A Simple Impact Measure and Its Evolution over Time

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Abstract

We propose a simple informetric measure, called the D-measure, for research performance. This index provides a new approach to combine publications and citations. It is related to Kosmulski's index for successful papers. We provide an attractive visualization of the evolution of these indices as trajectories in the plane.

Keywords: Informetric Measures; Dynamic Aspects; Visualization; D-measure; K-indicator

1. Introduction

Publications and citations are two basic units for research evaluation studies. Yet, complicated ratios such as used in the crown indicator may lead to problems (Lundberg, 2007; Opthof & Leydesdorff, 2010). Although improvements have been proposed (Waltman, van Eck, van Leeuwen, Visser & van Raan, 2011a), the problem is not completely solved (Waltman, van Eck, van Leeuwen, Visser & van Raan, 2011b).

Another simple indicator also based on publications and citations, namely the h-index, was introduced in 2005 (Hirsch, 2005). This indicator has quickly been applied as an academic measure for research performance (Alonso, Cabrerizo, Herrera-Viedma & Herrera, 2009; Egghe, 2010) and has led to a simple and meaningful unification of publications and citations (Ye, 2009; Ye, 2011). Yet, it has been shown that the h-index is logically flawed in the sense that in a static time window it is not independent (Marchant, 2009) - or not consistent in the terminology of (Waltman & van Eck, 2011). Even simple ratios as used in the impact factor or in the CpP (citations per publication) indicator are not always intuitively clear (Rousseau & Leydesdorff, 2011) as they too are not independent. We recall that an indicator IND is said to be independent if the following holds: Scientist A (represented by her publication-citation list) is considered to be at

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least as good as scientist B (also represented by a publication-citation list), hence IND (A) ≥ IND (B), and one adds the same publication (with the same number of citations) to the publication lists of A and B, then IND (A') ≥ IND (B'), where A' and B' denote scientists A and B to which this same publication has been added. A more recent approach, evading the use of averages is the I3 indicator as proposed by Leydesdorff and Bornmann (2011).

In this contribution we focus on a simple visual representation of the numbers of publications and received citations. We do not apply tests of hypothesis and we do not have direct applications for research evaluation in mind. We hope though that our visualizations may be of benefit during peer review exercises.

2. The D-measure as a simple publication-citation measure

Different parts of research can be considered as input-output systems. In (Liang & Rousseau, 2008) an article's references (or the references of a group of articles) are considered as inputs and subsequent citations of the article or group of articles as outputs. It is observed that in this framework inputs are fixed but outputs grow dynamically over time, leading to the yield indicators introduced by them. These indicators focus on the time needed to receive the same number of citations as the number of references given. Kosmulski (2011) introduced so-called successful papers as those for which the number of received citations (C) is at least equal to the number of given references (R). Hence he studied the difference K = C - R. We apply his concept also to groups of papers.

Similarly one may consider a set of articles, e.g. those published in a journal, or those written by a scientist or research group, and consider the difference, D, between the number of citations received (C), and the number of articles published (P): D = C-P, calculated over given publication and citation windows. The interesting aspect is that D always starts negatively (or at zero in the case the observation period begins before the first publication) and depending on the citation window and the particular article set may end positively.

As simple measures D and K are independent in the sense that if $D_1 \geq D_2$ and one adds the same number of publications (X) (hence with the same number of citations, Y) to the two sets then for the new values of the D-measure, denoted as D', one also has $D'_1 \geq D'_2$. Indeed if $D1 = C_1 - P_1 \geq C_2 - P_2$, then $D'_1 = (C_1 + Y) - (P_1 + X) \geq (C_2 + Y) - (P_2 + X) = D'_2$. A similar reasoning holds for K = C - R.

Note that, as with other time series (Liu & Rousseau, 2008), several versions of the D-measure may be considered, depending on the used publication and citation window. Which one is used must always be specified.

3. A simple visualization of the citation yield over time of a set of publications

In this section we visualize the difference D(t)=C(t)-P(t) as a function of time t. The value D(t)=C(t)-P(t) is placed on the y-axis, while time is placed on the x-axis.

The change of D over time can now be visualized as a trajectory in the plane. When the first article in the set under study is published this will be represented by a point on the negative y-axis (time = 0, one publication but no citations). Yet, one may start the trajectory one time unit before the first event so that it always starts in the origin, see Figure 1. The next time unit (a month, six months, a year) this point may or may not move to the positive axis depending on the fact if this publication has been cited. Of course, if the set of articles under study has grown and no citations have been received then the trajectory may even move more away from the x-axis. Often, however, the number of citations is much larger than the number of publications. For this reason we suggest using different scales: one for the positive y-axis and one for the negative y-axis. Also K = C-R can be represented in this way. If K is calculated for just one article and t=0 corresponds to the publication of this article, then the corresponding curve begins below the x-axis (at the point -R) and is non-decreasing.

4. Some modeling aspects

If Heaps' or Herdan's law holds (Egghe, 2007), this means that a relation of the following form is valid:

$$C = kP^{\beta} \qquad (1)$$

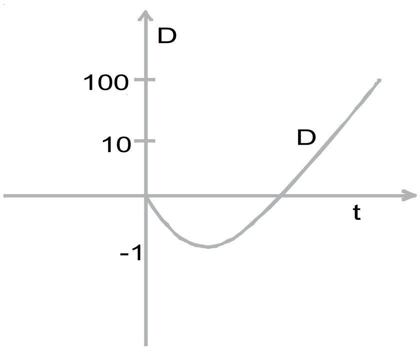

Figure 1. A general illustration of D(t) in the case that the observation period begins before the first publication, different scales are used on the positive and the negative vertical axis

where k is a multiplicative constant and $\beta > 0$ denotes a power exponent. This relation is an empirical law originally observed in linguistics. In that context C denotes the number of different words and P denotes the size of the text. Yet, Egghe (2007) has considered relation (1) in a general informetric context. Then T can be replaced by C (citations) and A by P (publications). Equation (1) can be rewritten as

$P = mC^{-\beta}$ (2)

where $m = (1/k)^{-\beta}$.

When Heaps' or Herdan's law holds $D = C - P = C - a\,C^{-\beta} = C\,(1 - a\,C^{-(1+\beta)})$. Depending on the values of a and $\beta > 0$, D is positive or negative.

5. Dynamic aspects

Assume that P(t) and C(t) are linear functions:

$P(t) = at+1$ (3)

$C(t) = bt$ (4)

then $D(t) = (b-a)t-1$

When b > a, D(t) quickly becomes positive; while when b < a D(t) falls completely on the negative side. This is illustrated in Figure 2.

If P(t) is a linear function and C(t) is a second order power function:

$P(t) = at+c$ $a > 0, c > 0$ (typically $c = 1$) (5)

$C(t) = bt^2$ $b > 0$ (6)

Then D(t) becomes

$D(t) = bt^2 - at - c$ (7)

In this case D(t) can be negative for small values of t, but will certainly be positive for large values of t as $D'(t) = 2bt-a$. Figure 3 illustrates the case a = 0.5, b = 0.1 and c = 1.

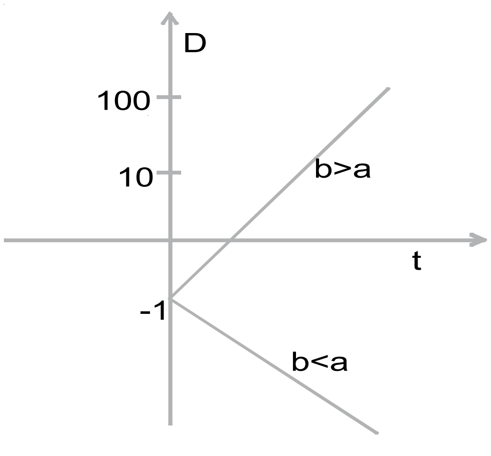

Figure 2. Evolutional plane of linear P(t) and C(t) functions

6. Examples

As examples we consider the publications and citations of Ye and Rousseau since 2007. For the two cases the publication and citation windows coincide and consist of the period [2007-2010]. Ye's publication and citation data in the SSCI are shown in Table 1.

The corresponding evolutional plane is shown in Figure 4.

Rousseau's publications and citations data in the Web of Science (WoS) are shown in Table 2.

The corresponding evolutional plane is shown in Figure 5. This is an example where scales really must be adapted.

The D-measure can also be used for journals. As an example we consider *Acta Mathematica Scientia* (ISSN 0252-9602, SCI edition 2010). We use a publication window of five years and a citation window of one year, namely 2010, i.e. we only considered citations received in the year 2010. The corresponding evolutional plane is shown in Figure 6. We notice that it stays completely below the horizontal axis. We note that all journals with IF(5) < 1 and using the corresponding publication and citation windows lead to a curve below the horizontal axis.

Finally, we also provide an example of a visualization of the K-indicator. We consider all publications by R. Rousseau, published in 1997 and included in the WoS. There are 4 such publications, with in total 58 references (not necessarily different). This is an example where the publication window is one fixed year (1997) while the citation window is [1997-2011] and hence K(t) is intended to increase with time. Figure 7 shows the evolution of K(t) = C(t) - R, with R = 58. Among those 4 publications two can be considered successful in the sense of Kosmulski (2011) as they received

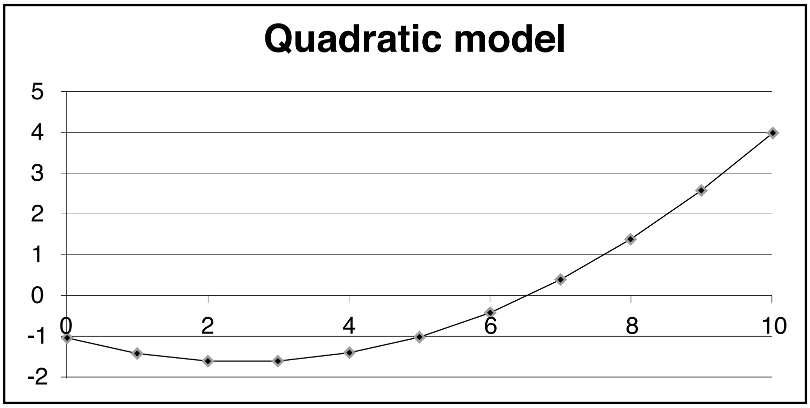

Figure 3. Evolutional plane of linear P(t) and a quadratic C(t) function

Table 1. Ye's data in SSCI, with values of the D-measure

t	2007	2008	2009	2010
P	1	2	3	4
C	0	1	8	10
D	-1	-1	5	6

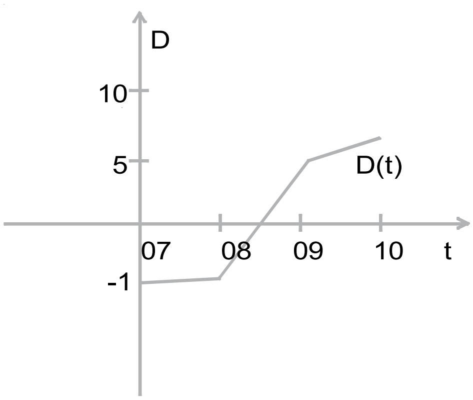

Figure 4. Ye's evolutional D-curve

Table 2. Rousseau's data in WoS, with values of the D-measure

t	2007	2008	2009	2010
P	9	21	38	47
C	5	50	145	305
D	-4	49	107	258

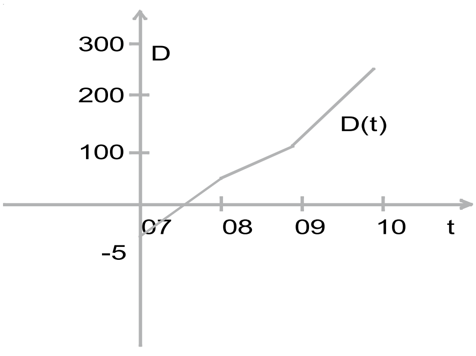

Figure 5. Rousseau's evolutional D-curve

Table 3. ***Acta Mathematica Scientia's*** **data in JCR, with values of the D-measure**

t	2005	2006	2007	2008	2009
P	83	167	254	353	489
C	31	81	123	149	173
D	-52	-86	-131	-204	-316

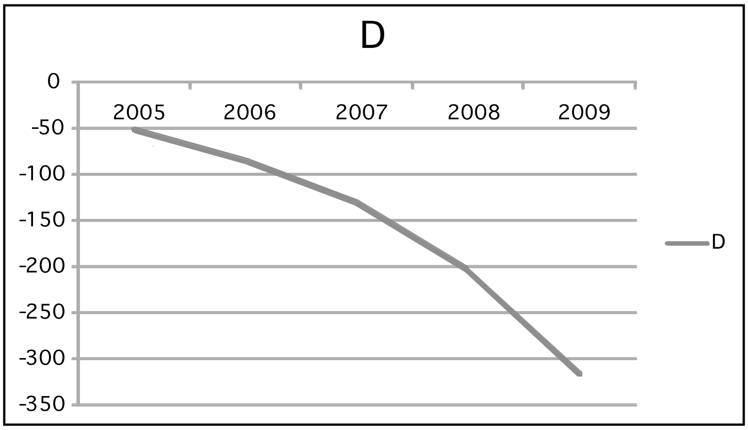

Figure 6. ***Acta Mathematica Scientia's*** **evolutional D-curve**

more citations than the number of references they contain. Yet, as a whole this group of publications cannot (yet) be considered as successful. Note that, as R is fixed K(t) cannot decrease.

7. Discussion and conclusion

In this article we have studied the D-measure, where D = P-C, as a function of time, and note that different publication and citation windows lead to different time series. We could have considered other simple combinations of C and P such as P+C or C × P. Yet we consider P+C a less intuitive measure as D as D is a kind of difference between input and output, while C × P is not independent (consistent). Indeed if $C_1 = 2$, $P_1 = 5$, $C_2 = 4$ and $P_2 = 3$ then $C_1 \times P_1 = 10 < C_2 \times P_2 = 12$. Adding 1 publication with ten citations to both leads to $(2+10) \times (5+1) = 72 > (4+10) \times (3+1) = 56$. This shows that the product is not independent.

The D measure = C - P and the K measure = C - R have similar characteristics:

1. They are mathematically and computationally simple.
2. They are independent (=consistent)

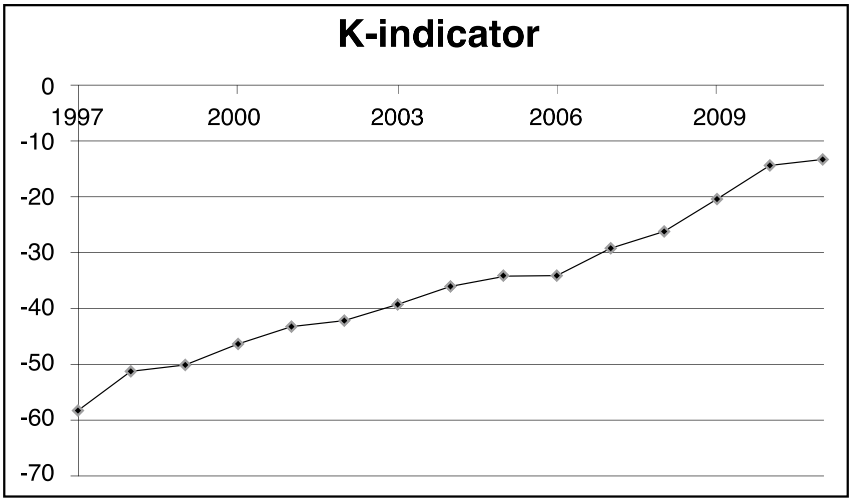

Figure 7. K(t) for Rousseau's 1997-publications

Like any other publication-citation measure they are field and database dependent.

We hope that the use of trajectories as illustrated in this publication for the D and the K indicator may prove useful in further studies. In this way we add a new simple visualization to our toolbox. Recall that previous ones proposed by us include the use of the barycenter method (Jin & Rousseau, 2001; Mahbuba & Rousseau, 2011) and the academic spectra (Ye, 2010).

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Appendix

Instead of D = C-P we tried to use the index

$Y^2 = C^2\text{-}P^2$, with C, P $\in$ [0,∞] (8)

Yet, this index turned out not to be independent (consistent). Indeed, let $C_1 = 9$ and $P_1 = 4$ then author A_1's Y^2 measure is 81-16 = 65. Let $C_2 = 8$ and $P_2 = 1$ then author A_2's Y^2 measure is 64-1 = 63. Hence author A_1 is considered to be the better one.

Assume now that these authors collaborate on an article, which has no citations. Then for the new situation we have:

$C_1 = 9$ and $P_1 = 5$, hence the new Y^2 measure of author A_1 is 81-25 = 56, while $C_2 = 8$ and $P_2 = 2$, hence the new Y^2 measure of author A_2 is 64-4 = 60. Hence author A_2 became better than author A_1.

Hence the Y measure is not consistent. We were attracted to it as it leads to other measures such as the academic angle defined as:

$$\theta = \arccos\frac{P}{C} = \arcsin\frac{Y}{C} = \arctan\frac{Y}{P} \in (-\frac{\pi}{2}, \frac{\pi}{2}) \quad (9)$$

where $\theta \subset (0, \pi/2)$ corresponds to the real branch and $\theta \subset (-\pi/2, 0)$ to the imaginary branch of Y.