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An annual JCR impact factor calculation based on Bayesian credibility formulas

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ABSTRACT

Our aim deals with appraising the annual impact calculation of journals belonging to the JCR, in terms of the expected citation (with or without selfcitations) by published paper in a range of *k*-years. A Bayesian approach to the problem, should reflect not only the current prestige of a journal, but also taking into account its recent trajectory. In this wide context, credibility theory becomes an adequate mechanism deciding whether journal's impact factor calculation to be more or less plausible. Under prior belief that journal quality is determined by its impact factor, we model the citation-quality process by choosing a conjugated family of the exponential class in order to obtain a net impact credibility formula. Proposed weighting schema produces the effect of smoothing out any sudden increases or decreases in the year-by-year impact factor.

1. Introduction

The use of citation analysis has been advocated to provide a quantitative mean to measure the impact of the published scientific journals (this topic has been widely treated by authors like King (1987), Porter, Chubin, and Jin (1988) or Van Leeuwen (2012)). Garfield (1955) proposed the concept of journal impact factor (IF) for journal evaluation reported annually by Thomson Reuters, and which is currently one of the most frequently used scientometric index (Thomson Scientific, 2011).

The IF of a journal reflects the frequency with which journal papers are cited in scientific literature, being a quotient the numerator of which is the number of citations in the current year to items published in the previous two (or five) years; the denominator is the number of substantive articles published within the same two (or five) years.

However, serious problems arise in using these indices (Cronin, 1984; Garfield, 1979; Gilbert, 1978; Macroberts & Macroberts, 1989). One is the variability of these rankings of journals in the same subject category, reflecting the variability of the number of the annual citations received by the scientific works published in the journals. Often such a fluctuation is due to sudden changes in editorial policies of the journals toward getting a higher IF, for instance by deciding not to publish specialized papers devoted to small audiences and unlikely to be cited. Amin and Mabe (2000) list all the important features and practical problems concerning the IF.

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Vanclay (2012) criticizes Thomson Reuters for the errors and limitations which may be attributed to IF. According to Vanclay the necessary statistical measures (mean, median, standard deviation, etc.) referring to the IF of journals fail from JCR, Thomson Reuters, and there is given no distribution of the citations among the publications of journals.

For Mutz and Daniel (2012), the IF may profit from its comprehensibility, robustness, methodological reproducibility, simplicity, and rapid availability, but it is at the expense of serious technical and methodological flaws.

Habibzadeh and Yadollahie (2008) propose the "weighted impact factor" instead of IF. For the calculation of the impact factor, they not only take into account the number of citations, but also incorporate a factor reflecting the prestige of the citing journals relative to the cited journal.

We do not disagree at all with the fact that the average citation per published paper should be the main indicator to decide the impact of a journal (in fact, we emphasize that this mechanism should be an adequate indicator), but we strongly support the idea that some prior information (e.g. previous IF) should have a weight in its calculation, and it would be desirable measuring "how credible" is this indicator. Credibility theory was originally developed in actuarial sciences (starting by Whitney, 1918) to determine risk premiums, as a convex linear combination of the the individual experience and a prior belief on the collective. Bailey (1945) showed that credibility formulas may be derived from Bayes theorem, and further Bayesian techniques were introduced in a big way in the late 1960s when Bühlmann (1967, 1969) laid down the foundation to the empirical Bayes credibility approach, which is still being used extensively.

Roughly speaking, we claim for a simply computed credibility formula of the impact of a journal combining both the IF and a "prior belief" I_0, betting by the IF whether we would have a lot of information on the citation behavior of a journal. Otherwise, if the information not to be enough, we should support I_0 as a more credible impact of the journal. Let us formulate the problem rigorously.

The *k-years impact factor* ($k \geq 2$) of a given journal belonging to the JCR (is widely assumed either $k = 2$ or $k = 5$) in the year $z \in \mathbb{Z}$ is defined by

$$\mathrm{IF}_z^k = \frac{m_z}{n_z},$$

where n_z denotes the total number of papers published by the journal in the previous range of k-years $\{z-k, \ldots, z-1\}$, and m_z is the total number of citations received by such n_z papers during the year z by papers belonging to the JCR (with or without considering selfcitations).

Definition 1. A credibility formula is a convex linear combination

$$I_1 = C\mathrm{IF}_z^k + (1-C)I_0, \tag{1}$$

being C an increasing function on n_z called *credibility factor*, bounded from below by 0 and from above by 1, and I_0 is a prior belief elicited from assuming propensity of a paper belonging to the journal to be cited follows a certain distribution of probability.

In accordance with the general estimation principle of "the larger the sample the better", the approach that more accurately should reflect the impact of a journal would be the one based on the larger number of contributing articles. In this sense, a naive approach could argue that the assigned weight should have

$$C \propto n_z, \quad (1-C) \propto n_{z-1} \tag{2}$$

where n_{z-1} is the total number of papers published by the journal in the range $\{z-k-1, \ldots, z-2\}$.

In order to enhance the readability of the manuscript we are outlining briefly the transition among the different sections of the research by highlighting the following:

1.1. Core-ideas

In Section 2 we model the citation process by means of a class of distributions of probability conditioned by a "quality parameter" which determines the propensity of a journal to be cited. We shall pay special attention to the Poisson distribution, an adequate candidate to describe citation phenomena under the assumption that the quality parameter follows a Gamma distribution (a Bayesian perspective to the problem consists on assuming that the quality parameter takes values of a random variable which follows some prior distribution).

Given an observed sample consisting of received citations in a year by papers published in a range of some previous years, we may obtain a posterior distribution of probability of the quality parameter conditioned to such a sample. We are claiming for citation-quality conjugated families, that is, pairs of parametric families such that both the prior and posterior distribution belong to the same family. A highlighting that the pair Poisson–Gamma becomes a conjugated family, i.e., whenever the citation process follows a Poisson distribution with quality parameter following a Gamma distribution, then the posterior distribution follows a Gamma as well.

We conclude this section by setting principles for the impact calculation, i.e., different forms of calculating the impact of a journal by means of a loss function (attributes the error assumed having a prestige indicator and meeting with an amount of citation). Once fixed a principle of impact, we obtain the main magnitudes of this study. The prior impact is the value I_0