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Ranking research institutions by the number of highly-cited articles per scientist

Giovanni Abramo [a,*], Ciriaco Andrea D'Angelo [b]

[a] Laboratory for Studies of Research and Technology Transfer, Institute for System Analysis and Computer Science (IASI-CNR), National Research Council of Italy, Via dei Taurini 19, 00185 Rome, Italy
[b] Department of Engineering and Management, University of Rome "Tor Vergata", Via del Politecnico 1, 00133 Rome, Italy

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ABSTRACT

In the literature and on the Web we can readily find research excellence rankings for organizations and countries by either total number of *highly-cited articles* (*HCAs*) or by ratio of *HCAs* to total publications. Neither are indicators of efficiency. In the current work we propose an indicator of efficiency, the number of *HCAs* per scientist, which can complement the productivity indicators based on impact of total output. We apply this indicator to measure excellence in the research of Italian universities as a whole, and in each field and discipline of the hard sciences.

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1. Introduction

In Abramo and D'Angelo (2014), we provide the definition, measurement operationalization, and underlying theory of an indicator for productivity in research, named Fractional Scientific Strength (FSS). We have now used FSS over the past eight years to rank the performance of Italian professors and universities. FSS embeds both publications and citation counts, and so departs from the traditional bibliometric definitions of productivity as the number of publications per researcher. Instead, the conception of the FSS is that the more researchers publish, and are cited over a period of time, the higher is their productivity.

Productivity is the quintessential indicator of efficiency in any production system. For this, we hold that it should also be the main indicator in the assessment of performance by individual researchers and their institutions. Certainly, it cannot be the only indicator. In designing evaluation systems, the appropriate choice of performance indicators depends on the context and the policy and management objectives intended for the evaluation. The task of the bibliometrician is thus to identify and recommend the indicators most suited to the particular assessment exercise. In addition to productivity, other measures which we typically propose to policy-makers and research administrators include: the rate of concentration of unproductive researchers; the rate of concentration of top scientists (defined as authors of highly-cited publications), and the dispersion of performance within and between and research units. For all these indicators, we produce rankings that inform the decision-maker on the different quality dimensions of the individual scientists, the research units, and the institutions by field, discipline, and as a whole.

* Corresponding author. Tel.: +39 06 72597362; fax: +39 06 72597362.
E-mail addresses: giovanni.abramo@uniroma2.it (G. Abramo), dangelo@dii.uniroma2.it (C.A. D'Angelo).

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In the current work we present and apply a further indicator of performance for the research unit, in some senses complementary to the measure of research productivity (FSS). The new indicator is the number of highly-cited articles (*HCA*s) per researcher[1]. To better demonstrate the complementary character of the two indicators, we begin from the axiom that is at the basis of the productivity measures for many production systems. In the stock market, for example, the axiom would hold that the performance of two traders investing the same amount of money in two different stock portfolios bearing the same risks, is the same if the rate of return on their investments is the same. The investor can hold a portfolio of size m, where $m-1$ of stocks earned nothing and only one stock earned n euro. The performance is considered equal to a portfolio where each of the m stocks earns n/m euro, all other factors constant. In the same way, with other conditions equal, a researcher publishing one publication with n citations is considered to have exactly the same productivity as another researcher producing m publications with n/m citations each. The axiomatic concept, of a linear relationship between the scientific impact of articles and the number of their citations, could be debatable: Someone could argue that an article presenting a breakthrough discovery or radical invention, and so cited 1000 times, is more important than 10 articles presenting incremental advancements of science or technology, each one cited 100 times.

The score by the more popular performance indicators, such as all those based simply on publication counts, and the h-index would rank lower the author of one, albeit highly-cited publication. Our FSS indicator of productivity does consider such cases as indifferent. That is why, we regard as useful to flank it with another indicator that ranks research units or universities by the number of *HCA*s per researcher. Fundamentally this is still an indicator of productivity (i.e. ratio of output to input), with the difference that here the output of interest is not the overall research impact, but rather the excellent results only. Conventional wisdom would suggest to expect a positive correlation between the rankings by the two indicators at the individual level. In fact, Abramo, Cicero, and D'Angelo (2014a) have shown that the most productive researchers (by FSS) are the ones that produce most of the *HCA*s.

A reasonable doubt to the reader could be whether there is any difference between the new indicator and the "concentration of top scientists", defined above as the authors of the *HCA*s. As a matter of fact, the literature suggests that these are indeed different conceptions of the measurement of the scientific excellence of institutions, as reflected in these two formulations, and that both can be usefully applied (Tijssen, 2003). The measurement can be conducted through two distinct approaches: from the perspective of the excellence of the research staff or of that of their research products. The first serves the purpose of identifying the institutions with the highest number of top scientists, regardless of the total number of top articles produced; the second is aimed to identifying the institutions that produce the highest number of top articles, regardless of whether they are produced by many scientists or only a few. The first approach is probably more appropriate for universities, where students would prefer a distribution of excellence among a number of professors in the faculty; the second approach instead might be more appropriate for research institutions, where the funding agency is concerned with maximizing the overall returns on research investments, regardless of how many scientists contribute to it. However, there could also be a dilemma for universities in considering the approaches, since they are at once educational and research institutions. We have previously adopted the approach of identifying the numbers of top scientists employed, in a study aimed at spotting the "excellent" research centers in Italy (Abramo, D'Angelo, & Di Costa, 2009). There are many more examples applying the approach of identifying research institutions with the highest numbers of top articles. According to Zitt, Ramanana-Rahary, and Bassecoulard (2005) *HCA*s is one of the most frequently used indicators for measurement of excellence. In the literature and on the Web we can readily find rankings of organizations and countries by either total number of *HCA*s or by ratio of *HCA*s to total publications. For example Bornmann and Leydesdorff (2011) used the ratio of 10% most-cited papers to total papers to locate the European cities producing more excellent papers than expected. Bornmann, De Moya Anegón, and Leydesdorff (2012) then tested the mathematical consistency of this indicator, named "excellence rate", which is also used by SCImago in its regular *SCImago Institutions Rankings*[2]. The same indicator, but named differently "PP(10%)", is applied in the *CWTS Leiden ranking*[3] better explained in Waltman et al. (2012). This perspective in analyzing excellence has also stimulated numerous studies focused on specific sub-fields, both in the hard sciences (for example environmental sciences, Khan & Ho, 2012; or urology, Hennessey, Afshar, & MacNeily, 2009) and in social sciences (for psychology, in Cho, Tse, & Neely, 2012; for law, Shapiro, 1991).

Neither the absolute value of *HCA*s from the institutions nor the percentage of *HCA*s in the total of articles serve as indicators of efficiency. The first is size-dependent: other factors held equal, large organizations and countries will rank above small ones. The second is inconsistent: the percentage value of *HCA*s could decrease as the number of publications rises[4], under parity of input, and therefore this too is inappropriate to measure any efficiency dimensions of research activity.

[1] We wish we could measure the number of HCAs per R&D spending. Unfortunately, we have no information about the resources available to each researcher, which is a common problem in most countries. Actually, we know the average cost of each researcher per academic rank. We exploit this information to reduce distortions in comparing university performance. We therefore normalize each researcher by the average salary of his/her academic rank. The actual indicator that we measure is then the number of HCAs per researcher's cost. For ease of exposition, in the following we simply refer to HCAs per researcher. This indicator should be easier to measure in those countries where the information on salaries is not available.

[2] http://www.scimagoir.com/research.php, last accessed on August 31, 2015.

[3] http://www.leidenranking.com/ranking/2014, last accessed on August 31, 2015.

[4] Suppose one wants to compare the performance of two researchers, A and B. A, all others equal, produced one article and it is an HCA. B produced 3 articles, but only 2 are HCAs. A has a better performance than B, by the indicator "number of HCAs per total publications".

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