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Ranking dynamics and volatility

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ABSTRACT

Scientific journals are ordered by their impact factor while countries, institutions or researchers can be ranked by their scientific production, impact or by other simple or composite indicators as in the case of university rankings. In this paper, the theoretical framework proposed in *Criado, R., Garcia, E., Pedroche, F. & Romance, M. (2013). A new method for comparing rankings through complex networks: Model and analysis of competitiveness of major European soccer leagues. Chaos, 23, 043114* for football competitions is used as a starting point to define a general index describing the dynamics or its opposite, stability, of rankings. Some characteristics to study rankings, ranking dynamics measures and axioms for such indices are presented. Furthermore, the notion of volatility of elements in rankings is introduced. Our study includes rankings with ties, entrants and leavers. Finally, some worked out examples are shown.

1. Introduction

Nowadays many colleagues complain about the ubiquity of rankings and the resulting increased competition in science. Besides competition between scientists to get a tenured job at a well-known university – something that has existed since such positions became available – we have nowadays competition among departments in the same university, among universities, spurred by university rankings, and even between continents or parts thereof, typically: America, China and Europe (Bonaccorsi, Cicero, Haddawy, & Hassan, 2017; Shelton & Holdridge, 2004).

Recently Criado, Garcia, Pedroche and Romance (2013) studied rankings in European football competitions, trying to answer the question "Which competition is the most exciting", in the sense that there are many position switches in the rankings. They answered this question using competitivity graphs and derived measures of competitiveness. As we will apply their idea to any ranking, not just football competitions, and as the term *competitiveness* has a specific meaning in economics (Ambec, Cohen, Elgie, & Lanoie, 2013; Buser, Niederle, & Oosterbeek, 2014; World Economic Forum, 2017), we will not use their term *competitiveness* but replace it by the term ranking dynamics, referring to the phenomenon of changes

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in rankings, mainly over time. In a follow-up paper Pedroche, Criado, García, Romance and Sánchez (2015), extended their approach to partial rankings, i.e., rankings in which ties may occur. In this generalization the authors apply the theory of multiplex networks (Boccaletti et al., 2014) and introduce a generalization of Kendall's distance with penalty p. Pedroche et al. (2015) apply their generalization to a study of the Spanish stock market.

It is well know that there is no theory without data, and hence measurement (Egghe & Rousseau, 1990, p.1). Vice versa, data become only meaningful when embedded in a theoretical model. Hence, it does not suffice to create or define concepts based on intuition or elementary observations: generating theoretical models complemented with 'verbal' interpretations is the proper thing to do. Applied to this study we note that explaining or even operationalizing terms like 'high' or 'low' dynamics has not been done much in the past and trying to, is what has motivated us to measure the dynamics of rankings.

Consequently, in this contribution we will discuss the notion of ranking dynamics, propose how to measure it, look in more detail to the approach proposed by Criado et al. (2013), introduce a generalization and apply it to rankings in academia. Our work is a generalization of work presented during the S&T Indicators Conference in Paris (García-Zorita, Rousseau, Marugan-Lazaro, & Sanz-Casado, 2017).

Before we come to possible measures of ranking dynamics we shortly discuss different aspects of a ranking framework.

2. Aspects when studying the dynamics of rankings

Rankings are the result of measurements, among which counting is the simplest. In football one adds scores (0, 1 or 3 points); in bibliometric studies one may count the number of publications, maybe restricted to a certain type, such as 'normal' articles, reviews or books. Many more aspects may play a role in rankings. These are reviewed in this section.

1) The underlying scoring method leading to a ranking.

For football it makes a difference if a winner receives 3 points or 2 (as it used to be in the past); it would make no difference if the winner received 6 points, the loser zero and both teams 2 points in case of a drawn. In qualitative comparisons the underlying scoring method may be based on two-by-two preference relations. In bibliometrics one can imagine journal rankings based on the 2-year JIF, the 5-year JIF, total cites, immediacy index etc., perhaps using different databases. For university rankings one can use the ARWU, THE, etc., rankings (Rousseau, Egghe, & Guns, 2018). For a group of scientists one could study each scientist's h-index (each year, but also per half-year, 2-year) and the resulting rankings.

2) Whether the ranking is complete or if ties are allowed.

Criado et al. (2013) studied rankings without ties, but they removed this restriction in Pedroche et al. (2015). Indeed, ties form an essential aspect of real-world rankings.

3) The 'timing' of the rankings.

For the football case the timing is each 'calendar week'. For the bibliometric rankings (journals, universities) it could be consecutive years (but other time intervals are feasible). Note that rankings must have a natural order, say time, but also elevation in diversity studies of mountainsides may be considered. Studying different preference rankings – drawn by different referees in a beauty contest – does not fit into the framework we study here.

4) One may study rankings of different entities as in Criado et al. (2013) who studied four football competitions; or rankings based on different criteria for the same entity (journals ranked by JIF, immediacy index, total number of received citations, etc. . .).

5) Possible dynamics

We mention three aspects:

a) In the football case changes between consecutive rankings (weeks) are small as the maximum change in the underlying score is 3, but if one considers final rankings at the end of different seasons then anything is (theoretically) possible. A similar remark applies to JIFs, especially if one would study the 2-year JIF with a time gap of two or more years (so that no article is used twice in the calculation of a JIF).

Rankings based on h-indices are probably more stable than those based on JIFs, as h-indices are cumulative, while JIFs refer to articles published in different journals and the number of possible citations has a very high upper limit.

b) Are ranking cumulative or not? Weekly rankings of football competitions are cumulative, while yearly rankings of the same competitions are not.

c) Are data underlying subsequent rankings overlapping or not? They are by definition overlapping for cumulative rankings, but monthly or yearly rankings of a group of researchers according to their h-index would also be based on overlapping data. Weekly ATP tennis rankings are based on the points obtained during the immediate past 52 weeks (with some exceptions) and hence are also overlapping.

d) Finally, another dynamic aspect is the fact that one must take into account that some teams/journals enter or leave the rankings. This will be studied later (see Section 6).

3. The Criado et al. (2013) framework

Before introducing a generalization of the Criado et al. (2013) work we first describe how these authors defined competitiveness. Consider a set E of n elements or nodes (when described in a network context), denoted as $\{e_1, e_2, \ldots, e_n\}$. Next we consider an ordered set **R** of rankings of these n elements. Rankings denoted as $c_1, \ldots, c_r$ are ordered (usually in time, referred to as instances), where each c_k is a complete ranking (no ties) of the n elements at instance k.