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Publication Performance Evaluation for Academic Institutes by Their Contributions to the Most Visible Publications Across Multiple Fields

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***Abstract*--We propose a method for evaluating the publication performance of academic institutes across multiple fields. With this method, we first determine the *most visible publications* (MVPs) for each field from all assessed institutes according to the field's *h*-index. Then, we measure an institute's performance in each field by its *contribution* to the field's MVPs as (a) the percentage share of the MVPs that is produced by the institute; or (b) the percentage share of the total citations of the MVPs that is received by the institute. Finally, we obtain an institute's cross-field performance measure as the average of its contributions to all fields. The proposed method is reasonable, intuitive to understand, and uniformly applicable to various sets of institutes and fields of different publication and citation patterns. The field and cross-field performance measures obtained by the proposed method not only allow linear ranking of institutes, but also reveal the degree of their performance difference.**

I. INTRODUCTION

An academic institute's expertise usually spans across a number of different fields, subject areas, or disciplines (hereafter, *fields*), and these fields are of different bibliometric features. Some fields (e.g., biomedicine) have a large number of publications with quickly accumulated citations whereas others (e.g., social science) have a limited set of publications with significantly fewer citations. Without taking such field-dependent publication and citation patterns into consideration, the comparison of publication performance for institutes across multiple fields may very possibly deliver distorted result.

The cross-field evaluation of institutional publication performance has already been targeted by various researchers. The most notable ones in recent years are the various variants to the crown indicator developed by the Centre for Science and Technology Studies (CWTS) at Leiden University. The crown indicator [9] is calculated by dividing the average number of citations for publications from a specific aggregated level with the average number that could be expected for publications of the same document type (e.g., articles, reviews, letters, etc.), from the same analyzed time span, published in journals within the same field. One variant to the crown indicator [8] is based on an alternative normalization scheme where the normalization is carried out on the level of individual publication, rather than on aggregated levels as the crown indicator does. There are empirical analysis and theoretical comparison to the two normalization schemes [15]. There are also various other improvements such as the I3 indicator [7].

On the other hand, the *h*-index [3], originally designed as a characterization of a researcher's publication performance, has its application quickly extended to institutional evaluation (cf. [13]), and to comparing the publication performance of a specific program, department, or field of institutes (cf. [6][10][12]).

The *h*-index, being a citation-related indicator, is susceptible to the field dependency issue as well. We can see this from a simplified example as follows. An institute i has *h*-indices n_{if} and n_{ik} for its publications in two fields f and k (hereafter, the institute i's field *h*-indices), respectively. According to the definition of the *h*-index, this means that the institute i has at least n_{if} (n_{ik}) publications in field $f(k)$, each having at least n_{if} (n_{ik}) citations. If the field f is a many-publication-high-citation field, and the field k is a few-publication-low-citation field, n_{if} is usually greater than n_{ik}. If the institute i is evaluated using *h*-index n_i across these two fields (hereafter, the institute i's cross-field *h*-index) by combining its publications in the two fields together, we would expect that the cross-field *h*-index n_i is mainly influenced by the institute i's performance in the many-publication-high-citation field f. In the worst case we would have $n_i = n_{if}$. In other words, even if the institute i has the greatest performance in the few-publication-low-citation field k compared to all other institutes, this condition would be completely ignored.

There are studies adapting the *h*-index for cross-field comparison using various normalization schemes. However, these studies have limited themselves to researchers, not institutes, specializing in different fields (cf. [1][4]). Our greatest concern over these approaches, if they are extended to institutional evaluation, is that they all require a thorough treatment or analysis for the publications from all institutes in a field in order to obtain the field's correction or normalization parameters, even though we are assessing only a limited set of institutes. Additionally, these schemes are rather complicated. From a practical point of view, a cross-field measure for the evaluation of institutional publication performance has to be intuitive so that its meaning can be easily communicated with, understood and accepted by the assessed institutes.

We therefore consider that an ideal method for the cross-field evaluation of institutional publication performance should deal with the performance in each field first, and then combine the field measures of an institute into a cross-field measure without favoring or disfavoring certain fields. In addition, the method should be intuitive to understand, and uniformly applicable to large or small sets of institutes and fields of different publication and citation patterns.

Furthermore, the cross-field performance measures obtained by the method should not only allow linear ranking of institutes, but also reveal the degree of their performance difference.

II. METHODOLOGY

A. Most visible publications

The key successful factor of an ideal method lies in the choice of a field normalization scheme. Vinkler [14] provides us a hint in determining the eminence of scientific journals. The relatively most important publications of a journal are jointly referred to as the journal's *elite set*. Several ways to determine a journal's elite set are proposed such as using the Lotak law, the citation rate, the *h*-index, etc. If the *h*-index is used and a journal has *h*-index 20, the most highly cited 20 publications constitute the journal's elite set. On the other hand, Rousseau [11] called these 20 publications collectively as Hirsch core or *h*-core, and these publications are considered as the most visible ones.

In this paper, we borrow the elite set and *h*-core concepts and build our elite set exclusively based on the *h*-index. However we refer to these publications as the *most visible publications* (MVPs) of the field as we apply the *h*-index differently. Vinkler and Rousseau determine their set and core by choosing those ranked ahead of or equal to the *h*-index whereas we determine the MVPs as those whose citations are greater than or equal to the *h*-index. The difference can be demonstrated by a simplified example as follows. A field has 5 publications with citations 5, 3, 3, 3, and 1, respectively, and the field therefore has *h*-index 3. The elite set determined by the *h*-index contains the first 3 publications whereas the MVPs contain the first 4 publications. The difference lies in the fourth publication which also receives 3 citations just like the second and third publications but is not considered as one of the elites. The way MVPs are determined seems to be more reasonable.

There could be other criteria in determining the MVPs other than the *h*-index and the reasons that we choose *h*-index are its ready availability from online databases such as Scopus and Web of Science, its simplicity in calculation, and, most importantly, that it integrates both quantity and quality (cf. [2]) and therefore would be better than using criteria purely based on the number of publications, or the number of citations.

B. Contribution to the MVPs

If the MVPs of a field are those leading to the field's eminence, it seems reasonable to relate an institute's publication performance in the field as the institute's *contribution* to the field's MVPs. Additionally, to avoid the bias by a field's publication and citation pattern, we propose that an institute's contribution to a field's MVPs is expressed as one of two ways: (a) the percentage share of the MVPs that is produced by the institute; or (b) the percentage share of the total citations of the MVPs that is received by the institutes.

To facilitate the following discussion, we assume that there are M institutes and N fields. By collecting the publications from the M institutes in a field f together, we can obtain the field *h*-index n_f for the field f, and determine the MVP V_f for the field f based on the field *h*-index n_f. By repeating the process for the fields 1, …, N, we can obtain the field *h*-indices $n_1, \ldots, n_N$ and the corresponding MVPs $V_1, \ldots, V_N$, respectively.

A major proposition of this paper is that we consider a greater contribution reflects a better performance. The reasoning is as follows. For example, assuming that a field f's MVPs V_f has 100 publications and 1,000 citations, it is these 100 publications and their 1,000 citations that lead to the field f's having certain degree of eminence in the scientific community. Then, for two institutes i and j measured using (a), if 50 of the 100 MVPs V_f are produced by the institute i and 10 are produced by the institute j, the institute i accounts for 50% of the field f's degree of eminence whereas the institute j only accounts for 10%. We therefore suggest that the institute i should be considered to have better performance than the institute j. We can also see that (a) and (b) are actually different approaches. Following the above example and assuming that the 50 publications of the institute i have received 300 citations whereas the 10 publications of the institute j have received 400 citations, if their contributions are measured using (b), the institute i then accounts for 30% of the field f's degree of eminence whereas the institute j accounts for 40%.

We then define an institute i's *field contribution* to a field f as follows. For simplicity's sake, we focus on (a) approach first. Assuming that a field f's MVPs V_f is a union of $V_{1f}, V_{2f}, \ldots, V_{Mf}$, where V_{if} is a subset of V_f containing publications produced by the institute i, the institute i's field contribution to the field f is calculated as follows:

$$C_{if} = \frac{|V_{if}|}{|V_f|} \cdot 100 \qquad \text{for } 1 \leq i \leq M, \tag{1}$$

where $|V_{if}|$ and $|V_f|$ are the numbers of the MVPs V_{if} and V_f. The field contribution C_{if} defined by (1) specifies that, for the $|V_f|$ publications of the field f's MVPs V_f, C_{if} percent is produced by the institute i. Please note that C_{if} could be zero if V_{if} is an empty set, meaning that the field f's MVPs V_f does not contain any publication from the institute i, or the institute i does not have any contribution to the field f's MVPs.

The field contribution defined by (1) has a nice feature that the field contributions from all M institutes to a field f satisfy the following equation:

$$\sum_{i=1}^{M} C_{if} = 1 \qquad \text{for } 1 \leq f \leq N. \tag{2}$$

The field contribution as such only allows us to rank the institutes but also allows us to infer the degrees of performance difference between the institutes.

Eq. (2) specifies that the field contributions of the M institutes to each of the N fields are summed to 1, and this is a form of normalization over the fields' various publication and citation patterns. As such, an institute i has contributed more, and therefore is considered to have better performance, in a field f than in another field k if $C_{if} > C_{ik}$. For example, assuming that the field f is few-publication-low-citation and has 10 publications in its MVPs, the field k is many-publication-high-citation and has 100 publications in its MVPs, and the institute i's field contributions in the two fields f and k are 50% (C_{if}) and 10% (C_{ik}), respectively, we can consider that the institute i has better performance in the field f than its performance in the field k even though it has only produced 5 publications to the few-publication-low-citation field f's MVPs, smaller than its 10 publications to the many-publication-high-citation field k's MVPs.

Another nice feature of the field contribution defined by (1) is that its calculation does not require us to conduct a thorough treatment or analysis for the publications from all institutes in a field so as to obtain the field's correction or normalization parameters. All we need is the field's MVPs. Additionally, we can interpret the field contribution by itself without involving the other institutes. For example, if $C_{if} >$ 50%, we know right away that more than half of the field f's MVPs is produced by the institute i.

Based on the above definition of the field contribution, we can further define an institute i's *cross-field contribution* as follows:

$$C_i = \frac{\sum_{f=1}^{N} C_{if}}{N} \quad \text{for } 1 \le i \le M. \tag{3}$$

According to (3), we simply calculate the arithmetic average of an institute's field contributions to the N fields as its cross-field contribution and, by using arithmetic average, we treat each field as having equal importance. Of course, if desired or required, an investigator can adopt a weighting scheme in (3) to place emphasis on certain fields. If (2) holds, we can see that the cross-field contributions of all M institutes satisfy the following equation:

$$\sum_{i=1}^{M} C_i = 1. \tag{4}$$

For two institutes i and j, the institute i on the average provides a greater contribution, and therefore can be considered to have achieved better cross-field performance than the institute j does if $C_i > C_j$. Since the cross-field performance of the M institutes are summed to 1, we can compare the relative performance of any pair of institutes i and j without calculating and involving the rest of the institutes' cross-field contributions.

The method described above can be utilized at various scopes. If the M institutes are those of the entire world and the N fields encompass all research disciplines, the method achieves a global evaluation. If the M institutes are those of a country, of a region, or of particular interest to the investigator, or if the N fields form a subset of all fields, the evaluation based on the method is then restricted to this particular subset of institutes, or with respect to this particular subset of fields.

As mentioned earlier, an institute i's contribution can also be expressed as the percentage share of the total citations of the MVPs V_f that is received by the institutes i. To achieve this, all is required is to replace $|V_{if}|$ and $|V_f|$ in (1) by $C(V_{if})$ and $C(V_f)$, respectively, where $C(V_{if})$ and $C(V_f)$ stand for the numbers of citations received by the MVPs V_{if} and V_f, respectively. Eq. (1) now becomes the following:

$$C_{if} = \frac{C(V_{if})}{C(V_f)} \cdot 100 \quad \text{for } 1 \le i \le M. \tag{5}$$

Please note that all features described above also hold for contribution defined in this way.

By comparing (1) and (5) we can see that (1) is more of a quantity measure as it mainly reflects the number of publications from an institute that are incorporated into a field's MVPs. The quality side of these publications is implied, but not directly expressed, as these publications have to accumulate enough citations so as to be incorporated into the field's MVPs. On the other hand, we can see that (5) is more of a quality measure as it mainly reflects the number of citations received by an institute that are incorporated into the total citations of a field's MVPs. Again, the quantity side is implied, but not directly expressed, as these citations must be those received by the publications that are incorporated into the field's MVPs.

C. Multiple affiliations and zero contribution

The proposed field and cross-field contributions are intuitive to understand, uniform across fields of various publication and citation patterns, and possess some nice qualities such as there is no need for a thorough prior analysis so as to obtain some normalization parameter. However, we find that the method has two problems requiring further treatment.

The first problem is multiple affiliations. The field contributions defined by (1) or (5) would satisfy (2) only if each of the MVPs is affiliated with one and only one institute whereas, in real life, it is common that a publication has multiple affiliations.

There is a great deal of research in the literature and various approaches have been proposed to deal with this type of credit distribution problem. However, the proposed field and cross-field contributions do not have to tie to a particular credit distribution scheme and an investigator can choose what is most appropriate to him/her as long as the scheme is uniformly applied to all fields. Here we simply choose a reasonable approach that seems the simplest to us: counting the credit repeatedly for each affiliated institute.

Formally, we define an extended MVPs W_f for a field f having MVPs V_f as containing a set of tuples (p, i) where, for each publication p of V_f, the institute i is one of publication p's affiliated institutes. Then, W_f is a union of W_{1f}, W_{2f}, …, W_{Mf}, where W_{if} is a subset of W_f containing the tuples (p, i) whose publication p is affiliated with the institute i. For example, if a publication p of V_f is affiliated with institutes 1 and 2, W_f then would contain two tuples, (p,1) and (p, 2), with (p,1) belonging to W_{1f} and (p, 2) to W_{2f}. Then, Eqs. (1) and (5) are redefined as follows. It is clear that C_{if} thus defined still satisfies (2).

$$C_{if} = \frac{|W_{if}|}{|W_f|} \cdot 100 \quad \text{for } 1 \leq i \leq M. \qquad (6)$$

$$C_{if} = \frac{C(W_{if})}{C(W_f)} \cdot 100 \quad \text{for } 1 \leq i \leq M. \qquad (7)$$

The second problem is related to institutes having field contribution equal to zero, and to institutes having cross-field contribution equal to zero. Even though we can consider these institutes as having identical field or cross-field performance, can we further differentiate them if there are a large number of these institutes?

The differentiation in a single field can be achieved by repeating the proposed method as follows. Let's say that we start with M institutes in a field. After a first application of the method, say, there are M' institutes having zero field contribution. We then perform a second application of the method only to the M' institutes by compiling the M' institutes' publications, obtaining a new field h-index, determining a new set of extended MVPs, and calculating the M' institutes' field contributions. Again, say, there are M'' institutes still having zero field contribution. We then repeat the method again only to the M'' institutes until there is no institute or only a handful of them with zero field contribution left.

The differentiation for institutes with zero cross-field contributions can be achieved in various ways. We will leave the detail to future research but, for the moment, the simplest way is to follow the process for differentiation in a single field. More specifically, we start with M institutes and there are M' institutes having zero cross-field contributions from the initial application of the method. We then conduct the proposed method again to obtain new cross-field contributions only for the M' institutes as described above. The process is then repeated if required.

III. RESEARCH DATA

To test-drive the proposed method, we need to assemble a representative set of academic institutes and fields. For the fields, we determined to use the 22 fields adopted by the Essential Science Indicators (ESI) in classifying journals and thereby publications of these journals, but skipped the field Multidisciplinary since publications of this field are further assigned to the other 21 fields.

For the academic institutes, we figured that, to demonstrate the proposed method, it would be better that most of them, if not all, should achieve non-zero field contributions and thereby non-zero cross-field contributions. Otherwise, we have to repeat the application of the proposed method several times to handle those with zero cross-field contribution as described in the previous section, which would be unnecessarily troublesome for the demonstration purpose of this paper.

Accordingly, we determined to use the top 10 academic institutes having the greatest numbers of citations in at least two of the 21 fields. The data was collected on 2010-03-03 from the SCI-EXPANDED and SSCI citation databases, and included the numbers of publications indexed between 2000 and 2009 and the numbers of citations of these publications for all institutes. Four types of publications (articles, reviews, research notes, and proceedings papers) were collected and they are jointly referred to as *publications* for consistency with the terminology so far. Finally we skipped the research institutes, and there were total 40 academic institutes. Again, for simplicity's sake, the term *institute* is used to refer to academic institute hereafter.

The 21 fields were too numerous for the result of our test drive to present in a clear and concise manner, yet arbitrarily selecting some fields and leaving out the others was not a sound approach either. We therefore separated the 21 fields into 6 field groups as depicted in Table 1 and used the 6 field groups as the fields of the proposed method. We refer to the field groups simply as *fields* hereafter so as to be consistent with the terminology used so far. We also refer to each field by the first word of its title (e.g., the field Physical, Chemical & Earth Sciences as the field Physical) for brevity. Finally, we collected each and every publication affiliated with the 40 institutes in the 6 fields indexed between 2000 and 2010 from the SCI-EXPANDED and SSCI citation databases. The collection was conducted between 2011-02-05 and 2011-02-12.

TABLE 1. THE 6 FIELD GROUPS AND THEIR CONSTITUENT ESI FIELDS.

Field Group	Constituent ESI Fields
Agriculture, Biology & Environment Sciences	Plant & Animal Science, Environment/Ecology, Agricultural Sciences.
Clinical Medicine	Clinical Medicine, Psychiatry/Psychology.
Engineering, Computing & Technology	Engineering, Materials Science, Computer Science.
Life Sciences	Biology & Biochemistry, Microbiology, Immunology, Neuroscience & Behavior, Molecular Biology & Genetics, Pharmacology & Toxicology.
Physical, Chemical & Earth Sciences	Chemistry, Physics, Geosciences, Mathematics, Space Science.
Social & Behavioral Science	Social Sciences (General), Economics & Business

IV. SINGLE-FIELD EVALUATION

In this section, we apply the proposed method to each of the 6 fields. For brevity, we provide only the result for the fields Agriculture (a less crowded field with 120,935 publications and total 1,658,645 citations) and Life (a rather crowded field with 354,120 publications and total 10,105,971 citations) in Tables 2 and 3, where the institutes are sorted in descending order by their field *h*-indices. Also for brevity only the institutes having the *h*-indices in the top 15 ranks are included. As described previously, there are two approaches in measuring contribution: one using share of publications and one using share of citations of the MVPs. The contributions obtained by the two approaches are listed in the middle and right columns. The rankings by the *h*-index and by the two types of contribution are listed to the right of their corresponding measures, with those of the same measure ranked at the same place. In the header, the number in parentheses is the number of different ranks achieved by the corresponding measure. For example, in Table 2, the *h*-index achieves 31 ranks and using publication share as contribution achieves only 18 ranks (including the rank for the zero contribution).

TABLE 2. *H*-INDICES AND CONTRIBUTIONS OF A SUBSET OF THE 40 INSTITUTES IN THE FIELD AGRICULTURE.

	h-Index(31)		Publication (18)		Citation(36)	
Institute	*h*	Rank	Share	Rank	Share	Rank
University of California - Davis	109	1	6.96%	3	6.72%	4
Cornell University	104	2	6.59%	4	6.94%	3
University of California - Berkeley	102	3	8.79%	1	8.32%	1
University of Wisconsin - Madison	99	4	7.69%	2	7.23%	2
University of Minnesota - Twin Cities	91	5	4.40%	6	4.39%	6
Harvard University	90	6	5.49%	5	5.66%	5
Wageningen University	88	7	4.03%	7	3.15%	12
University of Washington - Seattle	86	8	3.30%	9	3.60%	9
University of Georgia	83	9	2.56%	11	2.58%	16
University of California - Santa Barbara	83	9	2.56%	11	2.04%	18
University of Toronto	80	10	2.93%	10	2.45%	17
Swedish University of Agricultural Sciences	79	11	3.30%	9	3.73%	7
Pennsylvania State University - University Park	79	11	0.00%		0.00%	
University of California - San Diego	78	12	3.30%	9	3.38%	11
University of Michigan - Ann Arbor	78	12	1.47%	14	2.02%	19
University of Oxford	75	13	3.66%	8	3.53%	10
Stanford University	74	14	3.30%	9	2.93%	14
University of Illinois - Urbana-Champaign	74	14	1.83%	13	1.53%	26
University of North Carolina - Chapel Hill	72	15	1.47%	14	1.63%	24

TABLE 3. *H*-INDICES AND CONTRIBUTIONS OF A SUBSET OF THE 40 INSTITUTES IN THE FIELD LIFE.

	h-Index(32)		Publication(27)		Citation(39)	
Institute	*h*	Rank	Share	Rank	Share	Rank
Harvard University	302	1	16.31%	1	13.87%	1
University of California - San Francisco	216	2	5.49%	4	6.47%	4
Massachusetts Institute of Technology	209	3	7.16%	2	8.76%	2
University of California - San Diego	209	3	6.55%	3	7.64%	3
Johns Hopkins University	208	4	5.03%	5	4.85%	5
Stanford University	208	4	4.73%	6	4.24%	8
University of Pennsylvania	196	5	3.05%	11	2.45%	15
Yale University	196	5	3.35%	9	3.79%	9
University of Washington - Seattle	195	6	3.81%	7	4.34%	6
Washington University in St. Louis	195	6	3.81%	7	3.74%	10
University of California - Los Angeles	189	7	2.90%	12	2.52%	14
University of Cambridge	189	7	3.20%	10	3.05%	12
Columbia University	187	8	2.90%	12	2.25%	17
University of Oxford	186	9	3.51%	8	4.32%	7
University of London - University College London	180	10	1.98%	15	2.10%	18
University of Toronto	180	10	0.91%	21	0.72%	30
University of Michigan - Ann Arbor	175	11	2.59%	13	2.41%	16
University of California - Berkeley	172	12	2.29%	14	2.63%	13
University of North Carolina - Chapel Hill	166	13	1.22%	19	0.99%	27
University of Tokyo	166	13	2.29%	14	1.87%	19
Cornell University	161	14	1.37%	18	1.06%	25
Imperial College London	159	15	1.52%	17	1.27%	23

From Tables 2 and 3, we can see that there are numerous cases where institutes with high *h*-index are evaluated by the proposed method to be of little or even zero contribution. For example, in the field Agriculture shown in Table 2, Pennsylvania State University - University Park is ranked at the 11th place by *h*-index but achieves zero contribution. This is because, for Pennsylvania State alone, there are 79 publications considered to be the most visible ones but, when all 40 institutes are evaluated together, none of the 79 publications is qualified as the field's MVPs. Similarly, in the field Life shown in Table 3, University of Toronto is ranked at the 10th place by *h*-index, but it falls within the final 1/3 of the 40 institutes by contributions (21st place among 27 ranks using publication share, and 30th place among 39 ranks using citation share). There are also plenty cases where institutes are of identical or close *h*-indices but are of significantly different contributions, or vice versa. This suggests that *h*-index may not be an appropriate measure in comparing institutes even in a single field. In contrast, an institute's contribution to a single field is calculated using the field's MVPs where the publications from all institutes are involved, and is therefore a more appropriate measure.

However, the MVPs are determined using the *h*-index, and the contributions are still more or less related to the *h*-index. Therefore, we can see that, for the institutes at the leading places (e.g., the first 5 places) by the *h*-index, most of the time they are also located in the front by the two types of contribution and, even though not shown in the tables, this also applies to those ranked in the back by the *h*-index.

We can further see that the ranking by contribution using citation share is the most different one from those by the *h*-index and by contribution using publication share, and the rankings by the *h*-index and by contribution using publication share is more correlated. This is because, by using the publication share as contribution, we consider only those publications qualifying as the field's MVPs regardless of their citations. This type of contribution is more consistent with the *h*-index as, once a publication passes a threshold as one of the MVPs, its excessive citations are ignored. As to the contribution using citation share, every citation counts and as such its ranking is the most different one. This also explains why using citation share as contribution is more discriminating (achieving 36 and 39 ranks) than using the *h*-index and using the publication share as contribution. However, as will be seen in the next section, the lack of differentiation in using the publication share as contribution will disappear when multiple fields are evaluated together. The discriminating power of the contribution using citation share has its price. We can expect that an institute may be unduly favored due to its few extremely highly cited publications.

From our test-driving the proposed method above, we can see that an institute's contribution to a field can be interpreted by itself, which is a rare quality of bibliometric measures. For example, in the fields Life shown in Table 2, Harvard University (ranked at the 1st place by *h*-index) has contributions 16.31% and 13.87%, and we can understand that it has accounted for more than 16% and 13% of the publications and citations in shaping the field Life's MVPs without knowing other institutes' contributions. Additionally, for any pair of institutes in a field, we not only can see their relative performance but also can tell how superior or inferior one is relative to the other, again without involving other institutes.

V. CROSS-FIELD EVALUATION

In this section we continue to apply the proposed method to obtain the cross-field contributions for the 40 institutes across all 6 fields. The result is shown in Table 4 with the institutes sorted in descending order of their cross-field *h*-indices. For comparison's sake, we have also included the 2010 PUB scores from the Academic Ranking of World Universities (ARWU) by Shanghai Jiao Tong University (available at http://www.arwu.org/ARWU2010.jsp). The rankings by the *h*-index, by the two types of cross-field contributions, and by the ARWU PUB scores are listed to the right of their corresponding measures.

We can see that, when all fields are combined together, the lack of discrimination by the publication share when it is applied to separate fields is not present here as two institutes rarely perform equally strong or weak in all fields. The inadequacy of the cross-field *h*-index as a cross-field measure can also be seen in Table 4. For example, University of California - San Francisco has a rather high cross-field *h*-index ranking (the 5th place) due to its superior performance in a crowded field such as Life (see Table 3). Yet its inferior performance in other less crowded fields is reflected in its mediocre rankings by the two types of contribution (18th and 17th places).

We can also see that, unlike in separate fields, the rankings by the two contributions are rather consistent. We believe that this is due to (a) the two contributions are somewhat correlated in the first place; and (b) the cross-field contribution is an average of the field contributions and sharp difference is smoothed as such. However, there are still exceptions. For example, Pennsylvania State University - University Park (ranked at the 30th place by cross-field *h*-index) has the most different ranks by the two contributions (31 vs. 20). We find that it has very high contribution by citation share in the field Engineering (ranked at 3rd place). Additionally, in 5 of the 6 fields, its contributions by citation share are all better than its contribution by publication share, thereby moving its rank by citation share more ahead.

Some detailed examination also reveals interesting insight into these different measures. Johns Hopkins University is ranked at the 2nd place by cross-field *h*-index whereas it is ranked at the 6th and 7th places by contributions. In contrast, University of California - Berkeley is ranked at the 2nd place by contributions whereas it is ranked at 8th place by cross-field *h*-index. Their ranks in each field by various performance measures are summarized in Table 5 as follows.

TABLE 4. *H*-INDICES AND CROSS-FIELD CONTRIBUTIONS OF ALL 40 INSTITUTES FOR ALL 6 FIELDS.

	h-Index(39)		Publication(40)		Citation(40)		ARWU(40)	
Institute	*h*	Rank	Share	Rank	Share	Rank	Score	Rank
Harvard University	394	1	9.85%	1	9.29%	1	100	1
Johns Hopkins University	310	2	3.80%	6	3.63%	7	64	17
Stanford University	301	3	4.70%	4	4.45%	4	69.7	9
University of Washington - Seattle	297	4	3.87%	5	4.00%	6	72.5	6
University of California - San Francisco	288	5	2.29%	18	2.45%	17	60.7	23
Massachusetts Institute of Technology	285	6	5.52%	3	5.83%	3	61.4	22
University of California - San Diego	284	7	3.53%	8	4.12%	5	65.1	16
University of California - Los Angeles	280	8	3.58%	7	3.54%	8	75.1	5
University of California - Berkeley	280	8	5.96%	2	6.06%	2	70.6	7
University of Michigan - Ann Arbor	273	9	3.25%	10	3.36%	9	79.8	4
Columbia University	268	10	2.87%	11	2.91%	12	69.9	8
University of Pennsylvania	266	11	3.36%	9	3.22%	10	68.6	10
Yale University	263	12	2.25%	20	2.12%	21	62	21
University of Oxford	256	13	2.86%	13	2.96%	11	68.5	11
University of Cambridge	254	14	2.28%	19	2.37%	18	65.7	15
University of Toronto	249	15	1.73%	25	1.52%	29	80.3	3
University of Pittsburgh - Pittsburgh	244	16	1.90%	22	1.80%	23	63.1	18
University of Chicago	243	17	2.87%	12	2.87%	13	50.5	33
Washington University in St. Louis	241	18	1.69%	28	1.62%	27	54.8	31
California Institute of Technology	240	19	2.50%	17	2.24%	19	46.9	34
Cornell University	237	20	2.81%	14	2.84%	14	59.5	27
University of Minnesota - Twin Cities	236	21	2.53%	15	2.72%	15	66.6	13
Imperial College London	235	22	1.82%	24	1.79%	24	62.3	20
University of Tokyo	234	23	1.72%	26	1.51%	30	80.4	2
University of North Carolina - Chapel Hill	228	24	1.61%	30	1.60%	28	60.6	24
University of London - University College London	225	25	1.23%	33	1.28%	34	67	12
University of Wisconsin - Madison	222	26	2.51%	16	2.56%	16	66.1	14
Osaka University	210	27	1.35%	32	1.34%	33	60.2	26
Princeton University	202	28	1.90%	23	1.77%	25	44.3	35
University of California - Davis	198	29	2.14%	21	1.92%	22	63	19
Pennsylvania State University - University Park	189	30	1.57%	31	2.14%	20	56.1	30
University of California - Santa Barbara	180	31	1.68%	29	1.38%	31	42.6	37
University of Illinois - Urbana-Champaign	178	32	1.69%	27	1.71%	26	58.6	29
Swiss Federal Institute of Technology - Zurich	173	33	1.09%	34	1.36%	32	53.6	32
Tohoku University	160	34	0.84%	35	1.00%	35	60.3	25
National University of Singapore	143	35	0.67%	38	0.65%	37	59.1	28
University of Georgia	123	36	0.80%	36	0.80%	36	44.2	36
Wageningen University	116	37	0.73%	37	0.58%	39	39.3	38
Swedish University of Agricultural Sciences	99	38	0.57%	39	0.64%	38	28.6	40
University of Maryland - Baltimore County	79	39	0.06%	40	0.04%	40	38.6	39

TABLE 5. THE RANKINGS OF JOHNS HOPKINS VS. UC - BERKELEY IN EACH OF THE 6FIELDS.

	Johns Hopkins			UC - Berkeley		
	h-Index	Publication Share	Citation Share	*h*-Index	Publication Share	Citation Share
Agriculture	22	14	29	3	1	1
Clinical	2	2	2	26	19	26
Engineering	12	11	17	2	1	1
Life	4	5	5	12	14	13
Physical	11	6	8	2	2	2
Social	15	11	15	8	8	9

UC - Berkeley takes leading positions in 3 fields whereas Johns Hopkins takes leading position in at most 2 fields. For their respective worst fields, UC - Berkeley is still better than Johns Hopkins. Johns Hopkins' strong performance in two of the most crowded fields, Clinical and Life, is the main factor for its position as number two by the cross-field *h*-index. UC - Berkeley, on the other hand, has the overall best performance even though with an inferior cross-field *h*-index. The proposed method correctly suggests the more reasonable relative performance between Johns Hopkins and UC - Berkeley.

The included ARWU PUB scores are based on the total number of publications indexed in SCIE and SSCI in 2009 and is a pure quantity-based measure. The ranking by PUB score is therefore rather inconsistent with the others, and some cases may seem implausible. For example, University of Tokyo and University of Toronto are ranked at the 2nd and 3rd places by PUB score whereas both of them are ranked behind the 25th place by their contributions. Additionally, a special weight of two is given to publications indexed in SSCI for rewarding the more difficult SSCI publications. The proposed method deals with this issue more reasonably by not ignoring contributions to those difficult and therefore less crowded fields.

The advantages that we observe in the field-specific evaluation, such as the self-contained interpretation to an institute's performance without involving the other institutes, and the manifestation of the degree of performance difference, are also applicable here for cross-field evaluation.

VI. SUMMARY

Comparing the two types of contribution, contribution using citation share is rather discriminating whether it is applied to single-field or cross-field publication performance evaluation. Yet, in single-field evaluation, it may be biased by institutes having a few extremely highly cited publications. Such bias, however, would be lessened in cross-field evaluation. In contrast, contribution using publication share is seriously indiscriminating when it is applied to single-field evaluation. This shortcoming however would be obviated when it is applied to cross-field evaluation. Additionally, for cross-field evaluation, we find that it is difficult to tell which one of the two types of contribution is better. We suggest to use both, and an institute is indeed has a better publication performance if it is considered as such by both types of contribution.

Constrained by the length of this paper, a limited set of analytical results are presented in the previous sections. Interested readers can refer to [5] where additional analyses are reported, but these analyses are limited to field and cross-field contributions using shares of publications.

The proposed method can actually be expanded into a conceptual framework adaptable to fulfill an investigator's specific requirement. Some possible adaptations are outlined as follows. Firstly, the determination of the MVPs does not have to be fixedly tied to *h*-index. We can use other criteria to determine the MVPs as long as the determination is uniformly applied to all fields. Then, for multiple affiliations and zero contribution, there are also various different ways to handle them. For example, we can choose to divide the credit evenly to the affiliated institutes.

Even though this paper has focused on academic institutes, we do not see why the proposed method cannot be applied to entities at other aggregated levels such as a set of researchers, a set of departments, or a set of counties, and why it cannot be applied to patent assignees for innovation performance evaluation across a number of technical fields.

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