Article length bias in journal rankings*

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Abstract

The quality of publications, approximated by the containing journal's quality indicator, is often the basis for hire and promotion in academic and research positions. Over the years a handful of ranking methods have been proposed. Discussing the most prominent methods we show that they are inherently biased against journals publishing short papers.

Keywords: quality ranking, paper length, impact factor, invariant method, LP method

1   Introduction

The last decades saw an explosion in the number of journals. Libraries face higher subscription fees and must allocate budgets in an efficient way. Researchers find it more and more difficult to keep up with the growing literature even in narrow fields. Funding and promotion decisions are often taken considering researchers' publications which are becoming increasingly difficult to evaluate and compare. All these developments contribute to the growing interest in objective measures of journal quality.

The ranking of journals has long been dominated by the Impact Factor (Garfield, 1955) although numerous alternative measures have been introduced, such as the invariant method (Pinski and Narin, 1976; Palacios-Huerta

and Volij, 2004), the LP method (Liebowitz and Palmer, 1984; Laband and Piette, 1994; Kalaitzidakis, Mamuneas, and Stengos, 2003) and the H-index (Hirsch, 2004; Braun, Glänzel, and Schubert, 2005). These methods generated many variations, the best known being the PageRank (Brin and Page, 1998) algorithm which plays an important part in how Google ranks web sites.

While most of these methods have been intuitively motivated, if at all, Palacios-Huerta and Volij (2004) presented an axiomatization for the invariant method from a descriptive perspective. That is, they find a set of requirements that fully characterizes the invariant method.

Some of these properties are invariance properties that allow the comparison of journals with different characteristics and from different fields. Yet, a property that affects also journals rankings *within* the same discipline, *invariance to article-splitting*, requiring neutrality with respect to the length of articles, has not been studied. We introduce this property and show that the ranking methods above are not invariant to article-splitting, but are biased against journals publishing short articles, exposition notes or letters.

2   Ranking Methods

Let $\mathbb{J}$ be the universe of journals and $\mathcal{J}$ be the set of all non-empty finite subsets of $\mathbb{J}$. Let $J \in \mathcal{J}$, $j \in J$ and let a_j denote the number of articles published in j. For each $i, j \in J$, c_{ij} represents the number of citations to journal i by journal j, that is, the number of references *made* by journal j to journal i. Let us consider the *citation matrix* a $|J| \times |J|$ nonnegative matrix, $C = \{c_{ij}\}_{i,j \in J}$ and let $c_j = \sum_{i \in J} c_{ij}$ be the total number of citations made by j.

Definition 1. *A ranking problem is a triple (J, a, C) consisting of a finite set of journals $J \in \mathcal{J}$, a vector $a \in \mathbb{N}^{|J|}$ containing the number of published articles and a citation matrix $C = \{c_{ij}\}_{i,j \in J}$.*

Let $\mathcal{R}$ denote the set of ranking problems. A cardinal ranking of the journals in J is given by a transposed *valuations* vector $v^T = (v_1, v_2, ..., v_{|J|})$, where $v_i > 0$.

Definition 2. *A ranking method ϕ maps a ranking problem $(J, a, C) \in \mathcal{R}$ to a vector of valuations $v \in \mathbb{R}_{++}^{|J|}$.*

A ranking method induces a weak ordering of the journals via the *ranking rule* $i \succcurlyeq j$ if and only if $v_i \geq v_j$. Ties, i.e., $i \succcurlyeq j$ and $j \succcurlyeq i$, are allowed, but only occur if $v_i = v_j$.

Definition 3. *The* impact factor *(Garfield, 1955) ranks according to* $\mathrm{IF}_j = \frac{\sum_{i \in J} c_{ji}}{a_j}$, *where vector a and matrix C contain data for a two-year period.*

Before we present the next two ranking methods, we need an additional assumption and some extra notation. We require the citation matrix C to be *irreducible*: there is no partition of the set of journals J in two sets J_1 and J_2 such that [there are no inter partition citations] or [all inter partition citations are unidirectional, say from journals in J_2 to journals in J_1]. Let A and D_C be diagonal matrices with $\{a_j\}_{j \in J}$ and $\{c_j\}_{j \in J}$ along the diagonal.

Definition 4. *The* invariant method *(Pinski and Narin, 1976) ranks according to the vector v that solves*

$$A^{-1}CD_C^{-1}Av = v. \tag{1}$$

Definition 5. *The* LP method *(Liebowitz and Palmer, 1984) ranks according to the vector v that solves*

$$A^{-1}Cv = v. \tag{2}$$

It is known that both the invariant method and the LP method are well defined for irreducible matrices (Palacios-Huerta and Volij, 2004).

3   Article-Splitting

Next we introduce a basic desirable property of a ranking method: invariance to article-splitting. When we refer to an article's citations, we consider both citations sent (that we interpret as an article's "consumption") and received (that we interpret as an article's "production" which was consumed by other articles). We do not measure the length of a paper in terms of pages or characters. Length is indicated by the number of citations sent and received, which, we assume are both evenly spread in a journal. In particular, we assume that if a paper is split into k sub-papers, the citations are split evenly among them.[1] Our invariance property requires that having the split ex-post or ex-ante should make no difference. That is, splitting the citations between the sections of a paper, or publishing sub-papers, leave the ranking unchanged.

Formally, let $\lambda_j \in \mathbb{R}$, $\lambda_j > 1$, be a *split factor* and consider two ranking problems $\{(J, a, C), (J, a', C)\} \subseteq \mathcal{R}$ where for some journal $j \in J$, $a'_j = \lambda_j a_j$ and for all other journals $i \neq j$, $a'_i = a_i$.

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[1]Conversely, if a set of k articles with no overlapping citations and published in the same journal are merged into a single paper, like a survey or a book, then the resulting publication collects all citations.

Definition 6. *A ranking method ϕ is* invariant to article-splitting *if*

$$\phi(J, a, C) = \phi(J, a', C).$$

Observe that the citation matrix is not affected: the number of citations does not change, they are only distributed among more papers. The property thus relates ranking problems implicating journals having similar citation patterns but publishing different numbers of articles.

Definition 7. *A ranking method ϕ is* biased against article-splitting *if*

$$\phi_j(J, a, C) > \phi_j(J, a', C).$$

In the following we show that none of the listed ranking methods is invariant to article-splitting.

Proposition 1. *The impact factor is not invariant to article-splitting.*

Proof. Given journal j has a valuation IF_j for problem (J, a, C) covering data for the past two years, consider a modification of the problem where some of j's articles are split and hence $a'_j = \lambda_j a_j$ with $\lambda_j > 1$, while $a'_i = a_i$ for all $i \neq j$. Although this leaves the numerator unaffected, the number of articles goes up. $\text{IF}'_j = \frac{a_j}{a'_j}\text{IF}_j = \frac{1}{\lambda_j}\text{IF}_j$, thus the impact factor decreases. $\qquad \square$

Proposition 2. *The invariant method is not invariant to article-splitting.*

Proof. Let v_j be the valuation of journal j for problem (J, a, C). Then v solves Equation 1. Now consider a modification of the problem where some of j's articles are split and hence $a'_j = \lambda_j a_j$ with $\lambda_j > 1$, while $a'_i = a_i$ for all $i \neq j$. Then v' defined as $v'_j = \frac{1}{\lambda_j}v_j$ and $v'_i = v_i$ for $i \neq j$ is the solution of Equation 1, that is $A'^{-1}CD_C^{-1}A'v' = v'$. In order to see this, pre-multiply by A' and observe that $A'v' = Av$. Finally observe that as $\lambda_j > 0$, $v'_j < v_j$, while the valuations of other journals have not changed. $\qquad \square$

Proposition 3. *The LP method is not invariant to article-splitting.*

Proof. Using a similar technique as Roy, Saberi, and Wan (2008), we show that an increase (decrease) in the number of articles of a journal will decrease (increase) its valuation. All else equal, let journal j increase the number of its articles per issue from a_j to a'_j, i.e., $a'_j = \lambda_j a_j$ with $\lambda_j > 1$, while for all $i \neq j$, $a'_i = a_i$. Thus, Equation 2 becomes:

$$A'^{-1}Cv' = v' \tag{3}$$

Note that Equations 2 and 3 are algebraic eigenvalue problems. Let $\Gamma = A^{-1}C$ and $\Gamma' = A'^{-1}C$. Let $\varrho(\Gamma)$ denote the spectral radius of Γ and let v denote the eigenvectors associated with $\varrho(\Gamma)$. Similarly, we use $\varrho(\Gamma')$, Γ', v'. Since the matrix Γ is irreducible, Γ' is also irreducible and Equation 3 is well defined. Using the newly introduced notation, we rewrite Equations 2 and 3 as $\Gamma v = \varrho(\Gamma)v$ and $\Gamma'v' = \varrho(\Gamma')v'$. Observe that Γ and Γ' are obtained from the same citation matrix C which is pre-multiplied by A^{-1} respectively A'^{-1} and that for all $i \in J$, $a'_i \geq a_i$. Hence, Γ' is weakly smaller in every entry than Γ and therefore $\varrho(\Gamma) = \varrho(\Gamma') + \delta$ for some $\delta > 0$.

We scale v' such that $v'_j = v_j$ and rewrite v'^T as $\overline{v}^T = v^T - x^T = [v_1 - x_1, ..., v_j - x_j, ..., v_i - x_i]$ where $x \in \mathbb{R}^{|J|}$, such that $x_j = 0$. Thus, $\Gamma'\overline{v} = \varrho(\Gamma')\overline{v}$ and replacing $\overline{v}$ and $\varrho(\Gamma')$:

$$\Gamma'v - \Gamma'x = \varrho(\Gamma)v - \delta v - \varrho(\Gamma')x \tag{4}$$

Let v_{-j}, $\overline{v}_{-j}$, x_{-j} be the valuation vectors except for journal j. Similarly, let Γ_{-j} and Γ'_{-j} be the matrices Γ and Γ' where we removed row and column j and note that $\Gamma_{-j} = \Gamma'_{-j}$. Dropping the j'th equation from the system of Equations 4 and using that $\Gamma v = \varrho(\Gamma)v$ we obtain:

$$\Gamma_{-j}x_{-j} = \delta v_{-j} + \varrho(\Gamma')x_{-j}. \tag{5}$$

which can be rearranged to $(\varrho(\Gamma')I - \Gamma_{-j})x_{-j} = -\delta v_{-j}$. Minc (1988, Theorem 5.1 and Theorem 5.2, Chapter 1) shows that the spectral radius of an irreducible matrix is greater than the spectral radius of any of its submatrices. Hence, $\varrho(\Gamma') \geq \varrho(\Gamma'_{-j}) = \varrho(\Gamma_{-j})$. The matrix $M = (\varrho(\Gamma')I - \Gamma_{-j})$ is an M-matrix. Therefore, M^{-1} is positive. (For a reminder of M-matrices and their properties see Minc, 1988, Definition 4.1, Theorem 4.5, Chapter 6). Observing that v_{-j} is positive, x_{-j} has to be negative. Hence, $\overline{v}_j = v_j$ and for all $i \neq j$, $\overline{v}_i > v_i$. Rescaling $\overline{v}$ to v', we have $\frac{v'_j}{v'_i} < \frac{v_j}{v_i}$. $\qquad \square$

Theorem 1. *The impact factor, the invariant method and the LP method are biased against article-splitting.*

Proof. We have shown that for the impact factor and for the invariant method the valuation of a journal j whose articles are split into λ_j decreases by a factor of $\frac{1}{\lambda_j}$. Note that for an appropriate choice of λ_j it can be arbitrarily low. In particular, it can be lower than the valuation of the journal ranked next, thus changing also the relative order of the journals. For the LP method, we have shown that an increase in the number of articles of journal j decreases its relative weight that can lead to the same effect. $\qquad \square$

The following example shows that the bias against article-splitting affecting the ranking methods might also induce changes in the relative ordering of the journals:

Example 1. Let $J = \{j_1, j_2, j_3\}$, $a = (2, 2, 3)$, $a' = (4, 2, 3)$ and define C as:

$$C = \left(\begin{array}{ccc} 12 & 8 & 4 \\ 6 & 10 & 2 \\ 3 & 3 & 9 \end{array} \right)$$

Let $R = (J, a, C)$ and $R' = (J, a', C)$ be two ranking problems and note that the only difference between R and R' is that $a'_1 = \lambda_1 a_1$, with $\lambda_1 = 2$. For each problem R and R', the following table presents the vector of valuations produced by each of the ranking methods investigated.[2]

	$\phi_{IF}(R)$	$\phi_{IF}(R')$	$\phi_{IM}(R)$	$\phi_{IM}(R')$	$\phi_{LP}(R)$	$\phi_{LP}(R)$
j_1	0.46	0.30	0.48	0.31	0.50	0.29
j_2	0.35	0.45	0.33	0.44	0.37	0.51
j_3	0.19	0.25	0.19	0.25	0.13	0.20

Table 1: Article-splitting bias in ranking methods inducing changes in the relative ordering of the journals.

Note that for R, all ranking methods induce the ordering $j_1 \succ j_2 \succ j_3$, while for R', all ranking methods induce the ordering $j_2 \succ j_1 \succ j_3$.

4 Conclusion

We find that the most widely used methods to rank academic journals share a common drawback as they cannot distinguish quality from quantity at the paper level, which might create a bias against journals with briefer communications. One must therefore use and interpret those rankings with care when estimating the *quality* of journals.

Not all ranking methods are subject to such bias. In the case of the H-index (Hirsch, 2004; Braun, Glänzel, and Schubert, 2005) it is easy to see that article-splitting has an ambiguous effect, while the tournament method (Kóczy and Strobel, 2007) is by definition invariant to article-splitting. Further work is due to understand more about the properties and interpretations of different ranking methods.

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[2]Since in this example we are interested only in relative values, for each method we have normalized the vector of valuations so that they add up to 1.

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