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ORIGINAL ARTICLE

The meaning of the h-index[☆]

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Abstract The h-index originates from the assumption that the number of citations received by a scientist is a better indicator of the relevance of his or her work than the number of papers he or she publishes or the journals where they are published. It takes into account the number of papers published and the citations to those papers in a balanced way, and thus is useful to make comparisons between scientists. The present paper addresses the most frequent questions about the h-index. Specifically, it explains its origin, its advantages compared to other indices, the factors that can influence it (e.g. age, field of knowledge, topic of research and language of publication), its variants, and the injustices it may lead to. In short, this paper provides a clear exposition of the hoped-for role of the h-index in the evaluation of scientists: that it serves as a useful complement to other indicators that are more subjective, and that it contributes to the progress of science by aiding decision-making on allocation of research resources in a more effective way, and on rewarding researchers who contribute to scientific progress in a more fair way.

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PALABRAS CLAVE

Índice h;
Producción científica;
Investigación
científica;
Evaluación de la
ciencia;
Estudio teórico

Resumen El índice h surge del presupuesto de que el número de citas que recibe un científico constituye un mejor indicador de la relevancia de su trabajo que el número de artículos que publica o en qué revistas lo hace. Se trata de un indicador que, a partir del balance entre el número de publicaciones y las citas a éstas, permite la comparación entre distintos científicos. En este artículo se da respuesta a las preguntas más frecuentes acerca del índice h. En concreto, se describe su origen, cuáles son sus ventajas con respecto a otros índices, los factores que pueden influirle (edad, campo de conocimiento, las propias temáticas de investigación o idioma en que se publica), sus variantes y sus injusticias. En definitiva, se expone de forma clara cuál es la función esperada del índice h en la evaluación de los científicos: que complemente a otros indicadores más subjetivos, y que contribuya en forma positiva al avance de la ciencia al ayudar la toma de decisiones de alocación de recursos para la investigación en forma más efectiva y de recompensar a los que contribuyen al avance científico en forma más ecuánime.

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[☆]The questions in this article were formulated by G. Buela-Casal, the answers were given by J.E. Hirsch.

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How did you come up with the idea and the name of the h-index?

I always considered that the number of citations received by a scientist's publications is a better indicator of the quality of the scientist than the number of papers published or the journals where they were published. The fact that every paper published has its own number of citations implies having many numbers for each scientist. I had the idea of developing the h-index as a way of condensing all that information into one single number to facilitate comparisons between scientists.

I originally thought of calling it "x index" because it is obtained by determining the intersection between the "number of citations" (y) versus "paper number" (x) curve and the $y=x$ line, which leads to an x-shaped graph. Then I thought that "x" could suggest "x-rated" so I decided to call it "h" instead because a high h-index suggests "highly cited" and "high achievement" (Hirsch, 2005).

What makes for a useful bibliometric indicator?

I think a useful indicator should: (i) reflect elements of reality that are useful for evaluation and meaningful in a statistical sense (there are always exceptions to any criterion) and ideally have predictive power (Hirsch, 2007), (ii) not lead to undesirable incentives that are detrimental to the progress of science, (iii) not be too sensitive to small variations in bibliometric records that could be due to random events, and (iv) last but not least, be not too difficult to obtain from existing databases. I think the h-index satisfies these requirements relatively well.

Which are the advantages of the h-index over other indicators such as the number of papers, the number of citations or the cumulative impact factor...? (Buéla-Casal, 2010)

If a scientist writes many papers but they are not cited, it means that the papers are not having much influence on the progress of science and therefore that they do not have great merit. The total number of citations may not be very indicative of the quality of a scientist when such citations mainly correspond to a small fraction of the total number of papers published by that scientist. This is particularly true when highly cited papers are the result of collaborative work with other renowned scientists. A journal's impact factor is often not representative of the quality of papers published in it. In the field of Physics, for example, the few papers that are published in *Science* benefit from a very high impact factor. Yet, they are not usually more important contributions than the papers published in journals specific of the discipline that have a much lower impact factor. The cumulative impact factor does not take into account the fact that a scientist's most influential papers (i.e., those with the highest number of citations) are often published in journals with a relatively low impact factor. The h-index does not suffer from any of these shortcomings.

The h-index has been lauded but it has also been strongly criticized. What is your reaction to the criticism?

I believe much of the criticism is unfounded. But it is true that the h-index has its limitations. I think a high h-index is a strong indicator of high merit, however the contrary could be debatable in certain cases. The most important shortcoming of the h-index I think is its inability to discriminate between authors that publish alone or in small groups versus those authors whose papers have usually many coauthors. The latter will have higher h-indices, which would not necessarily reflect true higher merit, and this creates an incentive for authors to form collaborations that are not scientifically well justified. This has been pointed out in the literature and several proposals exist to fix it, but it is not clear what is the best way to do it.

How important is age in the h-index?

The h-index of a scientist monotonically increases with time and it has been empirically observed that the progression tends to be approximately linear. In fact, in my original paper I presented theoretical arguments suggesting that the h-index increases linearly with scientists' "scientific age" (i.e., the time elapsed since their first publication) while the total number of citations increases quadratically. For this reason, I suggested the "m index" (the quotient of the h-index divided by the number of years elapsed since the scientist's first publication) as a "timeless" index to make comparisons between scientists who are at different stages of their career.

Does the h-index, as the impact factor (Buéla-Casal & Zych, 2012), depend on the field of knowledge (Science, Arts and Humanities, Social Sciences,...) and even on the topic of research?

Indeed. In Natural Sciences, for example, h-indices are higher among researchers in Biology than in Physics, and Chemistry is situated in-between. In Biology some scientists lead very large research groups and attain very high h-indices because they coauthor all the papers produced by their group. H-indices are also lower in Social Sciences and Arts and Humanities than in Natural Sciences. This is determined by many factors. For example, it is more frequent that authors in Social Sciences and Humanities publish books with the results of their research rather than papers, and citations of books do not contribute to the h-index. Artists produce works of art that do not contribute to their h-index. In Social Sciences and Humanities, the number of publications per author is generally lower and papers tend to be longer than in Natural Sciences. In addition, the h-index is higher in disciplines in which papers include a higher number of references. Furthermore, h-indices depend on the number of researchers in the field and on the vitality of the field (i.e., how fast it is making progress). Within a field there are sometimes topics in which the h-indices of authors grow very

rapidly; in Physics, for example, graphene has recently been the subject of an explosion of interest, with a large number of authors publishing on the topic and high h-indices.

In some fields such as Health Sciences many researchers have very low h-indices; sometimes the mean is lower than 10. Considering that the h-index does not discriminate in these cases, would it be better not to use it? How can this be solved?

My experience in the field of Health Sciences is very limited. However, I can say that, overall, h-indices do not discriminate well in fields in which they are very low. This is because they are always subject to fluctuations, for example due to the number of self-citations, whose effect can be significant if the h-indices are lower than 10. In these fields, differences between h-indices may be mainly due to these random fluctuations, which do not provide real information on the quality of the researcher. Therefore, their use is not recommended. It is natural to expect researchers who devote substantial time and effort to clinical work and teaching to have lower h-indices. Yet, researchers in some areas of Health Sciences have very high h-indices (>50), which is impressive. Health professionals with high h-indices surely deserve to have this considered in their evaluation. If the h-index is used in these fields, special attention should be paid to the numerous other aspects of the professional life of such researchers.

There are currently about fifty variations of the h-index. Do they really make a contribution or do they create confusion instead? (Bornmann, Mutz, Hug, & Daniel, 2011)

This is difficult to determine and I have not studied them all. Although it is probably true that many variations proposed “improve” a given aspect of the h-index, the problem is that this may be at the expense of worsening another aspect and/or complicating the calculation of the index. For example, I myself proposed the “hbar” index, a variation of the h-index, to take into account the number of coauthors, but it has not gained wide acceptance. I think this is partly because it is considerably more difficult to calculate. One of the advantages of the h-index is its simplicity. It was very easy to calculate even before Web of Science and Scopus included it in the list of data they provide. In the future, a new bibliometric index may be accepted as being clearly better than the h-index, but I think this has not happened yet.

Is the h-index an indicator of quality, impact or dissemination?

The h-index is an indicator of the impact of a researcher on the development of his or her scientific field. Scientists with a high h-index strongly influence the scientific produc-

tion of other researchers and determine the development of their fields. For example, in condensed matter physics, which is my area of research, Philip Anderson is the scientist with the highest h-index. He is generally considered to be the most influential scientist in that area, to the extent that he himself says in his webpage, “I am a condensed matter theorist, a field in which I played the role of a major agenda-setter for 40 or so years”.

It is logical to expect the quality of research to go hand in hand with its impact. Although this is often the case, there are also exceptions. For example, scientists who are “ahead of their time” and have revolutionary ideas that their scientific field is not yet ready to accept may have impact years after their work has been published and in some cases may only earn recognition posthumously.

How does the language of publication influence the h-index?

English is the “universal” language of science. As a result, papers published in English necessarily receive more citations than those published in other languages such as Spanish. This means that scientists who publish in these other languages have lower h-indices. I myself have sometimes found interesting papers in languages that I don’t speak, such as Russian, and have sometimes had them translated and cited them. Yet, on other occasions I have found it easier to use similar papers written in English that may not have been as good but were easier to access.

Should the h-index be limited to journals indexed in the Journal Citation Reports or should it be broadened to other databases such as Scopus or even Google Scholar?

I generally use the Journal Citation Reports (Web of Science), which I consider trustworthy. The problem with Scopus is that it does not include research conducted many years ago, so it is only useful to evaluate the career of relatively young scientists. When I explored h-indices in Google Scholar I found significant differences with Web of Science. I don’t know what are the reasons for such discrepancies so I have not used Google Scholar. I think it is possible to use other databases provided that scientists are compared using the same database, as using different databases can introduce spurious differences.

Can the h-index lead to unfair results?

I think it can, and should therefore be used with care. Several of the reasons have been mentioned above. We should always bear in mind that an h-index in a field or subfield is often not comparable with h-indices in other fields or subfields. The h-index should never be used as the only factor to evaluate a researcher. There are many “typical” researchers whose h-index provides a true picture of their quality and position in their field compared to other researchers, but there are also many “atypical”

researchers whose h-index can provide a distorted image. For example, some scientists publish relatively few papers but most of them have exceptional quality. This results in a relatively low h-index and an exceptionally high number of citations. Other scientists may have a high h-index because they collaborate with influential scientists, while not being themselves the creative driving force in the research. Scientists who conduct research on subjects that are more “fashionable” will have higher h-indices even if they are not necessarily better than other scientists who work on profound questions and write papers that may have a lasting but not immediate impact. Scientists that publish in large collaborations will have larger h-indices than those publishing alone or with few coauthors. Each case is different, which is why in addition to the h-index and other bibliometric indicators it is important to consider the totality of the scientist, read his/her papers and consider his/her production beyond the published papers as well as his/her reputation among their peers, to obtain a comprehensive evaluation.

In a nutshell, what is the h-index good for?

I think it plays a useful role as an “objective” element in the evaluation and comparison of different scientists, complementing other elements that may be more “subjective” such as “prestige”, peers’ opinions, etc, and others that may be less indicative of individual quality, such as the institutions the scientists belong to or the journals in which they publish their work. In the past, it was easier to argue that a scientist was ‘excellent’ without much solid evidence. Now, if a scientist with a low h-index is argued to be ‘excellent’ it is legitimate to ask for an explanation for why the h-index is low: there may or there may not be plausible

reasons. Conversely, in the past it was easier to ignore scientists having wide and large impact but not a highly visible ‘home run’. I think that considering the h-index should result in better decisions pertaining to hiring and promotion of scientists, granting of awards, election to membership in honorary societies, and allocation of research resources by agencies that have to decide between different competing proposals. As long as this index is well used I think it should contribute positively to the progress of science and help reward those who contribute to such progress more fairly.

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