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Studies on Utilizing the Three Famous International Index Systems to Evaluate Scientific Research Level of Higher Learning Institutions

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Abstract: Science Citation Index (SCI), The Engineering Index (EI) and Index to Scientific & Technical Proceeding (ISTP) are widely accepted and used to evaluate the scientific research level of higher learning institutions by many country's science and technology field currently. After research, we point out the blemishes in this method and put forward the problems that need to be noticed, and then, under current conditions, bring forward brand-new standard and method to estimate research level, efficiency, fund exploitation and so on. One shouldn't over-emphasize the total amount of papers collected in SCI EI & ISTP when evaluating the scientific research level of higher learning institutions, whereas using 'comprehensive factor' analysis method can make it more scientific and efficient.

Key Words: SCI, EI, ISTP, Citation Index, Combinative Factor

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1. Brief introduction of SCI, EI and ISTP

With the reform of the research system successively deepened in the world, the question how to evaluate the research result causes more and more extensive concerns of the society. Currently, scientific field has gradually accepted the data-evaluating method of citation analysis provided by Science Citation Index (SCI) The Engineering Index (EI) and Index to Scientific & Technical Proceeding (ISTP). This is an objective, fair & quantitative evaluation method, and is also a general-accepted international method. When evaluating the research level of universities, one usually takes the total number of papers collected by SCI, EI and ISTP as the standard. Every year, some organizations would rank the universities and research institutions according to the total collected amount. Through studies, we think that this method lacks strict theoretical basis, is not scientific & rational enough and has already resulted in some mistakes in the attitude of many universities toward SCI, EI and ISTP. Therefore, we hold the view that we should appropriately make use of the three famous index systems to reasonably evaluate the research level of universities with objective attitudes.

SCI, edited and published by Institute for Scientific Information (ISI) in America, is a kind of Search Publication that reflects the relationship of scientific & technological literature and citation, and is also a tool to evaluate scientific & technological publications and papers with the method of metrology. SCI covers extensive fields, including mathematics, physics, chemistry, engineering, agriculture, forestry, medicine and so on, while life sciences, medicine, chemistry and physics possess the biggest proportion.

EI, the earliest article abstracts of engineering technique in the world, which started publication in October 1884, is edited and published by the Engineering Incorporation now. As one of the three famous indexical systems, EI is a large-scale indexical system mainly embodying engineering technique periodicals and conference literature. Now it has become the world-class authoritative indexical system and general-accepted international statistic source.

ISTP is a proceeding index database published by ISI, mainly including important literature of various conferences around the world. The ISTP covers many fields including life sciences, clinical medical, physics, chemistry, engineering technique, applied sciences, biology, environmental and energy science etc. Annually, the ISTP reports 4000 varieties of meetings and collects more than 200

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thousand papers.

2. Problems of using the SCI etc. to evaluate the research efficiency of higher learning institutions

Currently, science & technology field and higher learning institutions of many counties pay great attentions to the papers collected by SCI, EI and ISTP. After researches, one can notice that, under the situation that the developments of periodicals are fast and their quantities are also improved continuously, there are some mistakes existing in the understanding of science & technology field and library & information field of many counties for SCI, EI & ISTP.

The statistics of quoted articles offered by SCI, EI & ISTP is very reliable and scientific to serve as the basis of estimating academic achievements. It provides firm basis for evaluating the science & technology level of scientific research organizations. But it should be noticed that there are still some disadvantages in SCI, EI & ISTP. The conception of quoted articles in SCI, EI and ISTP is based on the assumption that the authors have absorbed and used the references. However, the complexity and variability of motivation in quoting references make the assumption less rigorous. Therefore, there exist some uncertain reasons in estimating system of SCI EI, and ISTP which are completely founded on quoting analysis.

As well, it is inevitable that there are some problems in using SCI, EI and ISTP to estimate the scientific research level of scientific research organization and universities. On one hand, this method inspires many universities to make better researches and, as a result, the level of science & technology has been increased. It makes a firm foundation for universities' modernization and internationalization. At the same time, it has aroused great impacts in the society that universities are graded according to the total number of articles embodied by SCI, EI & ISTP. However, researches have already proved that although it has some rationality in level grading of universities in this method and has been checked by several years' practice, it still has some disadvantages.

Higher learning institutions can be classified in different levels, including key universities, ordinary universities, research institutions and a large number of technical colleges. Therefore, employing diverse methods based on their actual situations is an advisable way. Only in this way can one see the development situation of a university and its developmental potential objectively and scientifically, which is indispensible for anyone to set appropriate destination for further investments or adjustments. Therefore, we believe the fact that it is not comprehensive, scientific or objective to take the total number of papers embodied by SCI, EI & ISTP as the only standard to evaluate higher learning institutions.

Take China as an example. From the statistics released by SCI, EI & ISTP, the top ten colleges and universities of China do not change greatly. Many colleges and universities have shown their strong scientific research capability, but the situation of personnel allocation and capital usage should also be noticed. In other words, these institutions must consider the ratio of input to output, that is, whether the valuable resources are adequately and efficiently utilized or not is more worthy to be concerned. Based on this consideration, we have introduced a brand-new evaluation standard, which is more scientific and effective for institutions of higher learning to evaluate their scientific & technological level.

3. Evaluation on efficiency of university by Comprehensive Factor

3.1 Amounts of embodied articles in 2002

The top-ten universities in China according to the amounts of articles embodied by SCI, EI and ISTP are shown in the following tables.

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Table1. Top ten colleges according to the amount of articles embodied by SCI

Universities	Amount of embodied articles in 2002	
	Amount	Position
Tsinghua University	1899	1
Peking University	1333	2
Zhejiang University	1114	3
Nanjing University	1020	4
University of Science & Technology of China	903	5
Fudan University	773	6
Shanghai Jiao Tong University	744	7
Shandong University	742	8
Jilin University	575	9
Nankai University	486	10

Table2. Top ten colleges according to the amount of articles embodied by EI

Universities	Amount of embodied articles in 2002	
	Amount	Position
Tsinghua University	1899	1
Shanghai Jiao Tong University	1333	2
Zhejiang University	1114	3
Harbin Institute of Technology	1020	4
Xi'an Jiao Tong University	903	5
Northeastern University	773	6
University of Science & Technology of China	744	7
Huazhong University of Science & Technology	742	8
Shandong University	575	9
Tianjin University	486	10

Table3. Top ten colleges according to the amount of embodied articles by ISTP

Universities	Amount of embodied articles in 2002	
	Amount	Position
Tsinghua University	1899	1
Shanghai Jiao Tong University	1333	2
Zhejiang University	1114	3
Harbin Institute of Technology	1020	4
Huazhong University of Science & Technology	903	5
Tianjin University	773	6
Xi'an Jiao Tong University	744	7
Peking University	742	8
Southeast University	575	9
Beijing University of Aeronautics & Astronautics	486	10

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3.2 The “Comprehensive Factor” analysis method

As shown from table 1 to table 3, many famous universities in china appear in the three tables and some universities have excellent records in all the three tables. In these tables, the only criterion of ranking is the total number of embodied articles of the universities, which reflects the emphasis on the total output value in current method. However, we think that a more effective ways should be employed, and then, put forward the “Comprehensive Factor” analysis method.

Essentially, the conception of “productive efficiency” is highlighted in the “Comprehensive Factor” analysis method. In fact, the importance of “productive efficiency” has long been accepted by people and “productive efficiency” has served as an evaluating standard in various fields in modern society. Thus, it is quite reasonable to adopt this conception in evaluating the scientific research level of institutions for higher learning. In short, productive efficiency is the ratio of output to input, i.e. the researched achievements obtained under the same conditions of human and money investment during the same period. Using this standard, after comparing the research efficiency between higher learning institutions, we can rate their scientific & technological research levels objectively.

Based on the basic idea above, there are two factors contributing most to scientific research in institutions of higher learning: human and money investments, which mean researchers & graduates and researching funds, respectively. As is known to all, teachers and graduates are the main forces of research in universities, and the researching fund is the necessary guarantee for engaging in scientific research, neither of which is dispensable. Therefore, we select the unit factors from the two above-mentioned aspects.

Through researches, we measure the scientific research efficiency of higher learning institutions from five aspects, including research payout, total of teachers & researchers, total of non-teachers & non-researchers, total of masters and total of doctors. In the five aspects, the research payout reflects the money investment; the total of teachers & researchers, masters and doctors represent the

human investment while the total of non-teachers & non-researchers can serve as a reference for organizing efficiency. As a result, various comparisons can be carried out through these aspects.

Up to now, based on the amount of collected papers and the data about the five aspects above of higher learning institutions in that year, we can obtain the five unit factors as following: $_{am}$ means the number of embodied articles (piece) per research payout (ten thousand Yuan), $_{at}$ means the number of embodied articles (piece) per teacher & researcher (person), $_{aw}$ means the number of embodied articles (piece) per non-teacher & non-researcher (person), $_{ag}$ means the number of embodied articles (piece) per master (person), $_{ad}$ means the number of embodied articles (piece) per doctor (person).

From the five unit factors, we can obtain the Comprehensive Factor $_{s}$ by multiplying them, because their contributions to the result are parallel. Otherwise, if we take the algebraic average of the five factors, the effects of various aspects contributing to the result cannot be objectively reflected, for some aspects might be excessively emphasized or ignored. Then the efficiency of a higher learning institution can be comprehensively measured by the values of $_{s}$: the greater the value is, the higher the rank of efficiency should be.

As a necessary supplement to the comprehensive factor, the efficiency of human resource utilization, i.e. the researching ability, and that of money utilization should also be considered as ranking standards respectively. On one hand, it is necessary to rank higher learning institutions by their researching abilities, for the teachers, researchers and postgraduates are the main body of researching in higher learning institutions. Therefore, on the basis of Comprehensive Factor, we put forward the factor $_{ac}$, referring to the number of embodied thesis (piece) per person who has the ability to research (person), including the teachers, researchers and graduates (Though some excellent undergraduate students may also contribute to indexed papers, but their number is so smaller than that of the others that can be ignored). The greater $_{ac}$ is, the higher the rank should be, which represents its greater strengths in studying. On the other hand, the higher learning institutions should as well be ranked by $_{am}$ to measure the exploitation efficiencies of research funds which are the necessary guarantee for engaging in scientific research.

These factors are the primary ingredients responsible for research level and total number of collected papers of any higher learning institutions. Taking advantages of them, we can not only realize universities' situations, but also find the problems in each aspect through analyzing relative unit factors. Concretely, one can rank and compare institutions according to each of the five unit factors. For example, the factor $_{aw}$ & $_{at}$ can reveal that whether the assigning proportion of personnel, consisting of researchers and non-researchers, is appropriate or not, and can serve as a firm evidence to adjust personnel assignment of higher learning institutions to further optimize the structure of institutions.

3.3 Evaluate the research efficiency of higher learning institutions by "Comprehensive Factor" analysis method

Based on the thoughts and methods of the previous section, we are going to rearrange the research level of high learning institutions with the help of the data in 2002. First, we list the information of those universities in the above five aspects in table 4 below.

Table4. Basal circumstances of parts of the above universities

Name of universities	Outlay of research funds (ten thousand Yuan)	Total of teachers and researchers (person)	Total of non-teachers and non-researchers (person)	Total of masters (person)	Total of doctors (person)
Peking University	22146.5	3506	12567	5633	2417
Fudan University	25197	2064	3893	7016	3132
Zhejiang University	60198	4174	1423	11207	5525
Tsinghua University	73433	3582	4245	7921	4214
University of Science and Technology of China	19353.1	2737	930	3016	2120
Tongji University	50111.9	3302	5218	8151	2696
Sichuan University	25999	5085	5950	10392	2740
Nanjing University	11305.6	2020	2356	6420	3030

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Jilin University	31786.3	9797	6404	10614	3316
Harbin Institute of Technology	52519.7	4604	2551	7328	2880
Xi'an Jiaotong University	30370.9	2639	2702	7412	3302
Beijing University of Aeronautics & Astronautics	39770.9	2153	847	3107	1496
Huazhong University of Science & Technology	32886.8	4385	8615	9062	3735
Tianjin University	29478.5	3094	1375	6672	1941
Sun Yat-sen University	17024.4	2066	9934	8000	3000
China South University	39569.6	2988	6446	7636	2819

Secondly, from the information in table 1 to table 3, we can obtain the five unit factors ($_{am}$, $_{at}$, $_{aw}$, $_{ag}$ & $_{ad}$), $_{ac}$ and the "Comprehensive Factor" $_{s}$. Then, the universities are ranked according to the Comprehensive Factor with the results shown from table5 to table7. If the information of some universities is incomplete, we abandon it and do not take it into consideration, but this process obviously will not affect the results of analysis.

Table5.Sequencing Results of universities by Comprehensive Factor (Articles embodied by SCI)

Name of universities	Position	$_{am}$	$_{am}$ place	$_{at}$	$_{aw}$	$_{ag}$	$_{ad}$	$_{ac}$	$_{ac}$ place	$_{s}$	$_{s}$ place
Tsinghua University	1	0.0259	***5***	0.5302	0.4473	0.2397	0.4506	0.1208	***1***	0.000663	**3**
Peking University	2	0.0602	***2***	0.3802	0.1061	0.2366	0.5515	0.1154	***2***	0.000317	**4**
Zhejiang University	3	0.0185	***6***	0.2669	0.7829	0.0994	0.2016	0.0533	***6***	0.000077	**5**
Nanjing University	4	0.0902	***1***	0.5050	0.4329	0.1589	0.3366	0.0889	***4***	0.001055	**2**
University of Science & Technology of China	5	0.0467	***3***	0.3299	0.9710	0.2994	0.4259	0.1147	***3***	0.001906	**1**
Fudan University	6	0.0307	***4***	0.3745	0.1986	0.1102	0.2468	0.0633	***5***	0.000062	**6**
Jilin University	9	0.0181	***7***	0.0587	0.0898	0.0542	0.1734	0.0242	***7***	0.000001	**7**

Table6.Sequencing Results of universities by Comprehensive Factor (Articles embodied by EI)

Name of universities	Position	$_{am}$	$_{am}$ place	$_{at}$	$_{aw}$	$_{ag}$	$_{ad}$	$_{ac}$	$_{ac}$ place	$_{s}$	$_{s}$ place
Tsinghua University	1	0.0285	***1***	0.5846	0.4933	0.2644	0.4969	0.1332	***1***	0.0010802	**1**
Zhejiang University	3	0.0125	***5***	0.1802	0.5285	0.0671	0.1361	0.0360	***5***	0.0000109	**5**
Harbin Institute of Technology	4	0.0132	***4***	0.1507	0.2721	0.0947	0.2410	0.0469	***4***	0.0000124	**4**
Xi'an Jiaotong University	5	0.0218	***2***	0.2509	0.2450	0.0893	0.2005	0.0496	***2***	0.0000240	**3**
University of Science & Technology of China	7	0.0197	***3***	0.1396	0.4108	0.1267	0.1802	0.0485	***3***	0.0000258	**2**
Huazhong University of Science & Technology	8	0.0116	***7***	0.0869	0.0442	0.0420	0.1020	0.0222	***7***	0.0000002	**7**
Tianjin University	10	0.0124	***6***	0.1180	0.2655	0.0547	0.1880	0.0312	***6***	0.0000040	**6**

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Table7.Sequencing Results of universities by Comprehensive Factor (Articles embodied by ISTP)

Name of universities	Position	$_{am}$	$_{am}$ place	$_{at}$	$_{aw}$	$_{ag}$	$_{ad}$	$_{ac}$	$_{ac}$ place	$_{s}$	$_{s}$ place
Tsinghua University	1	0.0156	***1***	0.3194	0.2695	0.1444	0.2715	0.0728	***1***	0.00005257	**1**
Zhejiang University	3	0.0072	***6***	0.1033	0.3029	0.0385	0.0780	0.0206	***5***	0.00000067	**5**
Harbin Institute of Technology	4	0.0068	***7***	0.0780	0.1407	0.0490	0.1247	0.0242	***3***	0.00000046	**4**
Huazhong University of Science & Technology	5	0.0103	***2***	0.0771	0.0392	0.0373	0.0905	0.0197	***7***	0.00000010	**7**
Tianjin University	6	0.0096	***3***	0.0911	0.2051	0.0423	0.1453	0.0241	***4***	0.00000110	**3**
Xi'an Jiaotong University	7	0.0090	***4***	0.1031	0.1007	0.0367	0.0824	0.0204	***6***	0.00000028	**6**
Peking University	8	0.0084	***5***	0.0531	0.0148	0.0330	0.0770	0.0161	***8***	0.00000002	**8**
Beijing University of Aeronautics & Astronautics	10	0.0043	***8***	0.0794	0.2019	0.0550	0.1143	0.0253	***2***	0.00000043	**2**

4. Discussion on "Comprehensive factor" analysis method

From the analytic results above, there are great differences between the result of this method and the former evaluation system. After computation, some universities, with a small Comprehensive factor, have a lower position than before, while some universities, with a large Comprehensive factor, change oppositely..

Take the University of Science & Technology of China as an example. The numbers of articles embodied by SCI & EI in 2002 are respectively 903 & 744 which respectively rank five and seven in the result of the conventional method. After the analysis by our method, $_{am}$ & $_{ac}$ of articles embodied by SCI are 0.0467 & 0.1147, respectively, and $_{s}$ is 0.001906 which ranks the first. $_{am}$ & $_{ac}$ of articles embodied by EI are 0.0197 & 0.0485, respectively, and $_{s}$ is 0.0000258 which is on the second position.

The differences of the two evaluation systems are majorly caused by the dissimilarities of the calculation principles of the two systems. On one hand, using the Comprehensive Factor analysis method, we can evaluate the research level of a university more objectively & scientifically, and further compare the efficiencies of different universities. On the other hand, the differences can also arouse some deeper discussions.

4.1 Difference analysis

It is valuable for us to think over the difference between evaluated results of the two systems, and the reason of these differences includes the following aspects.

4.1.1 Abrupt increase of personnel number caused by the combination of universities

In last few years, many universities adopted the consolidation strategy to enhance their strengths, to improve the construction of subjects, and to amplify the influence of their universities; some universities have merged some other colleges of different types, such as medical or art colleges, while others have merged some local colleges such as technical colleges or private colleges. These actions have led to the fact that the number of students & teachers are increased abruptly and greatly. Even though the merger of universities indeed promotes the reform and development of universities to a certain extent, some problems coming with it cannot be neglected. Through analyzing the Comprehensive factor, one can know that although the resources can be integrated and better utilized through combination of universities, the number of students and teachers increases so abruptly that the Comprehensive factor becomes smaller due to the abrupt increase of the denominator's value in calculation. Therefore, enlarging the size of a university blindly will not necessarily improve the research abilities which cannot be enhanced by mechanically increasing the number of personnel without regarding the average quality.

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4.1.2 Lower money exploitation efficiency caused by excessive funds concentration

Some prestigious universities, with a long history and many first-class teachers, attract great amounts of funds which provide strong support to their own research, but some objective reasons leading to the fact that these funds may not be fully utilized should not be ignored.

From table 5 to table 7, the ranking results have clearly shown that some universities have great payout of research funds, i.e. they have spent much money in researching activities, but the values of $_{am}$ are small, and their ranks are low. This reflects that these funds invested on these universities cannot be adequately take advantage of by the researchers and the rates of funds utilization are not high enough. So, a financial waste will inevitably happen. On the contrary, for some less prestigious universities, the lack of funds will hinder their due developments. From the above tables, it can be found that some universities have less money than those prestigious ones, but their $_{am}$ are far larger, ranking in higher positions, which manifestly indicates the full exploitation of the funds.

As an obvious solution to the problems above, before making their investing budget, the governmental or private investors should evaluate the funds exploitation efficiency $_{am}$ of the target institutions in the last few years. For the institutions with lower or declining efficiency $_{am}$, the investment should be designedly decreased so that it can be diverted to the institutions with higher or increasing efficiency $_{am}$ to provide forceful guarantee for further research and to excite its research potential.

4.2 Predominance of "Comprehensive factor" analysis method

The adoption of the "Comprehensive factor" to assess the researching ability of higher learning institutions provides a more objective and trustful way through not only considering the total research achievement of a higher learning institution, but also taking the factors which may impact the research result into consideration, including the number of teachers & researchers, the number of graduate students and the expenditure for research.

Concretely, "Comprehensive factor" has the following advantages. First, the conception of "productive efficiency" is emphasized in "Comprehensive Factor" analysis method while the conventional methods only consider the "production amount". This new method measures the research level in the perspective of efficiency, and adopts both exploitation efficiencies of money & human resources which obviously contribute to the research level of a higher learning institution, so that the consequence of evaluation will be more reliable than that of the former system. Second, we can rank the higher learning institutions by each of the five unit factors, which make the analytic results clearer than before. Thus, institutions can realize their own situations and further analyze the existent problems in each aspect. Third, it is favorable to objectively and effectively assess the scientific research abilities of ordinary universities and local colleges. We should pay more attention and provide more support to these institutions whose Comprehensive Factor is high enough. Fourth, even though the Comprehensive Factor analyzing method has taken many key factors contributing to the research efficiency into consideration, the calculation is so concise and straightforward that no complicated calculation methods are needed. Even more, from the ranking results of both "Production amount" and "Productive efficiency" method, we can find that the ranks in "Comprehensive Factor" analyzing method of those universities which magnify their sizes through merging other colleges is lower than those in the former "Production amount" system. This result is consistence with our well-established experiences in other areas, hence proves our analyzing method objective, scientific & effective and shows that this method has just well grasped the long-ignored essence of the existent problems in current evaluating methods.

5. Conclusion

After comparing and analyzing the criterion and results of the different systems, we can achieve some conclusions as below. First, the current methods of analysis, provided by SCI, EI & ISTP, are external, candid and quantificational to some extent. However, we cannot turn a blind eye to its limitation or neglect its existent problems. Second, the evaluating systems for higher learning institutions based on SCI, EI & ISTP as well inevitably have some fatal shortcomings and fail to be really objective or scientific. Therefore, it cannot unquestionably measure the efficiency and competence of one institution. Third, in light of these problems,

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based on the conception of “productive efficiency”, we put forward the analytical method named as “Comprehensive Factor”. Then, we analyzed the combination of the arranged data from SCI, EI & ISTP and the data about the investment of corresponding institutions, discussed the origins of the differences between the different evaluation systems and showed the predominance of “Comprehensive Factor” analytical method.

The advantages include more reliable criteria adopting efficiency instead of total amount, a clearer & more inspective analyzing method which can systematically check the potential problems in every considered aspect, and a concise & straightforward method needing no complicated calculation method. What is more, the problems of abrupt increase of personnel number caused by the combination of universities and lower money exploitation efficiency caused by excessive fund concentration have been perspicaciously revealed, which can serve as a cogent evidence to prove our analyzing method objective, scientific & effective.

The development of institutions of higher education affects the education and scientific research level of one country, which is the key factor to improve the cultural literacy of the nationals. Moreover, the operating efficiency, capacity about scientific research and the use of funds in higher learning institutions are the key indicators to see whether an institution can satisfy the requirements of development and times. Therefore, we aim to better evaluate the operating situation of institutions and to bring forward better evaluation criteria for institution reform. On the basis of current system used to rank institutions by total numbers of embodied papers in SCI, EI & ISTP, we proposed a new analysis method named as “Comprehensive factors” which is more scientific, effective and objective. This method contains brand-new evaluation criteria to evaluate the level of research, operating efficiency, the use of funds and other aspects of an institution, which can serve as the criteria for a country, an education department, the local authorities & a financial sector to evaluate the institutions and as the reference to decide the investment of funds. And the concrete applications of the method proposed in this paper in China are first given, which shows the feasible property, advantage and superiority of the method. In addition, this method accords with the practical & realistic operating-style which can promote the reform and development of higher learning institutions and the development of scientific & technological research of any country. In all, the method employing “Comprehensive factors” has a far-reaching significance to inspect the research level and research performance of higher learning & researching institutions. The method developed here is very feasible, and is worthwhile to be popularized in research evaluation systems all over the world.

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