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Unpacking the Matthew effect in citations

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ABSTRACT

One problem confronting the use of citation-based metrics in science studies and research evaluations is the Matthew effect. This paper reviews the role of citations in science and decomposes the Matthew effect in citations into three components: networking, prestige, and appropriateness. The networking and prestige effects challenge the validity of citation-based metrics, but the appropriateness effect does not. Using panel data of 1279 solo-authored papers' citation histories and fixed effects models, we test these three effects controlling for unobserved paper characteristics. We find no evidence of retroactive networking effect and only weak evidence of prestige effect (very small and not always significant), which provides some support for the use of citation-based metrics in science studies and evaluation practices. In addition, adding the appropriateness effect reduces the size of the prestige effect considerably, suggesting that previous studies controlling for paper quality but not appropriateness may have overestimated the prestige effect.
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1. Introduction

Citations received by scientific publications are increasingly used as proxies or measures for quality, creativity, and impact in science studies and research evaluations. However, one important issue pertaining to the use of citation-based metrics is the Matthew effect described as "the accruing of greater increments of recognition for particular scientific contributions to scientists of considerable repute and the withholding of such recognition from scientists who have not yet made their mark" (Merton, 1968, p. 58). If citations are unfairly bestowed to papers and individuals in the science reward system, then citation-based metrics should not be used as fair tools for research evaluations.

Many studies have contributed to the understanding of the Matthew effect, in science in general and in citations in particular. "The rich get richer and the poor get poorer." On the one hand, the Matthew effect emphasizes the self-reinforcement or the positive feedback on one aspect or dimension. For example, famous scientists get more fame from their work (Merton, 1968, 1988), already highly-cited papers are more likely to be cited by new incoming papers (Barabasi & Albert, 1999; Krapivsky, Redner, & Leyvraz, 2000; Price, 1976), and richly-funded scientists get more research funds (Laudel, 2006). On the other hand, the mechanism underlying the Matthew effect in science often involves a positive feedback loop between multiple aspects. For example, prestige attracts scientific resources (e.g., talented graduate students and research facilities), which in turn help produce high-quality science and reinforce the prestige (Merton, 1968, 1988). Higher prestige of the author, institution, or journal contributes to higher citation rates of their papers, which in turn constitute the prestige of the author, institution, or journal (Cole & Cole, 1973; Crane, 1965; Judge, Cable, Colbert, & Rynes, 2007; Lariviere & Gingras, 2010; Medoff, 2006). Research systems with a higher level of recognition (as measured by the number of citations) are able

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to attract more resources and grow, and the size raises recognition in a super-linear fashion (Katz, 1999, 2000; van Raan, 2006b). Scientific excellence (measured by the number and nature of publications) and entrepreneurial success (measured by the budget size) reinforce each other (Van Looy, Ranga, Callaert, Debackere, & Zimmermann, 2004).

Previous studies have adopted diverse strategies to test or estimate the Matthew effect. One type of strategy is to carefully control for the intrinsic quality of the paper or the ability of the author and then investigate the effect of certain factors, such as institution/journal/author prestige, on received citations. For example, Crane (1965) found that biologists, political scientists, and psychologists at major universities received higher recognition than equally productive scientists at minor universities. Medoff (2006) controlled for author quality, journal quality, and article characteristics, but still found that economic papers from Harvard University and the University of Chicago received disproportionate citations. Judge et al. (2007) coded and controlled for the originality, methodological aspects, quality of writing, and other attributes of papers published in 21 top management journals, but still found significant effect of journal prestige (measured as the journal citation rates and the quality of the journal rated by experts) on received citations. Lariviere and Gingras (2010) studied duplicate papers published in different journals and revealed that a paper published in a journal with a higher journal impact factor got more citations than the same paper published in a less influential journal. Aizenman and Kletzer (2011) assembled a sample of 428 papers written by 16 well-known economists who died well before retirement, compared citations of these papers with a matched sample of other papers, and found that, for half of the sampled economists, the average missing citations per paper attributed to premature death ranged from 40% to 140%. These findings demonstrate the Matthew effect as a perversion of the science reward system and challenge the validity of citation-based metrics for evaluation practices, because in a normal science reward system governed by Merton's norms, recognition should be awarded on the basis of the intrinsic qualities of the contribution regardless of the status of the author or institution (Merton, 1973).

Another type of strategy is to analyze, at the level of the whole system, the distribution of citation counts or the scaling relationship between citations and other factors such as size and rank. For example, Katz concluded a strong Matthew effect based on the observation that "a scientific community experiences a non-linear increase in the amount of recognition it receives as its size increases" (Katz, 2000). He modeled the power law scaling relationship between the number of citations and publications and proposed to use the scale factor as an indicator of the Matthew effect (Katz, 1999, 2000). Furthermore, a stochastic process resulting in a power law distribution typically involves a mechanism of cumulative advantage or preferential attachment, that is, a paper that already has many citations is more likely to attract new citations (Barabasi & Albert, 1999; Krapivsky et al., 2000; Price, 1976). van Raan and colleagues demonstrated the power law scaling relationship between citations and size at the university, group, and individual levels (Costas, Bordons, van Leeuwen, & van Raan, 2009; van Raan, 2006a, 2006b, 2008a, 2008b). Tol adopted a statistical theory of firm growth and tested deviation from Gibrat's law (Tol, 2009, 2013). The baseline is that firms (or papers) of different sizes (or citations) should grow at the same rate, and then the size (or citation) distribution of those firms (or papers) will converge to Gibrat's law. Therefore deviation from Gibrat's law indicates increasing returns to scale or the Matthew effect. He tested both within-author (at the paper level) and between-author (at the scientist level) Matthew effects in citations of economists.

These two types of strategies have their respective strengths and limitations. One challenge confronting the first type of strategy pertains to controlling for the intrinsic quality of the paper and all other relevant factors. For example, Lariviere and Gingras (2010) studied identical duplicate papers published in different journals, which perfectly controlled for the intrinsic quality of the paper. However, Tol (2013) criticized that they failed to control for the readership of different journals. On the other hand, the second type of strategy also has a problem, that is, demonstrating the inequality without tracing its sources is insufficient to conclude the Matthew effect as a perversion of the science reward system. The observed inequality could be simply caused by economies of scale rather than perfidious behavior in the science reward system. For example, Simonton (2004) demonstrated that some small differences in individual talent or experience can lead to enormous differences in their creativity, without involving any discrimination or unfair institution. In addition, while demonstrating the power law scaling relationship between the number of citations and publications, van Raan still had reservations on adopting the power law adjusted citations for research evaluation, because "a larger impact as measured on the basis of citations cannot be simply waved aside as purely a scale-dependent effect. In this way groups are 'punished' growing because the number of citations received by them should be corrected for size." (van Raan, 2006b, p. 409).

This paper adopts the first type of strategy to study the Matthew effect in citations. We analyze the panel data of papers' citation histories. The fixed effects model allows us to control for the unobserved and time-invariant paper characteristics (such as quality, originality, and field) and investigate the within-paper effects. Our primary research question is whether an author's current networking activities and prestige retroactively affect current citations to his previously published papers. The rest of this paper is organized as follows. Section 2 reviews the role of citations in the science system and provides a theoretical background for understanding the Matthew effect in citations. Subsequently we decompose the Matthew effect in citations into three components: networking, prestige, and appropriateness. Section 4 reports our empirical design for testing these three effects, and Section 5 reports our findings. The implications of our findings are discussed in Section 6.

2. The role of citations in science

From Merton's perspective, the institutionalized practice of citations serves as an elementary building block of the science reward system and is essential for the effective working of science as an institution. The institutional goal of science is the advancement of knowledge, and peer recognition is the basic form of extrinsic reward that motivates scientists to

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