Disruptive papers published in Scientometrics: meaningful results by using an improved variant of the disruption index originally proposed by Wu, Wang, and Evans (2019)

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Abstract

Wu et al. (Nature 566:378–382, 2019) introduced a new indicator measuring disruption (DI_1). Bornmann et al. (Do disruption index indicators measure what they propose to measure? The comparison of several indicator variants with assessments by peers, 2019. <https://arxiv.org/abs/1911.08775>) compared variants of the disruption index and pointed to DI_5 as an interesting variant. The calculation of a field-specific version of DI_5 (focusing on disruptiveness within the same field) for *Scientometrics* papers in the current study reveals that the variant is possibly able to identify landmark papers in scientometrics. This result is in contrast to the *Scientometrics* analysis previously published by Bornmann and Tekles (Scientometrics 120(1):331–336, 2019) based on the original disruption index (DI_1).

Key words Bibliometrics · Disruption index · Citation analysis · Scientometrics

Recently, a new indicator measuring disruption has been introduced (Funk and Owen-Smith 2017; Wu et al. 2019). This indicator is connected to the ‘scientific revolutions’ concept of Kuhn (1962) and tries to identify exceptional research which is characterized by an overthrow of established thinking (Casadevall and Fang 2016). The indicator is based on combining cited references of citing papers with cited references data of a focal paper (FP).

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The disruptiveness of a FP is determined by the extent to which the cited references of the papers citing the FP overlap with the cited references of the FP. Disruptiveness is indicated if many citing papers do not refer to the FP's cited references. Then, it seems that the FP presents something new which is independent of the context of the FP.

Disruptiveness is described by Wu et al. (2019) as a weighted index DI_l (see Fig. 1) calculated for a FP: the difference between the number of papers citing the FP without citing any of its cited references (N_i) and the number of papers citing both the FP and at least one of its cited references (N_j^l) is divided by the sum of N_i , N_j^l , and N_k . N_k is the number of papers citing at least one of the FP's cited references without citing FP itself. Wu et al. (2019) claim that disruptive research is reflected in high positive values; developmental research continuing previous research directions is indicated by small negative values.

Bornmann et al. (2019) discussed and empirically investigated DI_l and some variants. They followed the idea of considering how strong the cited references of the FP's citing papers are coupled with the cited references of the FP. This is converted in the formula in Fig. 1: the subscript of DI_l corresponds to the threshold for the number of bibliographic coupling links. With $l = 1$, there is no restriction on the number of bibliographic coupling links which corresponds to the originally proposed index by Wu et al. (2019); $l = 5$ means that a threshold of five bibliographic coupling links is used. Bornmann et al. (2019) compared (among other indicators measuring disruption) the variants DI_1 and DI_5 . The empirical results show that DI_5 might be better able than DI_1 (and also better than the other indicators) to identify disruptive research. Thus, we took this indicator as a starting point for a modified variant which allows to focus on disruptive effects in a certain field.

Fig. 1 Different roles of papers in citation networks (see Wu and Wu 2019) for calculating the disruption index DI_1 (Wu et al. 2019) and DI_5 (Bornmann et al. 2019)

Table 1 *Scientometrics* papers with the highest DI_3 values (calculated based on the field-specific variant of (DI_3))

DI_3	Title	Author (publication year)	Citation count	Number of cited references
0.051093439	Citation review of Lagergren kinetic rate equation on adsorption reactions	Ho (2004)	1015	36
0.028654124	Advanced bibliometric methods as quantitative core of peer review based evaluation and foresight exercises	van Raan (1996)	228	10
0.026822157	The use of multiple indicators in the assessment of basic research	Martin (1996)	197	15
0.02572998	Problems of citation analysis	MacRoberts and MacRoberts (1996)	300	22
0.018650089	Bibliometric performance measures	Narin and Hamilton (1996)	115	10
0.015997388	Research profiling: Improving the literature review	Porter, Kongthon, and Lui (2002)	83	30
0.013426978	Scientometrics: State-of-the-art	van Raan (1997)	104	14
0.010502133	International visibility of Chinese scientific journals	Ren and Rousseau (2002)	63	15
0.010488777	The difficulty of achieving full coverage of international social science literature and the bibliometric consequences	Hicks (1999)	183	24
0.009913738	The literature of bibliometrics, scientometrics, and informetrics	Hood and Wilson (2001)	260	30
0.009690331	A bibliometric analysis of international scientific cooperation of the European Union (1985–1995)	Glänzel, Schubert, and Czerwon (1999)	112	11
0.008210181	Fatal attraction: Conceptual and methodological problems in the ranking of universities by bibliometric methods	van Raan (2005)	387	19
0.007471608	Cross-field normalization of scientometric indicators	Schubert and Braun (1996)	95	12
0.006994585	Using the curriculum vita to study the career paths of scientists and engineers: An exploratory assessment	Dietz et al. (2000)	92	20
0.006735519	What is special about patent citations? differences between scientific and patent citations	Meyer (2000)	130	11
0.005461283	Determinants of research productivity	Babu and Singh (1998)	49	27
0.004479448	Software survey: VOSviewer, a computer program for bibliometric mapping	van Eck and Waltman (2010)	1034	28
0.004477612	Science in America Latina: A comparison of bibliometric and scientific-technical indicators	de Moya-Anegon and Herrero-Solana (1999)	53	22
0.00423341	Bibliometric analysis of homeopathy research during the period of 1991 to 2003	Chiu and Ho (2005)	109	13

Table 1 (continued)

<i>DI</i> ₅	Title	Author (publication year)	Citation count	Number of cited references
0.004070981	Global knowledge management research: A bibliometric analysis	Gu (2004)	62	28

We calculated this variant for all papers published in *Scientometrics* and compared the results with DI_1 . Bornmann and Tekles (2019) calculated DI_1 for *Scientometrics* papers and showed a “concentration of disruption values around zero” (p. 332). Most of the papers identified by Bornmann and Tekles (2019) with the highest DI_1 values could not be characterized as landmark papers in the scientometrics field using manual inspection. To focus with DI_5 in this study on the scientometrics field, we defined N_j^l and N_k based on all papers cited by any paper published in *Scientometrics* in the same year as the FP instead of the FP’s cited references. The corresponding definitions of N_j^l and N_k are as follows:

- N_j^l : Number of papers citing the FP, and at least l of the cited references of all *Scientometrics* papers published in the same year as the FP
- N_k : Number of papers citing at least one of the cited references of all *Scientometrics* papers published in the same year as the FP, but not the FP itself

Table 1 shows the twenty *Scientometrics* papers with the highest DI_5 values (to base the values on reliable data, we considered only papers with at least 10 cited references counts). We selected all publications in *Scientometrics* available in Scopus for the years 1996–2015 (2145 papers with at least 10 cited references). As the values reveal, they are still close to zero. This is similar to the results based on DI_1 . However, the comparison of both results (DI_1 and DI_5) points out different foci: as Bornmann and Tekles (2019) reveal, DI_1 mostly brings out scientometrics papers with local focus (e.g., issues rooted in countries such as Iberian-American countries, Korea, or Iceland). DI_5 is more focused on basic scientometric papers which focus on bibliometric performance measures or state-of-the-art scientometrics. For example, Narin and Hamilton (1996) discuss “three different types of bibliometrics—literature bibliometrics, patent bibliometrics, and linkage bibliometric” (p. 293).

van Raan (1996) “gives an overview of the potentials and limitations of bibliometric methods for the assessment of strengths and weaknesses in research performance, and for monitoring scientific developments” (p. 397). Martin (1996) is a landmark paper in scientometrics discussing how government-funded basic research can be evaluated using different indicators. The paper by MacRoberts and MacRoberts (1996) is one of the core papers in the critical discussion of evaluative citation analyses. Ho (2004)—the paper with the largest DI_5 —demonstrated the problem of citation analysis by focusing on the reception of an equation published in one paper. The results show that “all of the examined references from the literature review in this study were incorrect for referencing Lagergren’s equation” (p. 175).

Taken as a whole, the results in Table 1 reveal that the field-specific variant of DI_5 may be better able than the original variant of DI_1 to identify disruptive papers which concentrate the attention of researchers within a discipline. This suggests that focusing on the citation links in a specific field (here: scientometrics as represented by the journal *Scientometrics*) is a promising approach for improving existing disruption indicators. Further exploration on a variety of datasets, journals, and disciplines is certainly needed to elucidate this possibility.

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References

- Babu, A. R., & Singh, Y. P. (1998). Determinants of research productivity. *Scientometrics*, 43(3), 309–329.
- Bornmann, L., Devarakonda, S., Tekles, A., & Chacko, G. (2019). Do disruption index indicators measure what they propose to measure? The comparison of several indicator variants with assessments by peers. Retrieved December 6, 2019, from <https://arxiv.org/abs/1911.08775>.
- Bornmann, L., & Tekles, A. (2019). Disruptive papers published in *Scientometrics*. *Scientometrics*, 120(1), 331–336. <https://doi.org/10.1007/s11192-019-03113-z>.
- Casadevall, A., & Fang, F. C. (2016). Revolutionary science. *mBio*, 7(2), e00158. <https://doi.org/10.1128/mBio.00158-16>.
- Chiu, W. T., & Ho, Y. S. (2005). Bibliometric analysis of homeopathy research during the period of 1991 to 2003. *Scientometrics*, 63(1), 3–23. <https://doi.org/10.1007/s11192-005-0201-7>.
- de Moya-Anegón, F., & Herrero-Solana, V. (1999). Science in America Latina: A comparison of bibliometric and scientific-technical indicators. *Scientometrics*, 46(2), 299–320. <https://doi.org/10.1007/Bf02464780>.
- Dietz, J. S., Chompalov, I., Bozeman, B., Lane, E. O., & Park, J. (2000). Using the curriculum vita to study the career paths of scientists and engineers: An exploratory assessment. *Scientometrics*, 49(3), 419–442.
- Funk, R. J., & Owen-Smith, J. (2017). A dynamic network measure of technological change. *Management Science*, 63(3), 791–817. <https://doi.org/10.1287/mnsc.2015.2366>.
- Glänzel, W., Schubert, A., & Czerwon, H. J. (1999). A bibliometric analysis of international scientific cooperation of the European Union (1985–1995). *Scientometrics*, 45(2), 185–202. <https://doi.org/10.1007/Bf02458432>.
- Gu, Y. N. (2004). Global knowledge management research: A bibliometric analysis. *Scientometrics*, 61(2), 171–190. <https://doi.org/10.1023/B:SCIE.0000041647.01086.f4>.
- Hicks, D. (1999). The difficulty of achieving full coverage of international social science literature and the bibliometric consequences. *Scientometrics*, 44(2), 193–215. <https://doi.org/10.1007/Bf02457380>.
- Ho, Y. S. (2004). Citation review of Lagergren kinetic rate equation on adsorption reactions. *Scientometrics*, 59(1), 171–177.
- Hood, W. W., & Wilson, C. S. (2001). The literature of bibliometrics, scientometrics, and informetrics. *Scientometrics*, 52(2), 291. <https://doi.org/10.1023/a:1017919924342>.
- Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.
- MacRoberts, M. H., & MacRoberts, B. R. (1996). Problems of citation analysis. *Scientometrics*, 36(3), 435–444.
- Martin, B. (1996). The use of multiple indicators in the assessment of basic research. *Scientometrics*, 36(3), 343–362.
- Meyer, M. (2000). What is special about patent citations? Differences between scientific and patent citations. *Scientometrics*, 49(1), 93–123. <https://doi.org/10.1023/A:1005613325648>.
- Narin, F., & Hamilton, K. S. (1996). Bibliometric performance measures. *Scientometrics*, 36(3), 293–310. <https://doi.org/10.1007/Bf02129596>.
- Porter, A. L., Kongthon, A., & Lui, J. C. (2002). Research profiling: Improving the literature review. *Scientometrics*, 53(3), 351–370. <https://doi.org/10.1023/A:1014873029258>.
- Ren, S. L., & Rousseau, R. (2002). International visibility of Chinese scientific journals. *Scientometrics*, 53(3), 389–405. <https://doi.org/10.1023/A:1014877130166>.

- Schubert, A., & Braun, T. (1996). Cross-field normalization of scientometric indicators. *Scientometrics*, 36(3), 311–324.
- van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 84(2), 523–538. <https://doi.org/10.1007/s11192-009-0146-3>.
- van Raan, A. F. J. (1996). Advanced bibliometric methods as quantitative core of peer review based evaluation and foresight exercises. *Scientometrics*, 36(3), 397–420. <https://doi.org/10.1007/Bf02129602>.
- van Raan, A. F. J. (1997). Scientometrics: State-of-the-art. *Scientometrics*, 38(1), 205–218. <https://doi.org/10.1007/Bf02461131>.
- van Raan, A. F. J. (2005). Fatal attraction: conceptual and methodological problems in the ranking of universities by bibliometric methods. *Scientometrics*, 62(1), 133–143.
- Wu, L., Wang, D., & Evans, J. A. (2019). Large teams develop and small teams disrupt science and technology. *Nature*, 566, 378–382. <https://doi.org/10.1038/s41586-019-0941-9>.
- Wu, S., & Wu, Q. (2019). A confusing definition of disruption. Retrieved May 15, 2019, from <https://osf.io/preprints/socarxiv/d3wpk/>.