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A Bibliometric Index for Selection Processes

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A bibliometric index is proposed that accounts for the differential contribution authors make to a joint paper published, the valuation of the number of publications, the quality of the journals in which the authors are published and which cite them, as well as the timeliness of the paper. This approach means the index can be used in selection processes for positions of employment or the award of research projects, as it abides by the premise of considering scientific merit based on the quality and quantity of publications. The term *weighted citability index* (WCI_{QT}) is used to refer to a mathematical process that uses filters proportionally both to the degree of involvement in the joint research and to the values of number, quality, and timeliness of the research papers.

Keywords: analysis of citations, research impact, *h*-index.

The valuation of research allows the accumulation of scholarly output with the corresponding increase in salary and the possibility of promotion within a researcher's academic career, as well as access to research projects, subsidies, and grants. This valuation is commonly effected using different metrics, such as the journal impact index, the number of citations, the total number of papers published, etc. The difficulties are apparent when establishing an objective yardstick for each scholar's merits, as the preference of certain metrics over others has so far not been clearly established. With a view to resolving this lack

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of consensus, the *h*-index was proposed by Hirsch (2005), who considered the possibility of using a simple method to evaluate research according to metrics for the quantity and impact of scholarly output. Subsequent studies have indicated that the index is better than others for predicting scientific achievements (Hirsch, 2007).

The *h*-index combines the quantity and impact of the publications in order to determine the outcome of each individual's research. Researchers have an *h*-index when *h* of their publications have received at least *h* citations each, and the rest of their publications have no more than *h* citations per document. Its calculation involves compiling two lists, one in ascending order (ranking), with the position the paper occupies according to the number of citations, and the other in descending order, with each paper's number of citations. When the two values coincide, this gives the *h*-index.

Table 1

Example of an author with seven papers and an *h*-index of six.

Ranking	Citations
1	20
2	12
3	8
4	7
5	6
6	6
7	5

One of the more salient characteristics of this index is that increasing the value of *h* requires an increasingly greater effort, as for each computable paper there is an increase of one in the number of citations required to increase it the next time. In the example presented here (see Table 1), the author will need to publish a paper that will generate at least seven citations in order to raise the index by one point. This aspect rewards the dedication and effort of researchers, at the same time as it stops isolated publications with a high citation rate inflating the index artificially. Certain studies have considered the possibility of using the index both to compare different research areas or groups (Batista, Campiteli, Kinouchi, and Martinez, 2006; Kinney, 2007) and to act as a yardstick in selection processes (Bornmann and Daniel, 2005). Nevertheless, the index has a number of possible drawbacks, such as its high positive correlation with the total number of citations, whereby the information given on the research capacity seems to be rendered redundant when giving the number of

citations (Aznar and Guerrero, 2011; Van Raan, 2006), or that it favours researchers with more protracted careers that accumulate a large number of citations compared to fledgling researchers (Kelly and Jennions, 2006). On the other hand, although the index takes into account both the quantity and the "quality" (or impact) of the publications (Meho and Rogers, 2008, p. 7), it is more focused on quantity; and there is still some controversy over the convenience or otherwise of including self-citations in the calculation of the index (Aksnes, 2006; Glänzel, Debackere, Thijs, and Schubert, 2006; Purvis, 2006; Van Raan, 2006). Nevertheless, given that research is an accumulative process, it is normal to expect a certain degree of self-citation (Aznar and Guerrero, 2011), which means that the exclusion of self-citations would not always be justified (Glänzel et al., 2006).

It should be taken into account that an individual *h*-index can never exceed the number of each corresponding author's publications, penalising those authors with selective publication strategies; in other words, those that give quality precedence over quantity. A further problem is that no account is taken of the number of times an article is cited, whereby publications with a very different number of citations may be making the same contribution to the index's value (Lehmann, Jackson, and Lautrup, 2008). This means that, as reported by Bornmann and Daniel (2009), authors with very different citation rates may have the same *h*-index, as suitable consideration is not given to either the number of publications or to the amount of citations in each one.

In short, the possible limitations of the Hirsch *h*-index, according to Aznar and Guerrero (2011), are as follows: (1) difficulties of assessing a scholar by means of a single digit; (2) it does not provide information that is any better than that provided by the number of citations; (3) it uses only publications included in the Journal Citation Reports; (4) it does not compare researchers from different fields; (5) it takes no account of the quality of the journals in which the papers are published; (6) it may be limited by the number of papers; (7) it does not distinguish between active and inactive researchers; (8) it does not value the context of the citations; (9) it may be influenced by the citations; (10) it includes citations corresponding to negative, fraudulent, or withdrawn papers; and (11) it does not take into account a paper's order of authorship.

In order to compare an author's number of citations with someone else's, a series of filters needs to be applied to determine the true value of those citations and allow an objective comparison to be made between authors. These filters need to be included in an index that specifies the number of true citations according to their proportionality regarding the quality, quantity, and authorship of the publications; that is, the citations made of a paper are to be attributed to the authors according to their contribution to research, the quality of the journal in which they have been published, and the quality of the journals in which they are cited. On the other hand, the inclusion of a temporal

variable in the index (n year) would allow account to be taken solely of those articles published n years before the index was calculated, with the outcome being that the value of the index obtained by an author at any given moment would be reduced over the following years until it disappeared if during that time the scholar did not publish any further papers (BiHui, LiMing, Rousseau, and Egghe, 2007).

In this sense, and according to these premises, the index proposed will provide objective values, as well as permit an updated measurement of the research impact, thereby distancing itself from the outdated concept that gives the highest values to renowned scientists on the basis of their past trajectory. Through the timeliness of n years, the competition for research resources will involve those scholars who at that stage of their careers have the best research ability, whereby they will be the ones best placed at a given moment to compete for those resources, with this undoubtedly having an impact on research outcomes. This does not mean devaluing someone's research trajectory, but instead the values that gave rise to that prestige should be contextualised within a timeframe that provides a developmental perspective of science. The updating of a person's research capacities is consistent with the law on the ageing of scientific literature (Price, 1976). The assessment of research capacity should take into account that the half-life of citations depends on the knowledge areas analysed, and so wider citation windows should be assumed for areas of slow ageing (Bordons, Fernández, and Gómez, 2002).

The method proposed here does not confine access to resources to a reduced group of researchers, because it will not be sufficient to access these resources, nor will it suffice to publish in top-tier journals, as we shall see in due course, as the values for the index presented here depend on peer citations of the work. This means, for example, that an author who has received a large grant and who manages to publish in a prestigious journal has many possibilities of being cited; however, if this does not occur, not only will the value of the index not increase, but it will also be penalised. The penalisation of research with no scientific impact will be a controversial step, but given that all publications will have positive or negative repercussions on the value of the index, a more balanced judgement will be forthcoming on the quality of the work, thereby requiring a conservative approach in response to the research requirements of both journals and authors, with the tendency being to accept and produce, respectively, a fewer number of papers but of greater quality.

In short, an index that seeks to provide an objective valuation of research ability should be based on the number of citations generated by a researcher's publications. These citations should pass through a series of filters that determine their true value. These filters could be integrated through an index that provides a weighted average of each author's citations. By seeking to use mathematical values to evaluate a scientist's research performance, there is a risk of

becoming lost in the details of formalism (de Bellis, 2009), assuming realities in the values obtained that are not always consistent with the purpose of the evaluation context. Especially regarding the field of bibliometrics, formulae are expected to evolve, adapt, and become fine-tuned over time. This paper deals with the beginning of this evolutionary process, adopting a more theoretical than applied approach that seeks to address the issue of evaluating research performance, integrating the most significant parameters into a single formula.

Consistent with this approach, a weighted citability index (WCI_{QT}) has been proposed, which is described in the following sections. The WCI_{QT} is based on the hypothesis that there are several key elements when establishing an author's research merits, and which should be used as filters to determine the true value of citations: (1) authors' contribution (A_c); (2) valuation of the number of publications (V_{np}); (3) impact of the citing journals (I_{cj}); (4) impact of the publishing journals (I_{pj}); and (5) timeliness (T), defined as the time span that will determine the papers to be considered for calculating the index. Below is a step-by-step explanation of the mathematical process for calculating these items, which will enable us to understand their inclusion in the index. Finally, the index's theoretical and practical implications will be analysed.

Model

Author's Contribution (A_c)

The value A_c establishes the number of citations stemming from each author's contribution to the research. Accordingly, albeit not explicitly, the authors' order of appearance in the heading reflects the extent of their contribution to the research. It determines that, as deduced from the survey conducted by Wren et al. (2007), the author making the largest contribution is the one appearing in first place, although there are cases of journals in which the prevailing criterion is that the author who has made the largest contribution appears in last place.

The point of departure is a hypothetical paper that receives 20 citations, in which the authors are distributed according to the following authorship positions (A_{pos}): A_1, A_2, A_3, A_4, A_5, A_6. It is assumed that the closer an author is to the front of the list the greater that person's research contribution will have been and, therefore, the greater the acknowledgement that person should receive for the citations the paper generates. The order of authors prior to the calculation of A_c is to take account of the degree of participation of the last of the authors, which will depend on the journal in which the article was published. In the case of those journals that apply the criterion of placing the author who has contributed the most to the paper in last position, the process is to be reversed.

In order to provide an objective reflection of each author's contribution to the work, the following points are to be awarded, which will depend on the number

of authors and to each one's position in the heading. In this example, as there are six authors, the first author is assigned the same number of points as the number of authors, and each author receives the preceding one's points minus one. The percentage of points over the total is therefore as seen in Table 2. The number of citations that can be "attributed" to each author is obtained according to the resulting percentage, being calculated by dividing the percentage by 100 and then multiplying it by the number of citations, which in this case is 20.

Table 2

Example of the calculation of A_c for a paper with six authors.

A_{pos}	Points	Percentage	A_c
1	6	[6/(6+5+4+3+2+1)] * 100 = 28.6	0.286 * 20 = 5.72
2	5	[5/(6+5+4+3+2+1)] * 100 = 23.8	0.238 * 20 = 4.76
3	4	[4/(6+5+4+3+2+1)] * 100 = 19.0	0.190 * 20 = 3.80
4	3	[3/(6+5+4+3+2+1)] * 100 = 14.3	0.143 * 20 = 2.86
5	2	[2/(6+5+4+3+2+1)] * 100 = 9.50	0.095 * 20 = 1.90
6	1	[1/(6+5+4+3+2+1)] * 100 = 4.80	0.048 * 20 = 0.96

A_{pos} = *author's position in the heading*
A_c = *author's contribution*

As can be seen, the first author would be assigned 5.72 of the 20 citations, the second 4.76, and so on. Therefore, the formula for finding the number of citations per paper "attributable" to each author depending on the number of authors and the author's position in the heading, in other words, each author's contribution to the research (A_c), is as follows:

$$A_c = [(N_{aut} + 1 - A_{pos}) / \sum_{i=1}^{N_{aut}} X_i] * N_c$$

A_c = *author's contribution*
N_c = *number of citations*
N_{aut} = *number of authors*
A_{pos} = *author's position in the heading*
$\sum_{i=1}^{N_{aut}} X_i$ = *aggregate over i from 1, up to the number of authors*

The formula would be applied to each and every one of the papers to be counted for each author, giving the average for all the papers $(AVERAGE\_A_c)$. The result would provide the average number of citations attributable to each author

depending on that person's contribution to the research and the number of authors per paper.

Nevertheless, the average value does not suitably consider the number of papers published by each author. In order to include this variable in the index, use has been made of what has been referred to as the valuation of the number of publications (V_{np}).

Valuation of the Number of Publications (V_{np})

As the number of publications increases, the index's final score is expected to rise. Yet provision should be made for a small number of publications to have a greater influence on the index, with this influence steadily falling as the number of publications increases. Why should this be the case? It stands to reason that a certain amount of research experience is required to be able to compare authors, and this experience should be valued in an objective manner.

Accordingly, as the number of publications increases, the impact on the index steadily decreases, being much more acute when an author has few published papers. For example, between an author with 100 papers and another with 150, the number of publications will not make any major difference to the value of the index, giving greater importance to the quality of the publications rather than to their quantity. This means a decelerating curve needs to be generated, in which the effect on the value of the index is higher when an author has fewer published papers, but as that number increases, whilst still making a greater and progressive contribution to the value of the index, this contribution will be increasingly smaller. Accordingly, the following treatment for the number of papers should be:

$$V_{np} = 1 - [(100 / \sum_{i=1}^{N_p} X_i) * N_p] / 100$$

V_{np} = *value of the number of publications*
N_p = *number of papers*
$\sum_{i=1}^{N_p} X_i$ = *aggregate over i from 1, up to the number of authors*

Therefore, the value for an author with 20 papers will be $V_{np} = 0.91$. The deceleration in the contribution the number of papers makes to the values of V_{np} can be seen in Figure 1. The difference between having one paper and having ten is 0.818; between ten and 20 it is 0.071; between 20 and 30 it is 0.026; between 30 and 40 it is 0.014, and so on. Thus, an asymptotic progression is

obtained in which the greater the number of papers, the closer the value of V_{np} is to 1.00 although this progression slows as the number of papers increases.

Example of the calculation of V_{np} for an author with 20 papers:

$$V_{np} = 1 - [100 / (1+2+3+4+5+6+7+8+9+10+11+12+13+14+15+16+17+18+19+20) * 20] / 100 = 0.91$$

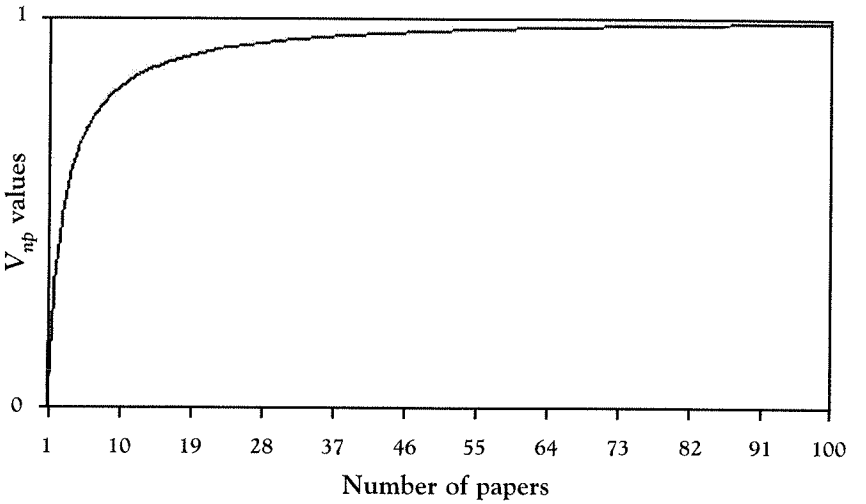

Figure 1: Relationship between the number of papers and V_{np}.

Once the factors A_c and V_{np} have been defined, the next step involves a practical application for the calculation of the *WCI* index (see Table 3), using the following formula:

$$WCI = V_{np} * AVERAGE\_A_c$$

WCI = weighted citability index
V_{np} *= valuation of the number of publications*
$AVERAGE\_A_c$ *= average number of citations*

The average number of citations ($AVERAGE\_A_c$) is obtained by calculating A_c for each paper and obtaining the average, which is then multiplied by the valuation of the number of publications (V_{np}), which in this case is 0.91. This provides an index with a value of 5.88.

Table 3

Example of the calculation of the *WCI* for an author with 20 papers

Paper	N_c	N_{aut}	A_{pos}	$(N_{aut}+1-A_{pos}) / \sum_{i=1}^{N_{aut}} X_i$	A_c
1	20	6	2	0.238	4.8
2	12	4	3	0.200	2.4
3	15	3	1	0.500	7.5
4	35	4	2	0.300	10.5
5	42	2	1	0.667	28.0
6	35	3	2	0.333	11.7
7	60	4	3	0.200	12.0
8	55	2	2	0.333	18.3
9	12	3	2	0.333	4.0
10	0	2	1	0.667	0.0
11	2	2	1	0.667	1.3
12	34	3	2	0.333	11.3
13	23	4	4	0.100	2.3
14	45	6	3	0.190	8.6
15	0	2	1	0.667	0.0
16	0	1	1	1.000	0.0
17	12	3	3	0.167	2.0
18	11	4	2	0.300	3.3
19	4	3	2	0.333	1.3
20	1	2	1	0.667	0.7
	$Np = 20$		$AVERAGE\_Ac = 6.50$		$WCI = 5.88$
	$Vnp = 0.91$				

$$A_c = [(N_{aut} + 1 - A_{pos}) / \sum_{i=1}^{N_{aut}} X_i] * N_c$$

$$V_{np} = 1 - [(100 / \sum_{i=1}^{N_p} X_i * N_p] / 100$$

$\sum_{i=1}^{N_{aut}} X_i$ = *aggregate over i from 1 up to the number of authors*

Paper = *numbered list of the author's papers*

N_c = *number of citations*

N_{aut} = *number of authors*

A_{pos} = *author's position in the heading*

A_c = *author's contribution*

N_p = *number of publications*

V_{np} = *valuation of the number of publications*

$AVERAGE\_A_c$ = *average number of citations*

WCI (weighted citability index) = $V_{np} * AVERAGE\_A_c$

The *WCI* reflects the average citations recorded for the author's 20 papers, after the papers have been rated according to the author's position in the heading (degree of involvement in the research) and to the number of published papers. Therefore, once the terms of the formula have been established regarding the number of publications (V_{np}) and the author's position in the heading (A_c), the next stage involves explaining the integration of the quality of the publishing and citing journals within the index's final composition. The data for our hypothetical author shall now be used again.

Impact Index of Citing Journals (I_{cj}) and Publishing Journals (I_{pj}). Index Levels: WCI_1, WCI_2, WCI_3, WCI_4

Classifying journals in terms of quality involves using a quartile for rating a journal's position with regards to other journals. The process consists of separating the journals from a specific field and ordering them from greater to lesser visibility (impact factor). When a list of journals arranged in order from a greater to a lesser impact factor is divided into four equal groups, each one of these groups forms a quartile. Those journals with a greater impact factor are in the first quartile, and those with the least impact are in the fourth quartile. This unit of classification will enable levels to be established for the index depending on the quartile containing the journal publishing the paper and the journals citing it.

In another example, the number of citations will be distributed depending on the quartile containing the citing journal. For calculating the levels of the WCI_Q index, where Q may have values of 1 to 4, the number of citations (N_c) will be established by adding up those from journals of the same or higher standing than the publishing journal. This ensures that a level of quality is upheld for the citing author that objectively corresponds to the level of quality of the cited author.

The data in Table 4 provide four *WCI* indices, to be calculated using the mathematical procedure applied in the preceding sections, but taking into account for level 1 (WCI_1) only those papers published in journals with an impact index in the first quartile and, likewise, account will be taken solely of the citations from journals in this quartile. This would be the most exclusive level. For level 2 (WCI_2), account is to be taken of papers published in journals in quartile 2, and consideration will be given solely to citations from journals in levels 1 and 2. For level 3 (WCI_3), only publications in quartile 3 are taken into account, with citations from journals in quartiles 1, 2, and 3. Finally, for level 4 (WCI_4), account will be taken solely of publications in journals in quartile 4 and the citations from journals in quartiles 1, 2, 3, and 4. This approach means that the higher the level, the more exclusive the requirements are. This level-based format for the index also means it can be adapted to selection processes, where depending on the vacancy to be filled, a pre-requisite for applicants may

be a minimum index level, with the most exclusive level being 1 (WCI_1), which involves not only having publications in high-impact journals, but also that the citations of that paper come from journals of this kind. It therefore introduces a twin measure of quality, namely, the journals and peers of the same standing who cite the paper. What about those journals that move into a different quartile after the author's article is published? Some stability is assumed in the position a journal maintains within the context of publications in its field, but account should be taken nonetheless of the value of the quartile the journal belongs to when the value is calculated. This makes it a value that is susceptible to change. The next step involves calculating the index levels for

Table 4

Example of the calculation of the *WCI* for an author with 20 papers, taking into account the level of the journals publishing and citing the papers.

Paper	N_c	A_c	*Q.Pub*	Q_1.Cit	Q_2.Cit	Q_3.Cit	Q_4.Cit
1	15	3.57	3	10	4	1	5
2	6	1.20	2	3	3	3	3
3	10	5.00	3	5	4	1	5
4	25	7.50	2	15	10	5	5
5	42	28.00	4	25	10	5	2
6	12	4.00	1	12	11	2	10
7	40	8.00	1	40	15	5	0
8	35	11.67	1	35	12	3	5
9	5	1.67	1	5	5	2	0
10	0	0.00	3	0	0	0	0
11	2	1.33	3	2	0	0	0
12	30	10.00	2	15	15	4	0
13	22	2.20	2	12	10	0	1
14	45	8.57	4	30	10	0	5
15	0	0.00	3	0	0	0	0
16	0	0.00	2	0	0	0	0
17	12	2.00	3	6	3	3	0
18	4	1.20	2	2	2	4	3
19	4	1.33	4	1	1	1	1
20	1	0.67	3	1	0	0	0

Paper = *numbered list of the author's papers*

N_c = *number of citations*

A_c = *author's contribution*

Q.Pub = *quartile containing the journal publishing the paper*

Q_n.Cit = *number of citations in journals in quartile n*

our example, using the data presented in Table 4, and which will be defined within the index's initialism with the letter Q to give WCI_Q.

The number of citations of each paper is distributed according to the quartile containing the citing journal (Q_1.*Cit*, Q_2.*Cit*, Q_3.*Cit*, Q_4.*Cit*). Therefore, the calculation of the different levels of the index will take into account only those citations from a journal of equal or higher standing to the journal publishing the paper. For example, regarding the first paper in the table, as it was published in a journal in quartile 3 (Q_3), consideration will be given to the citations from quartiles 3, 2, and 1. This premise will be understood if a comparison is drawn with the peer-review process. No researcher would agree to have his or her research assessed by an undergraduate. In terms of citability, and allowing for obvious differences, account should be taken solely of those citations involving journals of an equal or higher level, as this will guarantee the quality of the work and of the citation itself.

The number of papers used to calculate V_{np} will depend on the target level to be calculated, for WCI_1, account will be taken solely of those papers published in journals in quartile 1, in this case (see Table 5) there would be four (i.e., papers 6, 7, 8, and 9). On the basis of these premises, the next step is to calculate the four levels of the *WCI* index for our example.

Table 5

Example of the calculation of the four levels of the *WCI*.

$WCI_1 = V_{np} * AVERAGE\_A_c = 3.80$
Number of papers published in journals in quartile 1 (Q_1) = 4
$V_{np} = 0.60$
$AVERAGE\_A_c = (4+8+11.67+1.67)/4$

$WCI_2 = V_{np} * AVERAGE\_A_c = 2.62$
Number of papers published in journals in quartile 2 (Q_2) = 6
$V_{np} = 0.71$
$AVERAGE\_A_c = (1.2+7.5+10+2.20+0+1.20)/6$

$WCI_3 = V_{np} * AVERAGE\_A_c = 1.35$
Number of papers published in journals in quartile 3 (Q_3) = 7
$V_{np} = 0.75$
$AVERAGE\_A_c = (3.57+5+0+1.33+0+2+0.67)/7$

$WCI_4 = V_{np} * AVERAGE\_A_c = 6.32$
Number of papers published in journals in quartile 4 (Q_4) = 3
$V_{np} = 0.50$
$AVERAGE\_A_c = (28+8.57+1.33)/3$

Any value in one level is higher than the values in the preceding levels, whereby presentation will be made in selection processes of the value for the highest level, which in this case is level 1 ($WCI_1 = 3.80$).

Timeliness (T)

Finally, a period of timeliness (*T*) will be specified in years, which will be defined in the index initialism by the letter *T* ($WCI_{Q,T}$), and will be determined according to the demand criteria, whereby the shorter the established period, the greater the requirement in terms of each author's output and quality. In order to calculate the index taking this filter into account, computation is to be made solely of those citations made of papers published within the accepted timeframe. This undoubtedly penalises those classical articles that continue to receive citations, yet it should be considered that this index is of use in selection processes that prioritise the publications' topicality, whereby classical articles are not contemplated within a selection process that values a scholar's research potential at a given moment and not that person's trajectory.

The index is therefore constituted according to different levels and requirements. This means that in a possible tender for research projects or in a call for filling teaching vacancies, the index could be used for establishing the priority of the applicants. The grading of the levels of the index — from the most demanding to the least demanding one — could be used alongside the appraisal of other merits to score the personal summaries of the applicants and arrange them in order.

Results

Valuation of the Number of Publications (Papers Published)

The valuation of V_{np}, as expressed in the formula, allows comparing scholars with different research trajectories (fledgling, senior), whereby the number of publications does not increase the values of the index in an untenable manner. V_{np} fluctuates between 0.00 and 1.00 (the greater the number of articles, the closer the value is to 1.00). Given that in the final formula the value of V_{np} is multiplied by the average of the values obtained in A_c ($WCI = V_{np} * AVERAGE\_A_c$), the closer V_{np} is to 1.00, the less it will reduce the score recorded in $AVERAGE\_A_c$, and the greater the increase in the values of the index, although as noted, this increase will decelerate. This means that the effect of the number of papers on the index will decrease in importance as more papers are published. This is a fair procedure because once the continued ability to publish in a specific group of journals has been proven, the values of the index should consider quality over quantity. The difference between having ten or twenty papers published

is 0.071, so from ten onwards the number of publications hardly makes any difference to the values of the index between authors. Therefore, once they have published ten papers in which they have proven their ability to express their ideas in journals of a certain standing, scholars with shorter careers can compete on equal terms with their more seasoned peers. Under these conditions of equality, quality might have better chance of prevailing.

Accuracy in the Attribution of Results

Not all authors are involved to the same degree in research, and the attribution of merits (citations) should therefore be proportional to this involvement. The method proposed for defining this proportionality favours papers with fewer authors and those featuring in the first or last positions in the heading. In other words, the fewer the number of authors and the closer to the front the author's position, the greater the increase in the index, in the event the paper is indeed cited.

No Penalisation of the Number of Citations per Paper

In the *h*-index, the number of citations per paper is not properly valued, as a high number of citations could increase the value of the index by only 1.00, regardless of the number of the same, as it would be enough for the number of citations to be equal to or exceed the number of the paper's ranking. This is an advantage as it avoids the disproportionate effect a single paper of great repercussion would have on a researcher's career. However, a rule on this has been introduced, whereby no computation is made of values when the author has only one paper. At least two papers are required for this to happen. Furthermore, with fewer than ten papers there is a significant penalisation of the value obtained in the index, with subtraction from it of a percentage that is proportional to the number of papers. This means that a scholar who has only one paper in a journal contained within quartile 1, however high the number of citations it has received, cannot obtain an $WCI_{1,V}$ until that same scholar publishes again in journals of that same standing, and in the event another paper is published, if it is not cited it will be computed as "0" for calculating the average. It would therefore reduce the value of the citations of the first paper.

Penalisation of Papers not Cited

As noted briefly in the preceding section, if a paper is not cited, it will likewise be given the value "0" when calculating the average ($AVERAGE\_A_c$), so it will of course lower the average. This is a controversial point, but it should be

remembered that the index is measuring the ability to contribute data to the wealth of scientific knowledge that will help to advance a specific field. The citations of a paper reflect the impact the information has had on the scientific community, just as the ripples caused by a pebble falling into a pond indicate that the pebble has sunk to the bed. A publication might not be cited and may gain in importance over the years, and this would not be the first time this has happened, but if this criterion is not applied, the possibilities that many publications of scant significance would raise the value of the index would be greater than the chances that a publication of considerable importance would not do so. If all the possibilities cannot be considered, the highest possible levels of equity should at least be ensured.

Penalising the Lack of Output

The timeliness filter applied to this index means that the quality of an author's citations can be measured within a range of years prior to its calculation. For example, if a timeliness is established of 3 ($WCI_{Q,3}$), an author who does not publish in three years or whose papers are not cited may see the value of the index reduced until it disappears at the end of the three years. This means that researchers' abilities are constantly being reviewed.

Double Quality Filter

One of the main features of $WCI_{Q,V}$ is that increasing its value in one of the levels requires more than just conducting a great deal of research and publishing in journals in that level. This increase also requires the paper to be cited by journals of the same or higher standing than the one in which it was published. This provides a double quality filter, on the one hand regarding the publishing journals, and on the other peer citations.

Adjustment to Selection Processes

The use of four levels in the index facilitates the requirements for access to scholarly resources according to the candidates' recent merits. In this way, the minimum required for opting to an academic category or for opting to a subsidised project may be objectively approached by asking for a minimum in the levels of the index ($WCI_{1,T}$, $WCI_{2,T}$, $WCI_{3,T}$, $WCI_{4,T}$) and a specific timeliness ($WCI_{Q,1}$, $WCI_{Q,2}$, $WCI_{Q,3}$, $WCI_{Q,4}$, $WCI_{Q,5}$, $WCI_{Q,6}$, *etc.*), with the criteria being more demanding the lower the number is, as a value of 1.00 in both would require, on the one hand, publishing and having citations in journals in quartile 1, and on the other, that this level has been attained in the year preceding the index's calculation.

Discussion

The valuation of the merits of an individual, in this case a researcher, should be as objective as possible, although nothing within the human or social field is free of subjective assessment, so it would be very bold to attempt to be wholly objective. This end is justified according to the work by Martin (1996) in which it is established that the valuation of research activity requires a combination of different parameters, with some of the more important ones being as follows: the number of articles, the citations generated, and the quality of the journals. The index presented here should be adjusted through comparative analyses with other quality indices in order to understand how their values correlate and ensure their application to different fields is as effective as possible.

To conclude, we understand that research, as an environment in which researchers adapt and survive, should adopt a developmental stance that is consistent with their cognitive and motivational characteristics. The index proposed seeks to integrate factors that have been dispersed and which lacked a valued focus on research activities. In this sense, an index of scientific output should give rise to the need to increase it on an individual basis, and this motivation should be taken into account and harmonised with an understanding of the merits fairly required for comparing those individuals who compete to increase the values of this index. Accordingly, efforts should be made not only to avoid unduly increasing the number of superfluous publications, but also to marshal the implicit consent of the scientific community, whereby the need to increase the index signals the pathways (reduce the number of authors, and not publish without quality, as this may be penalised if there are no citations, etc.) that suit such purposes and avoid alternative practices that are damaging because they are unnecessary and pointless.

References

Aznar, J., and Guerrero, E. (2011). Análisis del índice-*h* y propuesta de un nuevo índice bibliométrico global: el índice global [Analysis of the *h*-index and proposal of a new bibliometric index: The global index]. *Revista Clínica Española, 211*, 251–256.

Aksnes, D.W. (2006). A micro-study of self-citations. *Scientometrics, 56*, 235–246.

Batista, P.D., Campiteli, M.G., Kinouchi, O., and Martinez, A.S. (2006). Is it possible to compare researchers with different scientific interests? *Scientometrics, 68*, 179–189.

BiHui, J., LiMing, L., Rousseau, R., and Egghe, L. (2007). The *R*- and *AR*-indices: Complementing the *h*-index. *Chinese Science Bulletin, 52*, 855–863.

Bordons, M., Fernández, M.T., and Gómez, I. (2002). Advantages and limitations in the use of impact factor measures for the assessment of research performance in a peripheral country. *Scientometrics, 53*, 195–206.

Bornmann, L., and Daniel, H.-D. (2005). Does the *h*-index for ranking of scientists really work? *Scientometrics, 65*, 391–392.

Bornmann, L., and Daniel, H.-D. (2009). The state of *h* index research. Is the *h* index the ideal way to measure research performance? *EMBO Reports, 10*, 2–6.

de Bellis, N. (2009). *Bibliometrics and citation analysis: From the science citation index to cybermetrics.* Lanham, Maryland: Scarecrow Press.

Glänzel, W., Debackere, K., Thijs, B., and Schubert, A. (2006). A concise review on the role of author self-citations in information science, bibliometrics and science policy. *Scientometrics, 67,* 263–277.

Hirsch, J.E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences, 102,* 16569–16572.

Hirsch, J.E. (2007). Does the *h*-index have predictive power? *Proceedings of the National Academy of Sciences, 104,* 19193–19198.

Kelly, C.D., and Jennions, M.D. (2006). The *h*-index and career assessment by numbers. *Trends in Ecology and Evolution, 21,* 167–170.

Kinney, A.L. (2007). National scientific facilities and their science impact on nonbiomedical research. *Proceedings of the National Academy of Sciences, 104,* 17943–17947.

Lehmann, S., Jackson, A., and Lautrup, B. (2008). A quantitative analysis of indicators of scientific performance. *Scientometrics, 76,* 369–390.

Martin, B.R. (1996). The use of multiple indicators in the assessment of basic research. *Scientometrics, 36,* 343–362.

Meho, L.I., and Rogers, Y. (2008). Citation counting, citation ranking and *h*-index of human computer interaction researchers: A comparison between Scopus and Web of Science. *Journal of the American Society for Information Science and Technology, 59*(11), 1711–1726.

Price, D.J. (1976). A general theory of bibliometric and other cumulative disadvantage processes. *Journal of American Society of Information Sciences, 27,* 292–306.

Purvis, A. (2006). The *h-index*: Playing the numbers game. *Trends in Ecology and Evolution, 21,* 422.

Van Raan, A.F.J. (2006). Comparisons of the Hirsch-index with standard bibliometric indicators and with peer judgment for 147 chemistry research groups. *Scientometrics, 67,* 491–502.

Wren, J.D., Kozak, K.Z., Johnson, K.R., Deakyne, S.J., Schillig, L.M., and Dellavalle, R.P. (2007). The write position. A survey of perceived contributions to papers based on byline position and number of authors. *EMBO Reports, 8,* 988–991.