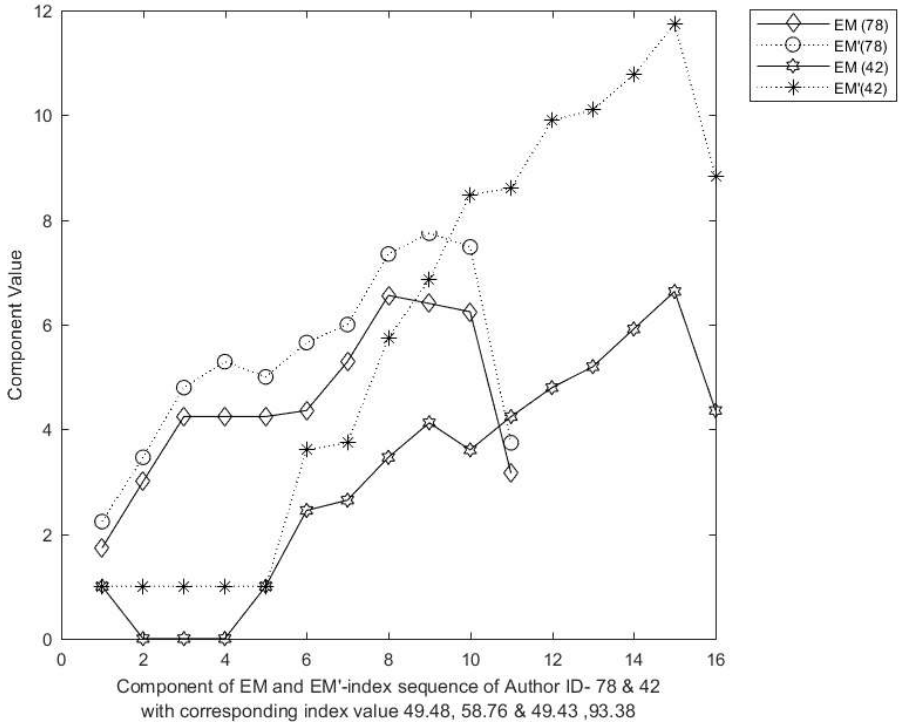


Fig. 6: Component level comparison of EM-index sequence and $EM^{'}$-index sequence of Author ID-78 & 42

To find the correlation between indices, the Spearman Rank Correlation test has been performed on h-index sequence value, EM-index sequence value and $EM^{'}$-index sequence value. Table 6 shows the result of correlation test between indices. The result shows that all the indices are highly correlated mutually. Hence, it can be said that the proposed EM and $EM^{'}$ index sequences are on the same path as the already established indicators.

6 Conclusion

The h-index sequence uses the series of h-index based on individual year citation count along with the career-span of research for scientific assessment of scholars. A set of indices values helps users to discriminate between the performance of scholars at a particular stage of their careers or their whole careers. However, the h-index sequence completely ignored the importance of excess citations. In this article, the EM-index sequence and $EM^{'}$-index sequence has been discussed. The EM-index and $EM^{'}$-index sequence values can provide a superior alternative – when compared to h-index sequence values – for assessing the scientific impact of scholars.

Acknowledgements The authors would like to acknowledge the help of Ministry of Electronics & Information Technology (MeitY),Government of India for supporting the financial assistance during research work through "Visvesvaraya PhD Scheme for Electronics & IT".

Table 5: Comparison of h-index, EM-index and $EM^{'}$-index sequence with corresponding rank

ID	h-index Sequence	Rank	Excess Citations	EM-index Sequence	Rank	Tail Citations	$EM^{'}$-index Sequence	Rank
1	65	18	897	55.24	8	606	69.47	17
2	64	19	401	39.06	27	1433	66.78	18
3	47	37	155	30.85	47	672	50.99	33
4	50	30	317	36.16	33	238	52.29	31
5	22	76	22	18.39	77	21	22.94	83
6	42	48	159	29.17	51	181	38.93	58
7	35	62	170	30.51	48	34	37.40	62
8	61	20	416	36.07	34	480	53.69	29
9	43	44	207	35.29	36	140	47.42	39
10	61	21	294	37.23	29	484	52.46	30
11	35	63	1	23.98	68	145	32.36	67
12	20	81	146	23.00	69	4	30.01	71
13	17	84	6	13.73	85	30	17.56	85
14	24	72	45	20.44	72	93	28.36	72
15	44	43	313	36.21	32	260	49.18	36
16	37	59	97	25.17	64	326	38.84	59
17	49	31	214	35.97	35	267	47.89	38
18	26	71	204	25.53	63	24	31.51	69
19	31	66	218	25.64	61	136	38.37	60
20	41	49	118	27.79	57	363	41.33	56
21	40	52	156	28.62	54	215	42.38	53
22	40	53	315	32.75	42	185	46.62	42

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Table 5: Comparison of h-index, EM-index and $EM^{'}$-index sequence with corresponding rank continued...

ID	**h-index Sequence**	**Rank**	**Excess Citations**	**EM-index Sequence**	**Rank**	**Tail Citations**	$EM^{'}$**-index Sequence**	**Rank**
23	88	8	962	68.69	5	1121	110.54	5
24	48	35	121	29.09	52	329	43.46	47
25	45	41	172	30.98	46	245	43.39	48
26	29	68	61	20.43	73	212	31.76	68
27	28	70	31	20.50	71	110	28.00	73
28	34	64	100	25.56	62	100	37.37	63
29	30	67	59	21.60	70	194	34.55	66
30	5	89	6	5.00	89	2	7.00	89
31	39	56	72	26.38	59	403	43.26	50
32	79	12	415	41.37	23	2694	85.50	10
33	24	73	41	19.85	75	37	25.16	79
34	34	65	67	24.16	67	133	31.46	70
35	47	38	274	31.51	44	275	47.37	40
36	15	86	11	14.20	84	13	18.63	84
37	105	5	4122	140.79	1	1342	225.12	1
38	48	36	205	31.10	45	235	43.33	49
39	52	26	564	42.25	21	201	64.69	21
40	58	23	442	44.69	15	393	58.34	24
41	57	24	943	42.13	22	155	81.70	12
42	108	4	584	49.43	11	2724	93.38	6
43	52	27	354	37.21	30	292	50.79	34
44	49	32	134	28.71	53	438	45.82	44
45	98	6	575	46.97	14	3037	91.10	7
46	52	28	535	40.81	26	114	65.38	20
47	22	77	49	17.26	82	127	26.34	76
48	71	15	591	44.00	16	699	58.04	25
49	90	7	508	47.42	13	2216	85.22	11
50	15	87	32	12.70	87	10	15.46	88
51	41	50	435	42.35	20	221	50.29	35
52	37	60	192	28.49	55	211	42.31	54
53	20	82	81	17.89	80	27	25.73	77
54	76	13	440	43.74	17	1491	77.54	13
55	40	54	98	25.01	66	177	35.08	65
56	157	2	1930	73.17	4	5242	111.18	4
57	69	16	466	41.33	25	586	57.22	26
58	84	10	947	58.17	7	1004	76.57	14
59	75	14	980	59.89	6	906	75.97	15
60	10	88	12	10.00	88	30	17.39	86
61	43	45	62	25.07	65	470	45.55	45
62	38	57	625	34.08	39	300	47.21	41
63	68	17	552	41.35	24	564	56.92	27
64	22	78	41	17.99	79	46	23.09	82
65	19	83	62	18.39	78	42	24.87	80
66	29	69	237	25.96	60	74	38.07	61
67	49	33	95	30.36	49	345	46.21	43
68	22	79	34	17.02	83	66	23.73	81
69	40	55	98	27.83	56	189	35.15	64
70	87	9	478	50.67	9	2152	87.09	9
71	61	22	633	43.30	18	343	56.56	28
72	22	80	53	17.39	81	38	26.44	75
73	45	42	226	31.87	43	250	44.36	46
74	175	1	1774	91.43	3	6215	181.65	2
75	52	29	340	34.46	37	316	51.30	32

Table 5: Comparison of h-index, EM-index and $EM^{'}$-index sequence with corresponding rank continued...

ID	**h-index Sequence**	**Rank**	**Excess Citations**	**EM-index Sequence**	**Rank**	**Tail Citations**	$EM^{'}$**-index Sequence**	**Rank**
76	113	3	6312	107.41	2	760	156.04	3
77	36	61	220	34.26	38	126	43.23	51
78	49	34	656	49.48	10	432	58.76	23
79	23	75	44	20.16	74	19	25.25	78
80	38	58	631	33.80	40	51	66.48	19
81	17	85	25	13.49	86	6	16.33	87
82	41	51	779	47.50	12	520	70.73	16
83	43	46	336	37.21	31	60	41.94	55
84	43	47	108	27.58	58	314	40.63	57
85	57	25	298	38.37	28	655	60.68	22
86	47	39	209	33.06	41	402	48.75	37
87	81	11	439	42.58	19	2819	88.33	8
88	24	74	29	18.65	76	70	26.50	74
89	46	40	94	29.57	50	237	42.65	52

Table 6: Result of Spearman rank correlation between h-index sequence, EM-index sequence and $EM^{'}$-index sequence

	h-index sequence	**EM-index sequence**	$EM^{'}$**-index sequence**
h-index sequence	1	0.93	0.94
EM-index sequence	0.93	1	0.96
$EM^{'}$-index sequence	0.94	0.96	1

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