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An empirical and theoretical critique of the Euclidean index

Jens Peter Andersen

Danish Centre for Studies on Research and Research Policy, Aarhus University, Bartholins Alle 7, Dk-8000 Aarhus C, Denmark

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ABSTRACT

The recently proposed Euclidean index offers a novel approach to measure the citation impact of academic authors, in particular as an alternative to the *h*-index. We test if the index provides new, robust information, not covered by existing bibliometric indicators, discuss the measurement scale and the degree of distinction between analytical units the index offers. We find that the Euclidean index does not outperform existing indicators on these topics and that the main application of the index would be solely for ranking, which is not seen as a recommended practice.

In a recent paper, Perry and Reny (2016) propose an indicator of the impact of individuals, designed to provide a more rigorous approach hereto than the *h*-index which has been a de facto standard in several assessment situations, ranging from academic hiring to research grant applications. Their proposed indicator, the Euclidean index, is interpreted as the Euclidean length of the vector composed of the total citation scores of an individual's papers, or in other words the square root of the sum of squares of an author's citations per paper. While the authors claim this to be a new indicator, it is rather a modification of two previously proposed indicators; the *R*-index (Jin, Liang, Rousseau, & Egghe, 2007) and the *e*-index (Zhang, 2009), which use the same general formulation as the Euclidean index, with only minor differences (further details in the methodology). Another variation of close resemblance is the Energy interpretation Prathap (2011). Despite this, the approach used by Perry and Reny (2016) warrants a discussion of this index in particular, and the properties of these types of indices in general.

Perry and Reny (2016) designed their index based on five axioms, which they consider crucial for an indicator of an individual's citation impact, and through two empirical tests, they find that it outperforms the *h*-index with regard to (1) maintaining inter-field rankings after rescaling and (2) matching a ranking of top universities created by the National Research Council (NRC) of the United States of America. The approach of using rigorous, pre-defined axioms for designing scientometric indices is commendable, and the resulting index possesses some qualities, which are obviously missing in the *h*-index, namely their five axioms; monotonicity, independence, depth relevance, scale invariance and directional consistency (Perry & Reny, 2016). However, we will claim that there are two essential discussions which are omitted in this paper, and a number of other papers related to the *h*-index; the validity and ethics of assessing individuals as well as the sufficiency

E-mail address: jpa@ps.au.dk

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of the proposed axioms. We will argue for the former in the following section, followed by a case for the latter, including macro-scale empirical analysis, in the remainder of the paper.

1. Assessment of individuals

All bibliometric research is divided into three parts, one of which is evaluative bibliometrics, descriptive bibliometrics another and referencing studies a third. Evaluative and descriptive bibliometrics may focus on citations or publications and are generally quantitative in nature. For both types of quantitative studies, methodological approaches depend on the aggregation level and thus the unit size being evaluated. Macro-scale studies focus on world- or nation-wide research outputs, meso-level look at large research units, such as universities and possibly university departments, while studies of individual authors are considered micro-scale bibliometric studies. It is essential for any type of quantitative bibliometric study to use these aggregated units of analysis just as well as citation counts are aggregated references, viewing not individual works but the collective works of larger units as the object of study. By doing so, we move from the sometimes arbitrary selections of one reference over another, due to norms, personal relations, availability, etc., to a generalized, statistical view (Van Raan, 1998). Whether these sociological, personal and normative variations at the reference level are actually randomly distributed over large aggregates is debatable (Waltman, Van Eck, & Wouters, 2013), and certainly requires a considerable amount of care, delicacy and large numbers of publications per unit of analysis (Costas, van Leeuwen, & Bordons, 2010; Vinkler, 2007). As a consequence, within the field of bibliometrics, analyses of individuals, or micro-level citation analysis, have focused on more descriptive elements, such as collaborative networks or factors influencing productivity (Costas et al., 2010) or as a support tool for informed peer-review (Aksnes & Taxt, 2004). Traditionally, ranking algorithms and hard impact assessments have not been applied to micro-level aggregates, such as authors, due to the sensitivity of indicators to even fairly small outliers when regarding small samples. Since the publication of the *h*-index (Hirsch, 2005), there has been a growing attention on the dangers of assessment on the individual level and the potential influence on the research process (Van Raan, 2006; Vinkler, 2007) but also a large number of papers utilizing and attempting to improve the *h*-index (Bornmann, Mutz, & Daniel, 2008; Braun, Glänzel, & Schubert, 2006; Glänzel & Moed, 2012; Moed, 2009). Perry and Reny (2016) are also critical towards the concept of evaluating individuals through citation counts, and the *h*-index in particular, yet maintain that these assessments are a matter of fact:

> [Citation indices] are regularly used to inform critical decisions about funding, promotion and tenure. With decisions of this magnitude on the line, one should approach the problem of developing a good index as systematically as possible. (Perry & Reny, 2016, 2722)

We should certainly take into account those practices that are currently part of the norms of various scientific disciplines (de Rijcke & Rushforth, 2015; Hicks, Wouters, Waltman, de Rijcke, & Rafols, 2015; Rushforth & de Rijcke, 2015), and the types of indicators which are used and understood outside the sciento- and bibliometric fields, e.g. by funders, managers or scientists themselves (Leydesdorff, Wouters, & Bornmann, 2016). In assessing and developing new indicators, we should thus consider if they are tools for use of bibliometricians or end-users. The Euclidean index is clearly aimed at the latter, and it should therefore also be clearly understandable and interpretable by these.

2. Assessment of indicators

As mentioned above, Perry and Reny (2016) apply an axiomatic approach to indicator design, basing the justification of the Euclidean index on five, mathematical requisites for a bibliometric indicator of individual, scholarly impact. These axioms – monotonicity, independence, depth relevance, scale invariance and directional consistency – are common, mathematical requirements for good measurements, and the authors argue well for the properties of the Euclidean index and how the index performs better than the *h*-index at ranking economics scholars. However, the authors have not tested the performance of their indicator against basic bibliometric units, nor other existing indicators, and it is thus unclear whether this new indicator even offers new or more robust information. The only empirical test performed is on the ranking ability of the indicator versus the *h*-index, compared to a peer-produced ranking. As it has been recommended that ranking should not be performed on the individual level (Costas et al., 2010; Van Raan, 2006; Vinkler, 2007), this practice should be avoided, and will not be pursued further in this paper, which will instead focus on the basic properties of all bibliometric indicators; size and impact. These two factors have been identified by Leydesdorff (2009) and Bollen, Van de Sompel, Hagberg, and Chute (2009) as the main categories in which the majority of bibliometric indicators can be arranged into. The *h*-index and its derivatives are most clearly separated from these two factors, although not necessarily for the better (Bollen et al., 2009; Leydesdorff, 2009; Perry & Reny, 2016; Waltman & Van Eck, 2012). The introduction of a new citation-based bibliometric indicator should provide new information or insight, in order to not be redundant. Alternatively, new indicators can seek to provide more precise or robust information on aspects of scientific outputs, thus replacing existing indicators. Both the novelty and robustness of the Euclidean index will be tested empirically and theoretically in this paper; in comparison with basic units as well as the *h*-, *R*- and *e*-indices, which are the most closely related indicators.

Also the ordinality of the Euclidean index will be discussed, in particular with regard to distinguishing between two units of analysis. This is a problematic aspect of the index, as Perry and Reny (2016) claim the index can be used not only for ranking, but also for general statements about the underlying distributions, or at least comparisons between distributions.