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Double rank analysis for research assessment

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ABSTRACT

Reliable methods for the assessment of research success are still in discussion. One method, which uses the likelihood of publishing very highly cited papers, has been validated in terms of Nobel prizes garnered. However, this method cannot be applied widely because it uses the fraction of publications in the upper tail of citation distribution that follows a power law, which includes a low number of publications in most countries and institutions. To achieve the same purpose without restrictions, we have developed the double rank analysis, in which publications that have a low number of citations are also included. By ranking publications by their number of citations from highest to lowest, publications from institutions or countries have two ranking numbers: one for their internal and another one for world positions; the internal ranking number can be expressed as a function of the world ranking number. In log–log double rank plots, a large number of publications fit a straight line; extrapolation allows estimating the likelihood of publishing the highest cited publication. The straight line derives from a power law behavior of the double rank that occurs because citations follow lognormal distributions with values of μ and σ that vary within narrow limits.

1. Introduction

Research assessment is the cornerstone of research policy. States and private companies invest large amounts of funds and other resources in scientific and technological research; therefore, as in any other productive system, research must be analyzed in terms of productivity and cost efficiency (Garfield & Welljams-Dorof, 1992) for the sake of taxpayers and shareholders. However, in contrast to the case for other productive systems, this simple idea hides a complex problem because for a long time there has not been complete agreement about the procedure for measuring research performance. Thus, based on the numbers of papers or of citations, a profusion of indicators have been proposed (van Noorden, 2010; historical studies in Delanghe, Sloan, & Muldur, 2011; Godin, 2006; Leydesdorff, 2005) that define research success “operationally” as simply amounting to the score of the proposed index (Harnad, 2009).

Fundamental to this issue the question arises of whether the assessment of the success of basic research in countries and institutions is better represented by the total number of published papers or by only the number of papers that were more influential and received a high number of citations. The origin of this question is partially conceptual, as it depends on whether a Kuhnian view of scientometrics is accepted (Andras, 2011; Martin & Irvine, 1983; Rodríguez-Navarro, 2012), but a wrong answer has real consequences. A good example is the European paradox and the notion of the excellence of European research that has led the research policy of the European Union astray for 20 years. By wrongly identifying excellence with

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the total number of publications, research policy has focused on the transfer of knowledge to the manufacturing sector when the real problem has been insufficient knowledge generation (Bonaccorsi, 2007; Dosi, Llerena, & Labini, 2006; Herranz & Ruiz-Castillo, 2013; Rodríguez-Navarro, 2016; Rodriguez-Navarro & Narin, 2017).

Counting publications with a high number of citations seems a simple dichotomous procedure to estimate the size of research output that is very influential. In another approach, the citation range can be divided into categories, considering that all publications in the same category have similar merit, and comparing the share of the publications in each category (Albarrán, Herrero, Ruiz-Castillo, & Villar, 2017). Percentile-based categories (Bornmann & Mutz, 2011; Bornmann, Leydesdorff, & Mutz, 2013; Waltman & Schreiber, 2013) can be used in both approaches. In dichotomous procedures, percentile indicators count the number or percentage of articles from a country or institution that belong to the top-x% of all cited papers in the world and that therefore exceed a certain citation level. At low citation levels, which apply to high percentiles (e.g., top-50%), the method provides results that are not very different from counting all publications, but this does not occur for small percentiles (e.g. the top-1.0 or top-0.1%), which implies highly cited papers. As mentioned above, the percentile dichotomous method is statistically robust but ambiguous without further definitions, because when two countries or institutions are compared, the research performance ratio that results varies depending on the percentile used (Rodríguez-Navarro, 2012, 2016). Furthermore, even if the smallest percentile that can be reliably applied to most countries and institutions, the top-1%, is used, the citation level of most publications in this percentile is not very high and the results do not correlate with the number of Nobel Prizes garnered by countries and institutions (Rodríguez-Navarro, 2011b).

Previous research has demonstrated that the capacity to publish highly cited papers reflects the capacity of the research actors to make important discoveries or to promote important advancements in science; this approach has been validated by correlation with the number of Nobel Prizes garnered (Rodríguez-Navarro, 2011a, 2016). Unfortunately, this correlation is satisfied when the citation level is very high, which gives rise to another problem because the number of publications with such a high citation level is too low to be counted reliably. As an alternative this number can be calculated instead of counted by using the function that describes the upper tail of the citation distribution. In most of the cases studied the data in this tail fit a power law with exponential cut-off or a lognormal distribution (Brzezinski, 2015; Katz, 2016; Price, 1976; Ruiz-Castillo, 2012); a power law function has been used for this calculation purpose with very active research actors (Rodríguez-Navarro, 2016). However, unfortunately, very few countries and institutions can be evaluated using this method because the proportion of publications that can be treated as a power law in the upper tail is normally low. Although across research areas, the average proportion is 2% of all articles, the percentage is much lower in many cases (Brzezinski, 2015; Ruiz-Castillo, 2012), which implies that in many institutions and countries the tail of the distribution that can be used for the evaluation is practically non-existent.

Taking into consideration the issues raised in this brief discussion, it seems that a convenient method of research assessment should allowed to calculate the capacity of the research actors to publish highly cited papers but that this calculation should be made by using the total number or a large proportion of their publications. With such a method, even not very active countries or institutions could be evaluated by their capacity to publish very highly cited papers. Pursuing this goal we describe here the double rank analysis, a new method that reveals the structure of the citation counts of the papers published by a country and institution in relation with the papers of the world.

To describe the double rank analysis, this article has two parts. In the first part (Section 2) we describe the characteristics of the double rank plots constructed with empirical data from two quiescent and two hot research areas. These double rank plots showed power law behavior. In the second part (Section 3) we investigated the mathematical reasons for this behavior. For this purpose we studied the double rank plots generated from simulated citation distributions that follow lognormal distributions.

2. Empirical double ranks

To perform the double rank analysis for the publications of a country or institution in a research field, we first construct two citation-rank plots, one for the country or institution and another for the world, by ranking the publications from the highest to the lowest number of citations. Because the publications of the country or institutions are in the two plots, they have two ranking numbers and the internal ranking number can be expressed as a function of the world ranking number. This function indicates how relevant are the publications of the selected country compared with the publications of the world. For instance, highly competitive institutions will typically get low numbers in the world ranking number, while low-performing institutions will concentrate many publications at the end of the world list, showing very high world ranking numbers. Double rank analysis can be interpreted as a Zipf's plot (Newman, 2005) in which the world ranking number substitutes for the number of citations.

The rest of this section applies the double rank analysis to several countries and research areas in order to reveal the underlying structure of citation counts. In particular, we will study two research areas, "plant sciences," and "physiology", and two research topics, "graphene" and "photovoltaic cells."

2.1. Citation counts

Citation counts were retrieved from the Thomson Reuters Web of Science (WoS) and its "Advanced Search" feature. To retrieve the corresponding publications from the WoS, we used the tags for the research area (SU=), topic (TS=), and year