

# Evaluation of Scientific Production Without Using Bibliometric Indicators: Decision-Making on *a Priori* Criteria

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**Abstract.** The present contribution contains the formalisation of a method (not based on bibliometric indicators) for assigning analytical scores to the scientific production of researchers who challenge in an open competitive exam in a Socioeconomic Scientific Sector. The preliminary decisions of the evaluation board are described subdividing them into six decision steps. The role of decision-making about *a priori* criteria is pointed out in relation to the respect of the researcher's identity and of the spontaneous evolution of science. In this work, also an example of application is proposed to the evaluation board. Some algebraic implications are highlighted and it is suggested to reflect on the usefulness of the rules of Boole's Algebra for the calculation of total scores deriving from the simultaneous application of criteria having different logical characteristics.

**Keywords:** Scientific evaluation · Non-bibliometric scientific sectors · Scientific productivity · *a priori* criteria decisions

## 1 Introduction

Recently, interesting scientific contributions have focused on new questions about the appropriateness of the bibliometric indicators in the evaluation of scientific production within the Social Sciences and Humanities [9]. A very significant conclusion of these studies is the individuation of the negative consequences that may originate from the implementation of the evaluation model based on bibliometric indicators in the areas of the Social Sciences and Humanities. In fact these areas are led to change their way of publishing in order to achieve the objectives proposed by the bibliometric indicators (for alternative approaches and criticism to the use of bibliometric indicators see, among others, [1–3, 5–8, 12]). This change is not good for the development of research, because it comes from the application of a model which is exogenous and unnatural for the evaluation of scientific productivity in the Social Sciences and Humanities.

In the recent past, many studies contributed to define methods for the evaluation of research performance, mainly in relation to bibliometric indicators (see, among others, [4, 11, 13, 14]).

The present contribution shows how, without using bibliometric indicators, it is possible to formalise a rigorous method for assigning analytical scores to the scientific production of researchers who challenge in an open competitive exam in a Socioeconomic Scientific Sector.

In Sect. 2 definitions, symbolism, quantitative conditions and parameters are formalised in an essential way to simplify the tasks of the evaluation board. In Sect. 3 two types of *a priori* criteria are defined in relation to the degree of necessity of the conditions required. Analytical consequences of these definitions into the evaluation formula are highlighted and an example of application is synthetically expressed by a calculation table. In Sect. 4 the preliminary decisions of the evaluation board are described, subdividing them into six decision steps. The conclusions essentially focus on the negative consequences, for the natural development of research in the Social Sciences and Humanities, of the use of the evaluation model based on bibliometric indicators, highlighting the necessity of creating instruments, models and objective criteria suitable to support an evaluation system that respects the researcher's identity and the spontaneous evolution of science.

## 2 Definitions, Symbolism, Quantitative Conditions and Parameters

The objects under evaluation, named by the symbol  $i$  ( $i = 1, \dots, N$ ), are the  $N$  scientific publications of each competing researcher. The set of *a priori* criteria for the evaluation of each publication is  $\{c_h\}$ ,  $h = 1, \dots, H$ . The set of *a priori* criteria for the evaluation of the scientific production as a whole (e.g. scientific productivity respect to time) is  $\{g_k\}$ ,  $k = 1, \dots, K$ .

The highest total score assignable to the scientific production of each researcher is  $S$ . The weights of the total scores coming from the application of the two sets of the above mentioned criteria are  $\alpha_c$  and  $\alpha_g$ . In particular,  $\alpha_c$  is the weight of the total score deriving from the application of the set of the criteria  $\{c_h\}$  and  $\alpha_g$  is that of the total score coming from the application of the set of criteria  $\{g_k\}$ , under the conditions:  $0 < \alpha_c < 1$ ,  $0 < \alpha_g < 1$ ,  $(\alpha_c + \alpha_g) = 1$ , so that  $(\alpha_c S + \alpha_g S) = S$ .

Consequently, the highest analytical score assignable to each publication is equal to  $(\alpha_c S)/N$ .

The score assigned to publication  $i$  on the base of each criterion  $c_h$  is  $s_{ih}$  and it must verify the following conditions:  $0 \leq s_{ih} \leq S_h$ , for all  $i = 1, \dots, N$ .

Moreover, the score assigned to the scientific production as a whole on the base of each criterion  $g_k$  is  $s_k$  and it must verify the following conditions:  $0 \leq s_k \leq S_k$ .

The parameter  $S$  usually is institutionally predetermined.

The weights  $\alpha_c$  and  $\alpha_g$  and the scores  $S_h$ ,  $S_k$ , ( $h = 1, \dots, H$  and  $k = 1, \dots, K$ ) are the  $(H + K + 2)$  quantitative parameters of the model, which are to be established by the evaluation board.

### 3 Two Different Types of Criteria and the Implications for the Evaluation Formula

The verification of certain criteria of the sets  $\{c_h\}$  and  $\{g_k\}$  may be considered by the evaluating board a necessary condition for the assignment of a non-zero score. Therefore, the evaluation criteria can be distinguished, by the evaluation board, into two types: those implying necessary conditions and those not implying necessary conditions.

The criteria of the first type are marked by the symbols  $c_k^*$  and  $g_k^*$ ; similarly the relative assigned scores are  $s_{ih}^*$  and  $s_k^*$ .

In relation to this type of criteria, the analytical formalisation of the model requires that the highest scores assignable to each publication or to the scientific production as a whole,  $S_h^*$  and  $S_k^*$ , must be equal to 1 and, consequently, that  $0 \leq s_{ih}^* \leq 1$  and  $0 \leq s_k^* \leq 1$ . In particular, there are the following equivalences:

- the equalities  $s_{ih}^* = 0$  and  $s_k^* = 0$  are equivalent to the non-verification of the corresponding criteria;
- the inequalities  $0 < s_{ih}^* < 1$  and  $0 < s_k^* < 1$  are equivalent to a partial verification of the corresponding criteria;
- the equalities  $s_{ih}^* = 1$  and  $s_k^* = 1$  are equivalent to the verification of the corresponding criteria.

The criteria  $\{c_h\}$  are ordered in the following way:  $\{c_1, c_2, c_3, \dots, c_\varphi, c_{\varphi+1}^*, c_{\varphi+2}^*, \dots, c_H^*\}$ , where  $(H - \varphi)$  is the number of the criteria implying necessary conditions; the criteria  $\{g_k\}$  are ordered in a similar way  $\{g_1, g_2, g_3, \dots, g_\tau, g_{\tau+1}^*, g_{\tau+2}^*, \dots, g_K^*\}$  and, in this set,  $(K - \tau)$  are the criteria implying necessary conditions.

In this model, the assigned scores  $s_{ih}^*$  and  $s_k^*$  are used as factors in the analytical formula for the calculation of the total score of the scientific production of each competing researcher. Moreover, the assigned scores  $s_{ih}$  and  $s_k$  (related to the criteria that do not imply necessary conditions) are used as addends.

The formula of the total score (TS) of the scientific production of each competing researcher is the following:

$$TS = \sum_{i=1}^N \left[ \left( \sum_{h=1}^{\varphi} s_{ih} \right) \prod_{h=\varphi+1}^H s_{ih}^* \right] + \left( \sum_{k=1}^{\tau} s_k \right) \prod_{k=\tau+1}^K s_k^* \quad (1)$$

It is useful to observe that, in relation to the criteria of the set  $\{c_h\}$  that do not imply necessary conditions, the following equality must be verified:

$$\sum_{h=1}^{\varphi} S_h = (\alpha_c S) / N.$$

Similarly, in relation to the criteria of the set  $\{g_k\}$  that do not imply necessary conditions, the following equality must be verified:

$$\sum_{k=1}^{\tau} S_k = \alpha_g S.$$

In Table 1, an example of application of the evaluation formula (1) is schematized on the base of some criteria expressed by Italian Ministry of Education, University and Research [10].

**Table 1.** Example

PUBLICATION NUMBER	C1 criterion score (referred to originality, innovativeness, methodological accuracy and relevance of each scientific publication)	C2 criterion score (referred to scientific relevance of each publication's publishing house and its diffusion among the scientific community)	C3 criterion score (referred to analytical evaluation of the candidate's contribution in the case of works in cooperation)	C4* criterion score (referred to congruence of each publication with the scientific area of the competitive exam)	C5* criterion score (referred to congruence of each publication with the required scientific profile, defined by indication of one or more scientific sectors)	C6* criterion score (referred to congruence of each publication with issues related to the required scientific commitment)	TOTAL SCORES
1	$S_{11}$	$S_{12}$	$S_{13}$	$S_{14}^*$	$S_{15}^*$	$S_{16}^*$	$\sigma_1 = (s_{11} + s_{12} + s_{13}) s_{14}^* s_{15}^* s_{16}^*$
2	$S_{21}$	$S_{22}$	$S_{23}$	$S_{24}^*$	$S_{25}^*$	$S_{26}^*$	$\sigma_2 = (s_{21} + s_{22} + s_{23}) s_{24}^* s_{25}^* s_{26}^*$
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
N	$S_{N1}$	$S_{N2}$	$S_{N3}$	$S_{N4}^*$	$S_{N5}^*$	$S_{N6}^*$	$\sigma_N = (s_{N1} + s_{N2} + s_{N3}) s_{N4}^* s_{N5}^* s_{N6}^*$
<b>Total score of the N publications (T<sub>1</sub>)</b>							<b>T<sub>1</sub> = <math>\sigma_1 + \sigma_2 + \dots + \sigma_N</math></b>
<b>g<sub>1</sub> criterion (Consistency of the scientific production as a whole)</b>							<b>s<sub>1</sub></b>
<b>g<sub>2</sub> criterion (Intensity over time of the scientific production as a whole)</b>							<b>s<sub>2</sub></b>
<b>g<sub>3</sub> criterion (Continuity over time of the scientific production as a whole)</b>							<b>s<sub>3</sub></b>
<b>Total score of the scientific productivity respect to time (T<sub>2</sub>)</b>							<b>T<sub>2</sub> = <math>s_1 + s_2 + s_3</math></b>
<b>TOTAL SCORE</b>							<b>T<sub>1</sub> + T<sub>2</sub></b>

## 4 The Six Decision Steps of the Evaluation Board

By the application of the formula expressed in the previous section, the evaluation board has to carry out a simplified work in order to perform the responsibility of assign an analytical score to the scientific production of each researcher.

In this section the preliminary decisions of the evaluation board are described subdividing them into six decision steps.

The number  $N$  of publications under evaluation and the maximum total score  $S$  to be assigned to the scientific production of each competing researcher are institutionally predetermined in the announcement of the selection.

The first decision step of the evaluation board is to establish  $\alpha_c$  and  $\alpha_g$ , i.e. the weights, respect to  $S$ , of the two maximum scores respectively assignable to the set of the scientific publications (examined one by one) and to the scientific production as a whole (e.g. the

scientific productivity respect to time); these two scores must result reciprocally complementary respect to the maximum total score  $S$ .

The second decision step for the evaluation board is to establish the two sets of *a priori* criteria  $\{c_h\}$  and  $\{g_k\}$ , which are mainly defined by the existing institutional guidelines and can be completed by other appropriate criteria.

The third step is to establish which *a priori* criteria must be considered equivalent to necessary conditions among the set  $\{c_h\}$  and the set  $\{g_k\}$ .

The fourth step for the evaluation board is to decide the maximum score related to each *a priori* criterion. In particular, the maximum scores  $S_h$  (related to each of the  $\varphi$  criteria that do not imply necessary conditions) are to be established controlling that the sum of these  $\varphi$  numbers is equal to:  $(\alpha_c S)/N$ . The maximum scores related to each of the  $(H - \varphi)$  criteria of the set  $\{c_h\}$  that imply necessary conditions must be equal to 1. Similarly, the maximum scores  $S_k$  (related to each of the  $\tau$  criteria that do not imply necessary conditions) are to be established controlling that the sum of these  $\tau$  numbers is equal to:  $(\alpha_g S)$ . The maximum scores related to each of the  $(K - \tau)$  criteria of the set  $\{g_k\}$  that imply necessary conditions must be equal to 1.

The fifth decision step and the sixth one (respectively regarding the set of criteria  $\{c_h\}$  and the set of criteria  $\{g_k\}$ ) are referred both to methodological and quantitative aspects.

Expressly, in the fifth step the evaluation board, in relation to each criterion of the set  $\{c_h\}$ , has to decide how to assign a score  $s_{ih}$  (not exceeding the established maximum score  $S_h$ ) to each publication  $i$ . For this purpose, the evaluation board can establish to use instruments and parameters conventionally shared in the related scientific community, *e.g.* classifications of scientific journals (for the criterion referred to originality, innovativeness, methodological accuracy and relevance of each scientific publication); presence of an international editorial board in the publishing house (for the criterion referred to relevance of each publication's editorial house and its diffusion among the scientific community); number of co-authors and order of co-authors in the sequence of authors (for the criterion referred to the analytical evaluation of the candidate's contribution to works in cooperation). Moreover, for the congruence of the publication with the scientific area of the competitive exam, with the required scientific profile and with issues related to the required scientific commitment, the evaluation board can use the information emerging from the journal classifications and from objective elements of the publication. The score  $s_{ih}$  can be adequately graduated in relation to the adopted instrument and parameter, provided that it does not exceed the established maximum  $S_h$ . Similarly each score  $s_{ih}^*$  (related to the criteria equivalent to necessary conditions) can be adequately graduated in relation to the adopted instrument and parameter, provided that it does not exceed 1.

In the sixth step the evaluation board, in relation to each criterion of the set  $\{g_k\}$ , has to decide how to assign a score  $s_k$  (not exceeding the established maximum score  $S_k$ ) to the researcher's scientific production as a whole. For this scope, the evaluation board can establish to refer the scores to quantitative aspects whose computation is objective and certain, *e.g.* the number of publications of high classification, the number of publications in publishing houses with international editorial board, the average number of publications

in a year, the number of years without publications. The score  $s_k$  can be adequately graduated in relation to the adopted quantitative indicator, provided that it does not exceed the established maximum  $S_k$ . Similarly each score  $s_k^*$  (related to the criteria equivalent to necessary conditions) can be adequately graduated in relation to the adopted indicator, provided that it does not exceed 1.

The calculation of the total score assigned to the scientific production of each competing researcher can easily be made using the support of the format represented in Table 1, in which the application of the evaluation formula (1) is subdivided in two phases in relation to the different sets of criteria. In the calculation, the scores related to the criteria that imply necessary conditions are factors and this algebraic aspect has the following practical implications: if, for a publication  $i$ , the score of only one criterion (among those which are equivalent to necessary conditions) is zero (*i.e.* if only one of the necessary conditions is not verified), the total score to be assigned to the publication is zero (because it results multiplied for a factor equal to zero); moreover, to the publication  $i$  it will be wholly assigned the score deriving from the sum of the partial scores  $s_{ih}$  if, and only if, all the scores related to the criteria that are equivalent to necessary conditions are equal to 1 (*i.e.* if, and only if, all the necessary conditions are verified); a halfway non-zero score, related to a criterion that is equivalent to necessary conditions (*i.e.* the presence of a necessary condition which is partially verified), implies the reduction of the total score to be assigned to the publication.

It is likewise possible to explain the algebraic implications referred to the similar calculation of the score corresponding to the evaluation of the scientific production as a whole.

## 5 Conclusions

The principal aim of this work is to alert the scientific community of evaluation specialists about the negative consequences of the use of evaluation models based on bibliometric indicators for the natural development of research in the Social Sciences and Humanities. The evaluation method proposed in this contribution is an example useful to observe that it is possible to achieve an effective evaluation of scientific production without bibliometrics. It is also important to highlight that, for this scope, it is necessary to create instruments, models and objective criteria suitable to support an evaluation system that should respect the researcher's identity and the spontaneous evolution of science. Particularly, the observations inspired by the method presented in this contribution lead to note the usefulness of Boole's Algebra for the calculation of total scores deriving from the simultaneous application of criteria having a different logical nature.

This paper is not focused on the aspects that are fundamental for the analysis of researchers' behaviour. Many of these aspects are at the base of distorting and obsessive consequences on the researcher's nature. However, these conclusions represent a starting point for addressing future research lines in this field.

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