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A Comparative Analysis of the Application of *H*-index, *G*-index, and *A*-index in Institutional-Level Research Evaluation

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Abstract

This study compared the application of *h*-index, *g*-index, and *A*-index in institutional level research evaluation. 99 universities in Taiwan were ranked by the three indices. Most of the universities had relatively low publication and citation numbers at the time of this study. The analysis focused on the range of equal values resulted from the three different indices, the range of disparity, the order or rank, and the degree of correlation among the indices. The results showed that g-index and h-index were similar in that the use of the two indices produced similar values and rankings. Both had the problem of equal value in which multiple universities got the same index value, making it difficult to differentiate the universities' performance. In contrast, *A*-index was able to rank the universities by emphasizing on the highly cited articles and at the same time avoided the problem of equal value. It was thus considered a better index for the institutional level research evaluation in Taiwan.

Keywords: *h*-index; *g*-index; *A*-index; Research Evaluation

1. Introduction

H-index proposed by Jorge Hirsch in 2005 defines that "A scientist has index *h* if *h* of his or her N_p papers have at least *h* citations each, and the other (N_p – *h*) papers have fewer than ≦ *h* citations each" (Hirsch, 2005, p. 16569). In other words, *h*-index is a single-number indicator for evaluating the scientific achievement of a given researcher. It ignores the long-tails of the publication (quantity) and citation (quality) distribution but focuses on where the numbers of papers and citations intersect, which signifies the "middle part" concept of the Zipf's Law (Vanclay, 2007). It assesses a scientist's performance based on the quantity and quality of his/her papers taken together.

H-index has many advantages. It integrates the evaluation of productivity (the number of a scientist's total publications) and impact (the impact of the papers on the scientist's peers) in a single indicator. Data is

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easily retrieved and processed for calculating *h*-index. It is rather insensitive to both the lowly and highly cited papers, which may distort the assessment of productivity and impact in the other approaches. It is also free from the influences of document types when counting the total publications and citations (Batista, Campiteli, Kinouchi, & Martinez, 2006; Bornmann & Daniel, 2007; Egghe, 2007a; Oppenheim, 2007; Roediger, 2006). However, it also has a number of disadvantages. For instance, it may not be an appropriate indicator for comparing performance across a main and its subfields. It might under weight achievement in co-authorship. Further, because it is an integer, many scientists may have the same *h*-index value and thus it does not differentiate their scientific achievement. It is not suitable to rank scientists of varying level of seniority. It is also not fair to take this single index as the only measurement to assess scientists' scientific performance. Using data directly from Web of Science alone might be another problem when calculating *h*-index (Batista et al., 2006; Bornmann & Daniel, 2007; Glänzel, 2006; Kelly & Jennions, 2006; Van Raan, 2006). Due to the disadvantages, modifications of the index such as *g*-index and *A*-index have been proposed by other scholars.

Egghe (2006a, 2006b, 2007b, 2008a, 2008c) has noted that, although it is an advantage for *h*-index to be insensitive to the "tail" papers (lowly cited papers), a good indicator should be sensitive to the impact of the outstanding highly cited papers. However, *h*-index failed in this respect. Consequently, Egghe modified the index by replacing the idea of calculating the number of citations received by each article with calculating the total accumulated citations of the top *g* articles. *G*-index therefore is defined as follows: a scientist has an index number g when his top g papers were cited at least g^2 times. As such, g-index is capable of highlighting papers that are highly cited, namely, papers with higher impact. A higher *g*-index means more and better papers (Tol, 2008).

Egghe pointed out that the *g*-index value will always be higher than the *h*-index value and lower than the total publication number. It compensates a shortcoming of *h*-index, which is insensitive to authors with few and lowly-cited (or non-cited) papers. The higher values of *g*-index make it easier to differentiate the performance of authors. Further, it gives more weight to one or several highly cited papers, thus highlighting the impact of authors. However, like *h*-index, *g*-index values are also integers and many authors may get the same *g*-index value, making it difficult to differentiate performance. It is thus not an appropriate indicator when evaluating a small group of authors.

Jin (2006) considered that *h*-index is powerful in recognizing the more impactful scientists, but is relatively unable to differentiate the performance of the average scientists. She therefore proposed a new index which was later called as *A*-index by Rousseau (2006) and other scholars. *A*-index first calculate the citation number of the top h papers is calculated by the average number of citations of the publications in the Hirsch core (Schreiber, 2008a).

Using *A*-index avoids the problem of equal values because its value doesn't have to be an integer. In addition, the *A* score is usually higher than the *g* score; it is even much higher than the *h* score. Accordingly, *A*-index seems more capable of distinguishing the performance of a group of scientists or institutions.

Numerous experiments have been conducted on these three indices (Egghe, 2008b; Jin, Liang, Rousseau, & Egghe, 2007; Schreiber, 2008a, 2008b). Most of the research has evaluated the three indices by comparing their weights (Jin et al., 2007; Schreiber, 2008a, 2008b), rankings (Bornmann, Marx, & Schier, 2009), ratios (Jin et al., 2007; Schreiber, 2008b), and the Spearman's rank-order correlation coefficient (Bornmann et al., 2009; Schreiber, 2008a) and Pearson's correlation coefficients (Schreiber, 2008a) of results based on the indices. This study examines the range of equal value, the range of disparity, the order of ranks resulted from the use of the three indices, and the degree of correlation among the indices.

This study uses 100 Taiwan universities as a sample to observe their scores and rankings as a result of the use of the three different indices, in assessing the performance of the institutions, this study examines the long-term accumulation of research papers rather than looking only at short-term output because very few universities in Taiwan had a *h*-index value over 20 at the time of this study, which means that few universities had larger numbers of papers and citations at the same time. Consequently, the *h*-index values of the universities showed a highly skewed distribution below the value of 20; the average *h*-index value was 19.86 with 64 universities had *h*-index value below 20. Given the situation, this study sought to answer which of the three indices was a better index for evaluating Taiwan's universities.

2. Methodology

This bibliometric study used data set retrieved in January, 2008, from the Web of Science database (WOS). The data covered the papers and citations of 100 universities in Taiwan for the period of 1998 to 2007 (i.e., 10 years). The total number of papers was 122,437, which were cited 582,926 times by the publications indexed in WOS. It should be noted that one of the 100 universities did

not have any paper listed in WOS within this time window; therefore, only 99 universities were examined for their *h*-index, *g*-index and *A*-index performances. Ranks resulted from the use of the three different indices were statistically analyzed with the Spearman's rank-order correlation coefficients to examine the correlations of the rankings. The analyses shed lights on the applicability and constraints of the indices in the evaluation of Taiwan's universities.

3. Results

3.1. Range of Equal Value

For the distribution of *h*-index, only 18 of the 99 universities did not have the problem of equal value. Besides, most of the universities had *h*-index value below 20; only 18 had value above 20. Table 1 shows that 80 universities had the same *h*-index, and 9 universities had the *h*-index value of 7. Similar situations occurred with *g*-index because *g*-index values are also integers. 68 universities, which accounted for a rather high percentage of the pool, had the same *g*-index value. Further, 6 universities had the same *g*-index value of 22. In contrast, none of the 99 universities had exactly the same *A*-index value. This is reasonable because chances were very low for two universities to have exactly the same number of citations for *h* articles.

3.2. Range of Disparity

For all of the universities, the *g*-index and *A*-index values were greater than *h*-index values; meanwhile, the *A*-index values were also all greater than the *g*-index values. As Table 2 shows, the highest *A*-index value observed was 150.46, much greater than the 129 of the *g*-index and 89 of the *h*-index. In addition, when observing the mean, median and standard deviation of the three indices, *A*-index had a greater difference between the mean and median, which suggests that *A*-index had the highest extreme value. Compared to *A*-index, the distribution of the *h*-index values appeared more even. In short, *A*-index generated the highest value, while *h*-index resulted in the lowest. The *h*-index values were relatively

Table 1. Equal values for h-index, g-index and A-index

	No. of Universities with Equal Value	*The Most Frequently Repeated Value*	*No. of Universities with the Most Frequently Repeated Value*
***h*-index**	80	7	9
***g*-index**	68	22	6
***A*-index**	0	0	0

much lower than those of the two other indices.

Table 3 shows the value differences among the three indices. The value differences between *A*-index and *h*-index were the greatest (max difference: 72.27, mean difference: 14.06, median difference: 10, and the standard deviation: 13). A contrasting result is the smaller value differences between *g*-index and *h*-index (mean difference: 8.38, median difference: 6, and the standard deviation: 7.77). The ratio of the differences between *A* and *h* to the *h*-index was 76.64%. As one can see in the table, it was very different from the ratio of the differences between *g* and *h* (41.77%) and the ratio of the differences between *A* and *g* (34.87%). On the other hand, were the *h*-index value smaller, the differences between *A*-index and *g*-index would have become smaller accordingly. Besides, the mean difference (5.68) and the standard deviation (5.45) for the *A*-*g* pair were the closest index values among the three pairs. In addition, there were 16 universities with the differences between *A*-index and *g*-index values more than 10, 23 universities with the differences between *g*-index and *h*-index values more than 10, and 49 universities with the differences between *A*-index and *h*-index values more than 10, indicating that *A*-index value departed very strongly from *h*-index and *A*-index versus the *g*-index value was quite similar as presented in Table 3.

Table 2. Distribution of *h*-index, *g*-index and *A*-index

	Max	***Min***	***M***	***Mdn***	***Sd***
***h*-index**	89	0	19.86	16	15.52
***g*-index**	129	0	28.24	22	22.95
***A*-index**	150.46	0	33.92	26.33	27.65

*(maximum (max), minimum (min), mean (m), median (mdn) and standard deviation (sd), of three indices are calculated.)

Table 3. Value differences among *h*-index, *g*-index and *A*-index

	Max Difference	Min Difference	M Difference	Mdn Difference	Sd Difference	The average ratio of the differences between two indices to *h*-index	No. of universities with different values more than 10
Difference between *g* and *h* indices	41	0	8.38	6	7.77	41.77%	23
Difference between *A* and *h* indices	72.27	0	14.06	10	13.00	76.64%	49
Difference between *A* and *g* indices	31.27	0	5.68	4.21	5.45	34.87%	16

3.3. Order of Rank

Table 4 lists the ranks of the top 10 universities with the highest *h*-index values and their ranks by *g* and *A* indices. One can see that the ranks of these universities by the three indices were actually similar; it was particularly true with the top 6 universities.

A closer examination of the rankings of the universities with the same *h*-index values reaffirmed the close relations between *h*-, *g*-, and *A*-indices. Most of the universities with the same *h*-index values got identical ranks in *g*- and *A*-index. The only exceptions were schools whose *h*-index values were 7 (9 universities), 8 (6 universities), and 18 (7 universities); however, their *g*- and *A*-index ranks were still similar. It was also found that *A*-index was capable of differentiating the performance of different universities when they got the same *h*- and *g*-index values.

As mentioned previously, a major problem of *h*-index is that it often generates the same value for a number of universities. This study shows that *g*-index and *A*-index can supplement *h*-index in differentiating those universities with the same *h*-index value. *G*-index and *A*-index produced rankings that were nearly the same. The *g*-index and *A*-index rankings were different from each other only in three instances: when the *h*-index value was 18, 7 universities' rank positions varied in the *g*-index and *A*-index rankings; when the *h*-index value was 8, 6 universities' rank positions differed in the other two rankings; and when the *h*-index

Table 4. Rank of the top 10 highest *h*-index universities in the three indices

Universities	Rank of *h*-index	Rank of *g*-index	Rank of *A*-index
National Taiwan University	1	1	1
National Yang Ming University	2	3	3
National Cheng Kung University	3	2	2
National Tsing Hwa University	4	5	5
National Central University	5	6	6
Chang Gung University	6	4	4
National Chiao Tung University	7	7	9
National Chung Hsing University	8	12	15
Kaohsiung Medical University	9	8	10
Taipei Medical University	9	10	11

was 7, 9 universities had rank position changes. The findings confirmed that both *g*-index and *A*-index were derivatives from *h*-index. Further, since *g*-index had the same problem with that of *h*-index in generate equal values for a group of universities, *A*-index seems a relatively better tool for distinguishing the university performance, given the high similarity of the rankings as revealed in this study.

3.4. Degree of Correlation

Table 6 shows the Spearman's rank-order correlation coefficients among the three indices. The ranking of the *g*-index is similar to those of the *h*-index and *A*-index; nevertheless, the correlation between *A*-index and *h*-index is lower than the correlation between *A*-index and *g*-index as well as the correlation between *h*-index and *g*-index. The correlations among the three indices were quite high because they are all derived from the same idea which combines the measuring of qualitative and quantitative performance in a single indicator. Besides, *g*-index is a variant of *h*-index which calculates the value by taking square root of papers and total cited times; naturally, the correlation between *g*-index and *h*-index was expected to be high. The correlation between *A*-index and *h*-index is slightly lower; this is also an expected result since *A*-index differs from the other two indices in that it uniquely

Table 5. Rank position changes in *g* and *A* indices in comparison to *h*-index

	No. of universities with the same rank position as that of the h-index ranking	*No. of universities with higher rank position than that of the h-index ranking*	*No. of universities with lower rank position than that of the h-index ranking*	*No. of universities with position change more than 5 places (compared to the h-index ranking)*	*No. of universities with position change more than 10 places (compared to the h-index ranking)*	***Maximum*** rank position change ***(compared to the h-index ranking)***
***g*-index**	15	35	50	17	3	17
***A*-index**	9	35	56	37	15	34

Table 6. Spearman's correlation coefficients of the rankings of the three indices

	Rank-order of h-index	***Rank-order of g-index***	***Rank-order of A-index***
Rank-order of *h*-index	--		
Rank-order of *g*-index	.990**	--	
Rank-order of *A*-index	.964**	.989**	--

** Results were considered statistically significant when correlation values reached the significant level of 0.01 (two tails).

emphasizes papers with better performance.

4. Discussion & Conclusion

Because the numbers of papers and citations were lower for those universities examined in this study, the *h*-index values for most of these universities were highly similar. The distribution of the *h*-index values was skewed toward universities with values below 20, and the average *h*-index value for the universities was 19.86 (64 universities had *h*-index values below 20.). Both *g*-index and *A*-index were capable of distinguishing the performance of the universities that got the same *h*-index value, while *A*-index in particular was particularly useful because it hardly generated the same value for two or more universities.

When the indices were applied to Taiwan' s universities, the results of this study show that *g*-index and *h*-index produced similar index values and rankings because the indicators were of the nearly identical design concept. Therefore, even *g*-index has a wider range of values which might be helpful in differentiating performance, it still causes the same problem of giving the same index value to different universities. For instance, in this study, 68 of the 99 universities had encountered the same-value problem.

A-index solved the problem in this study. Each university in this study obtained a unique *A*-index value, which overcame the same-value problem from the use of *h* and *g* indices. This is caused by the emphasis of *A*-index on the highly cited papers. If a university had more highly cited articles, then its *A*-index value would have been higher. This emphasis distinctly differentiated the *A*-index from the other two indices.

In summary, given the very high correlation among the three indices as well as the persistent same-value problem in h and g indices, *A*-index appeared to be the most appropriate index for the evaluation of Taiwan's universities, which represent an evaluation context where the subjects' numbers of papers and citations were not hugely different. The more refined *A*-index may successfully overcome the same-value problem potentially caused by *h*-index and *g*-index.

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