

The Correlations Between Article Citation and References' Impact Measures: What Can We Learn?

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ABSTRACT

We examined the correlations between an article's citation count (as an indicator of the article's quality) and different impact measures regarding the article's references (as indicators of the quality of the authors' information seeking while producing the article). Two research questions of interest were studied. First, do authors' information seeking and use affect the quality of their research output? Second, if yes, which metrics can better identify those references that may inspire researchers to produce high quality research work (so that we can recommend these references to others)? We found that the impact measures for the references have a slight or moderate correlation with article citations. Among these measures, references' article level impact measures calculated based on altmetrics data sources have a consistently stronger correlation with high quality research output, which may serve to identify helpful articles for researchers.

Keywords

Bibliometrics; altmetrics; information seeking and use.

INTRODUCTION

Perceived quality of academic articles and the reputation of the authors and their sources can affect scholars' decisions on whether or not to read the articles (Hemminger, Lu, Vaughan, & Adams, 2007). Many impact measures (e.g. citation, *h*-index, journal impact factor) may also affect scholars' decisions (Meho & Tibbo, 2003), as they are usually provided by academic databases in which scholars are seeking academic information. However, as none of the impact measures were designed specifically to facilitate information seeking (Jiang, He, Han, & Jeng, 2013), it is unclear to what extent these impact metrics can really help scholars and contribute to their academic activity.

We address this problem by looking into the correlations between an article's citation count and the impact measures of the article's references at the article, author, and venue levels. It is assumed that an article's references (to some extent) indicate the outcomes of the authors' information seeking and

use and that they may affect the quality of the research output (here, it is roughly measured by the citation count of the article). Examining the correlations may help to answer two research questions of interest:

- 1) Do scholars' information seeking and use throughout the process of conducting a study affect the quality of research output related to the study?
- 2) If yes, what metrics can better reveal the most useful references to scholars and contribute to their research?

The rest of this paper presents our results and analysis.

METHODS

We performed a correlation analysis using articles as the unit of analysis. Each article was considered as the outcome of a research effort, the quality of which (the dependent variable) was measured by its citation count. The quality of the article's references (the independent variables) were measured at the article, author, and venue levels, using either citation or altmetrics data sources. Table 1 enumerates details about the variables. We computed and compared the Spearman's correlation coefficients between the dependent variable and each of the independent variables.

Dependent Variable: Quality of Research Outputs

The dependent variable measures the quality of scholars' research output. Despite its many drawbacks, citations are still the most widely-adopted measures of the impact of research output. Here, we simply equate the impact of an article (as measured by its citations) to the quality of the article due to the lack of human assessments on article quality. We used a two-year time frame to calculate citation counts, e.g. for an article published in 2009, we counted its citations up until the end of 2011.

Independent Variables: Outcomes of Information Seeking and Use

The independent variables measure the quality of the outcomes of the scholars' information seeking and use by assessing the overall quality of an article's references.

As shown in Table 1, we computed the venue-level quality (IF), author-level quality (H_{1st} , H_{avg} , and H_{max}), and article-level quality (RCT_k) for each reference. These metrics can be computed based on either citation or altmetrics data. Here, we adopted CiteULike readership as an example of altmetrics data. The CiteULike citation of an article is the

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| | Data Source | Level of Measurement | Variables | Explanation (y is the year in which the article being analyzed was published) |
|-----------------------|-----------------------------------|-----------------------------------|--|--|
| Dependent Variable | | | CT ₂ | Citation count of the article roughly after 2 years it was published (counting from year y to the end of year $y + 2$). |
| Independent Variables | Citation | Venue level | IF | The 2-year impact factor of the journal where the reference was published (measured for year $y - 1$). |
| | | Author level | H _{1st} | The reference's first author's h -index (measured for year $y - 1$). |
| | | | H _{avg} | The average h -index of the reference's authors (measured for year $y - 1$). |
| | | | H _{max} | The highest h -index of the reference's authors (measured for year $y - 1$). |
| | Article level | RCT _{k} | Citation count of the reference in the past k years (from year $y - k$ to the end of year $y - 1$). | |
| | Altmetrics (CiteULike readership) | Venue level | IF_CUL | IF calculated based on CiteULike citation (the CiteULike citation of an article is defined as the number of users in CiteULike who saved the article to their personal libraries). |
| | | Author level | H_CUL _{1st} | H _{1st} calculated based on CiteULike citation. |
| | | | H_CUL _{avg} | H _{avg} calculated based on CiteULike citation. |
| | | | H_CUL _{max} | H _{max} calculated based on CiteULike citation. |
| Article level | | RCT_CUL _{k} | RCT _{k} calculated based on CiteULike citation. | |

Table 1. Dependent and independent variables for the correlation analysis.

number of CiteULike users who saved this article to their personal libraries. The overall quality of an article's references were computed as the mean value of each reference's quality.

For each article, the quality measures of its references were computed for one year in advance of the publication of the article, which was meant to reflect the period in which the authors were collecting information related to the research. For example, if an article was published in 2010, the quality measures of its references were computed as of the end of 2009.

EXPERIMENT PROCEDURE

As values of citation and other quality measures may vary greatly in different domains, we selected nine conferences and individually examined the Spearman's correlations for each conference. The nine conferences were SIGIR, CIKM, JCDL, WWW, HyperText (HT), KDD, SIGMOD, ICML, and CHI. We selected them because they are very prestigious within their domains. This was to make sure that high-quality research output (i.e. highly cited articles) could be included into our analysis.

| Impact Measure of References | Correlation with Article Citation (average value of the 9 conferences) | |
|---------------------------------|--|-----------------|
| | Citation-based | CiteULike-based |
| IF | 0.284 | 0.278 |
| H _{1st} | 0.276 | 0.315 |
| H _{avg} | 0.288 | 0.327 |
| H _{max} | 0.290 | 0.332 |
| RCT (all past years) | 0.211 | 0.348 |
| RCT ₁ (past 1 year) | 0.273 | 0.364 |
| RCT ₂ (past 2 years) | 0.265 | 0.361 |
| RCT ₃ (past 3 years) | 0.256 | 0.354 |
| RCT ₄ (past 4 years) | 0.245 | 0.347 |
| RCT ₅ (past 5 years) | 0.236 | 0.348 |

Table 2. Spearman's correlations between article citation and the references' quality measures (mean values of the correlations for articles published in the selected nine conferences).

We examined only those correlations for articles published in 2009, because at the time of this study, it was the only year for which we could harvest sufficient data to calculate both citations of articles (from year 2009 to 2011) and the prior CiteULike readership for the references (as CiteULike was not initiated until 2004). Citation-related measures were computed only for items in the ACM digital library.

RESULTS

Venue Level Quality

Figure 1 (a) shows the correlations between article citation and references' 2-year impact factors calculated based on citation (IF) and CiteULike readership (IF_CUL) for the selected conferences. With the exception of SIGMOD and CHI, the references' IF and IF_CUL are at least slightly correlated ($\rho > 0.2$) with article citation in the other seven conferences. This indicates that a venue's impact, although it is difficult to provide article-level impact measures (Priem, Taraborelli, Groth, & Neylon, 2010), may still be useful in identifying helpful literature. As shown in Table 2, we did not observe much difference between the correlations computed using citation (0.284) and those using CiteULike readership (0.278).

Author Level Quality

When article citation is unavailable (e.g. for new articles), it seems plausible that the prior impact of the authors is a meaningful indicator of the usefulness of articles. For example, it is likely that a new article written by an influential author will be worth reading and informative.

Figure 1 (b), (c), and (d) shows the correlations between article citations and the three different author level quality measures. Except CIKM and SIGMOD, we found article citations and the references' author level quality measures are at least slightly correlated ($\rho > 0.2$), indicating that the reputation of article authors are of certain usefulness in identifying pertinent articles.

As an article can be co-authored by different scholars, we calculated three different author level quality measures by taking into account only the first author (H_{1st}), only the most

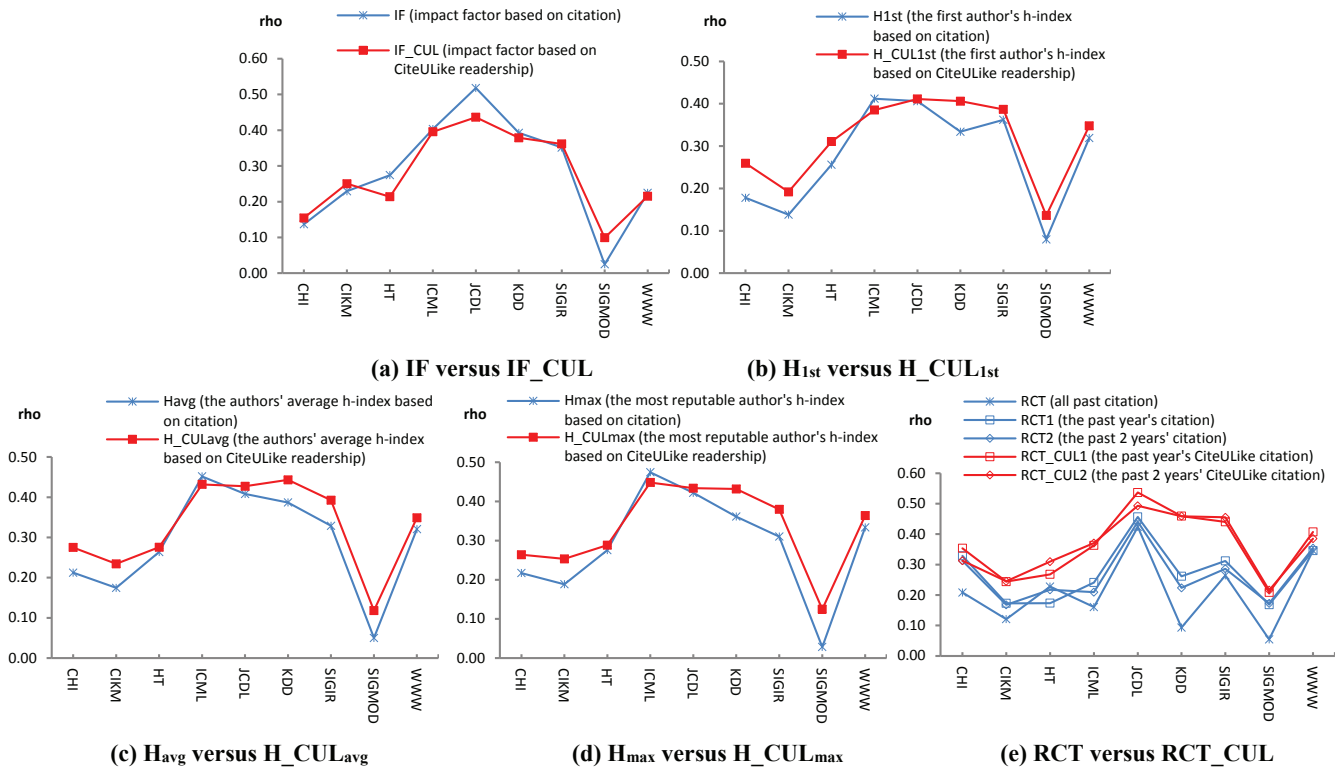


Figure 1. The Spearman's correlations between article citations and references' different quality measures. (All the correlations are statistically significant at 0.05 level of significance)

reputable author (H_{max}), and all of the co-authors (H_{avg}). As shown in Table 2, on average H_{max} has the highest correlation, H_{1st} has the lowest, and H_{avg} lies in the middle. However, there are only slight differences among them (less than 0.02 in rho values).

Table 2 shows that, compared with the measures based on citation, the references' author level quality measures based on CiteULike readership are better correlated with article citation, with the differences of rho values ranging from 0.03 to 0.04. As shown in Figure 1 (b), (c), and (d), for eight out of the nine conferences (except ICML), the CiteULike-based measures have higher correlations than the citation-based ones. This indicates that altmetrics data sources such as CiteULike readership may provide better author-level quality measures for identifying useful literature.

Article Level Quality

As shown in Figure 1 (e), on average, references' article level quality measures are slightly or moderately correlated with article citation. The CiteULike-based measures have observably higher correlations than the citation-based ones, with the differences in rho values ranging from 0.1 to 0.15.

According to Table 2, it is most effective to calculate article level quality measures based on solely the past year's citations (RCT_1) or CiteULike readership (RCT_{CUL1}). This indicates that article level quality measures are time-sensitive and should be calculated based on the most recent changes rather than a long term aggregation of impacts.

The article level measures have slightly weaker correlations than the venue and author level measures when calculated based on citation data. However, when altmetrics data were utilized, the article level measures are better correlated with article citation than any other measures. This indicates that article level metrics are indeed better indicators of useful literatures, but it also depends on the types of data sources being employed in the calculations. Citation, as indicated by our results, is an inappropriate data source for computing article level metrics. However, this is exactly the strength of the altmetrics data source such as CiteULike readership.

DISCUSSION

New Research Agenda

Results in Table 2 and Figure 1 support that the outcomes of information seeking and use are connected with the research output of scholars. Currently, it is unclear whether or not such connections come from a causal relationship as we can also identify other reasonable explanations. For example, effective academic information seeking and high quality research output may share a common reason, i.e. the scholar's superior research capability. Nevertheless, we still believe that the assumed causal relationship is reasonable, as sometimes we ourselves find innovative ideas in new articles and produce high quality research work based on them.

According to our results, slight or moderate correlations exist. Although information seeking and use may not constitute the most significant or decisive factor for scholars' success in

research, it is the factor that we can “manipulate”, e.g. building proper information retrieval and recommendation systems to identify helpful literature. In contrast, it is difficult to improve other possible factors over a short time, such as the scholars’ intelligence, personality, and diligence, etc.

Current studies of bibliometrics focus on designing and applying metrics to science & technology studies, which may fail to serve the interests and needs of a wider audience, i.e. scholars and scientists as a whole. Our study suggests a new research agenda, i.e. designing metrics specifically for the purpose of helping researchers identify useful articles in order to enhance their research output. Although existing metrics may have a certain effectiveness to serve this purpose, there is room for improvement (as none of the current metrics specifically modeled this problem).

Article Level Metrics and Altmetrics Data Source

Recently article level metrics were advocated along with the use of altmetrics data sources (Priem & Hemminger, 2010; Priem, Piwowar, & Hemminger, 2012). However, few studies offered any evidence that article level metrics or the use of altmetrics data source are better than conventional citation-based metrics other than its fast speed of data accumulation (Jiang, He, & Ni, 2011; Priem et al., 2012). Most studies found only moderate correlations between altmetrics and citation-based ones (Bar-Ilan et al., 2012; Li, Thelwall, & Giustini, 2011; Priem et al., 2012), which only partly validated the use of the altmetrics data sources. We also noticed that data from online social websites are very biased regardless of whether from one discipline or among different disciplines (Jiang, Ni, & He, 2012). This makes it difficult for what to be applied to disciplinary and interdisciplinary studies.

Our results indicate that, if computed based on CiteULike readership, article level metrics can be better indicators of useful literature than the author and venue level metrics, which supports the advocates of article level metrics. Nonetheless, we still observed weak correlations between the author and venue level quality measures of the references and scholars’ research output. Considering that it may be difficult to compute article level quality measures for newly-published articles, we should not underestimate the author and venue level quality measures. As shown in Table 2, an author’s *h*-index calculated based on CiteULike citation is still a relatively effective indicator of useful literature.

In our study, the use of altmetrics data sources has also been confirmed in its overwhelming advantages over citation in identifying useful literature. As shown in Table 2, except venue level metrics, it is beneficial to adopt the CiteULike readership to calculate author level and article level metrics, which result in stronger correlation values than those calculated based on citation.

CONCLUSION

In this paper, we found that the outcome of scholars’ information seeking and use is very likely a factor affecting the quality of scholars’ research output. We compared article,

author, and venue level metrics for their effectiveness in revealing important references associated with the high quality research output. We found that article level metrics based on altmetrics data sources are the most effective of those being evaluated. Our study suggests a new research agenda of exploring scientometrics measures and advocates the use of altmetrics data in helping scholars’ information seeking and use.

Admittedly, there are many limitations to our current study. For example, the articles being examined are limited to ACM conferences and the citation data and altmetrics data sources are also limited. Another challenge of our method lies in the unverified relationships between article references (assumed to be indicative of the outcome of the scholars’ information seeking and use) and scholars’ research output. In the future, we need to further verify the existence of such relationships.

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